MARS 2021

TOWARDS A JUST TRANSITION OF FOOD SYSTEMS

Challenges and policy levers for France

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Citation : Aubert, P.-M., Gardin, B., Aillot, C., (2021). Towards a just transition of food systems. Challenges and policy levers for France, IDDRI.

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Funded by:

La responsabilité des ministères ne saurait être engagée

The VALUMICS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727243

Le projet VALUMICS a été financé par le programme de recherche et d'innovation Horizon 2020 de l'Union européenne dans le cadre de la convention de subvention n° 727243.

Cette publication a été co-financée par le programme LIFE+ de l'Union Européenne, sous la direction de l'Agence Exécutive pour les Petites et Moyennes Entreprises (EASME). La publication ne reflète que les positions des auteurs. EASME n'est pas responsable de l'information fournie dans cette publication, ni de son utilisation.

Acknowledgements

While the authors take sole responsibility for any errors or omissions in this document, they would like to thank the members of the scientific committee for their advice and critical feedback:

***Valentin Bellassen** (CESAER, INRAE) ; **Philippe Boulet** (Director of the Performance and Prospects Unit, CerFrance) ; **Pierre-Alain Jayet** (INRAe) ; **Christophe Perrot** (Institut de l'Elevage) ; **Jean-Louis Rastoin** (Montpellier Supagro) ; **Bernard Valluis** (Honorary President of European Flour Millers).*

This study has received financial support from the French government in the framework of the programme "Investissements d'avenir", managed by ANR (the French National Research Agency) under the reference ANR-10-LABX-01. Access to some confidential data, on which is based this work, has been made possible within a secure environment offered by *CASD* – Centre d'accès sécurisé aux données (Ref. 10.34724/*CASD*)

Graphic design: Ivan Pharabod.

ISSN 2258-7535

EXECUTIVE SUMMARY

French and European food systems need to be transformed in order to address health, environmental and social challenges.[1] The policy measures in place to foster this transition are however not ambitious enough, because its socio-economic costs are generally deemed to be too high. In this context, IDDRI has developed an innovative methodological approach[2], which combines biophysical and socio-economic modelling in order: (i) to understand the structural changes at play in the transition; (ii) to assess their impact on four challenges: agricultural employment and income, employment in the agri-food sector, food, and biodiversity; and (iii) to identify the political conditions for a just transition.

Based on the indicative decarbonisation pathway for the agricultural sector laid down by the French National Low-Carbon Strategy, two different scenarios for the evolution of the French food system are developed to assess their impacts by 2030 on two key sectors: dairy cattle and arable crops, which together account for 70 % of the utilised agricultural area (UAA), 52 % of value creation in agriculture and 40 % of value creation in the food industry.

Key messages

- A scenario that focuses exclusively on climate issues, without questioning the concentration/specialisation processes underway at the production level, and relying mostly on supply side measures, would have significant socio-economic impacts: an increase in the rate of farm closures and associated job losses (-9 % compared to current trend), and job losses in the agri-food sector (-12 % compared to 2015), without any substantial improvement in the quality of food or biodiversity.
- A multifunctional scenario (climate, biodiversity, health, employment) could generate multiple benefits: maintaining agricultural jobs (+10 % compared to current trend) without a loss of income; increasing jobs in the agri-food sector (+8 % compared to 2015); and contributing to the restoration of agro-biodiversity and the development of a range of food products more in line with government nutritional guidelines.
- The economic viability of such a scenario relies on simultaneous changes in supply, demand and market organization, which implies significant policy changes:
  - taking a proactive approach to national level demand, in contrast to current reluctance on the issue, mobilizing a wide range of tools and ensuring that the healthiest and most sustainable options are the most attractive to the consumer;
  - bringing together the visions of EU Member States, so that the implementation of national strategic plans in the context of the Common Agricultural Policy sets comparable objectives and production conditions for producers;
  - taking an ambitious approach to international trade to promote and support the adoption of ambitious production standards.
- The conclusions drawn here from the analysis of the two sectors require consolidation by their extension to all agricultural sectors and EU countries, while the methodology on agricultural income needs further development.

TOWARDS A JUST TRANSITION OF FOOD SYSTEMS: EMPIRICAL ISSUES, METHODOLOGICAL CHALLENGES

The findings of recent prospective studies on sustainable food systems in Europe, despite certain differences,[3] converge around transformation issues: a shift towards more plant-based protein consumption and production; a two or threefold reduction in food sector losses and waste; and a significant improvement in the environmental performance of farming systems, particularly through an absolute reduction in the quantities of synthetic inputs used, and their re-diversification from the plot to the landscape.

When carried out together, these transformations would result in European food systems that are radically different to those that exist today, with significant changes to production volumes: a decrease in most types of European production (cereals, livestock), and an increase in others (legumes, market gardening, arboriculture). However, the prospect of ensuring that the transition is fair in terms of employment, the salaries of food sector jobs, and the provision of food for the greatest number of people, including outside of Europe, is widely debated. For example, many analysts predict - based on standard economic models in general or partial equilibrium, or sometimes on apparent "common sense" - that an ambitious implementation of the "Farm to Fork" strategy would result in massive price increases for agricultural raw materials at the global level (due to the fall in production), a loss of competitiveness in European agriculture and the agri-food sector, and therefore an associated loss of jobs, and a decline in agricultural income.[4]

However, these analyses have three major weaknesses: they are based mainly on constant or semi-constant systems, when in fact the structure of farms and the agri-food sector will have changed by 2030; they endogenize consumer demand as well as price formation on the basis of price elasticities and production functions that are difficult to establish empirically, when food practices are actually evolving rapidly as a result of major non-economic factors;[5] and they do not link (or do so poorly) the physical balances needed for a food system that exists within planetary boundaries with the socio-economic dynamics within sectors.

To contribute to the current debate, IDDRI and BASIC have developed an innovative analysis framework that aims to not only resolve some of the identified difficulties, but also to address tensions between long-term issues and short-term limitations. The Model of Food system Transition (MoFOT) thus proposes the simultaneous (i) a characterization of the changes to the production systems required at the different sectoral levels (farming systems and processing industry), that are consistent with biophysical scenarios; (ii) a quantification of the impacts of the envisaged transformations on agricultural and agri-food employment and on agricultural income; (iii) and the identification of the political conditions under which a transition of the food system can be both socially just and environmentally sustainable.

TWO LOW-CARBON TRANSITION SCENARIOS FOR THE FRENCH FOOD SYSTEM

The MoFOT conceptual framework has been used to understand the political conditions to enable the sustainable implementation of the agricultural pathway proposed in the French SNBC of 2020.[6] The agricultural aspect of the SNBC was draw n up by the French Ministry of Agriculture in consultation with the main actors, between September 2017 and June 2018. It envisages four structural changes between now and 2050 that could halve the agricultural sector's greenhouse gas emissions compared to 1990 levels, which are: an improvement in the overall efficiency of production, both in terms of the use of nitrogen inputs (particularly through a major increase in the cropped area of legumes) and animal feed; a decrease in the production of animal protein (especially pigs and cattle) and an increase in organically farmed land; a major expansion in the application of anaerobic digestion; and an increase in the carbon storage potential of agricultural soils, hedgerows and agro-ecological infrastructure.

Based on this indicative biophysical pathway, two food system scenarios were developed, both of which achieve the same decarbonization objectives, but via contrasting trajectories in terms of both socio-political aspects and the evolution of the economic strategies of actors within the sectors. By comparing these two scenarios, it is possible to assess their quantitative implications (in terms of employment and income) and to identify the socio-political conditions for a just transition.

The Dual France scenario is based firstly on a political framework in which the climate issue dominates over all others, and where the transition primarily involves support for agricultural supply without any notable interventions on the market framework or demand. Such a scenario is likely to increase polarization in the food system at all levels - from producer to consumer - between highly sustainable but not very accessible niche markets and production methods that are based on a price competitiveness model. This results in a continued trend of concentration on the supply side, which promotes efficiency gains and reduces production costs. On the demand side, the trend towards a reduction in meat consumption continues, but in a very unequal way across the population; the consumption of highly processed products with no direct link to their agricultural origin is maintained or even increased.

In contrast, the socio-territorial Recompositions scenario fully assimilates the proposals of the European "Farm to Fork Strategy" and assumes that ambitious changes are made to all aspects of production and consumption trends: through the implementation of ambitious measures, demand evolves towards more local, seasonal and less-processed products, while the consumption of animal protein continues to decrease. In terms of production, the agricultural sector is encouraged to pursue relative de-specialization, which also enables a slowing down of the rate of concentration, while agricultural systems and landscapes are re-diversified. At the agri-food level, a less concentrated "Italian style" system is implemented, giving more room to VSEs and SMEs in the sector's overall economic structure.[7] The labour intensity of production increases due to declining standardization and more links to agricultural production.

The impact of these two scenarios by 2030 has been assessed in detail for two key sectors of the French food system: dairy and arable farming, which together represent 70% of the Utilized Agricultural Area (UAA), 52% of value creation in agriculture, and 40% of value creation in the food industry.

CONTRASTING RESULTS

The Dual France scenario, which does not challenge the dominance of the price competitiveness model among economic actors, is accompanied by significant socio-economic impacts: a 10% loss of agricultural jobs compared to the current trend due to continuation concentration and an increase in the capital intensity of farms; a risk of income losses for farmers in the absence of compensation, particularly due to an increase in debt; and job losses in the agri-food industries reaching 12% of the current employment level. The impact on final consumer prices, which is difficult to assess accurately with the available tools, may be limited because increases in production costs at the agricultural level may be offset by possible decreases at the agri-food level. However, this possible stasis in prices comes at the cost of an increased intake of highly processed foods, the health impacts of which would need to be studied in detail.

Conversely, the results of the Recompositions scenario for the two sectors make the just transition of the food system a plausible hypothesis regarding the production aspect: agricultural employment is 10% greater than the current trend, while incomes are maintained without major constraints on subsidy levels or the prices paid to producers; agri-food employment increases by 7% while offering more diversified and less processed foods. The average cost of food may rise as a result of the increased labour intensity in the agri-food sector. These results need to be reinforced by extending the analysis to include other major agricultural and agri-food sectors - particularly meat production, which accounts for almost one third of jobs and of the value of the agri-food sector, as well as market gardening, which is highly labour-intensive and represents an important element in terms of both health and trade balance. Nevertheless, a comparison between the two scenarios already highlights a number of key political issues for the transition. In particular, it shows that the social and political conditions for such a transition are numerous and, to put it bluntly, difficult to achieve.

KEY POLICY CHALLENGES

Firstly, a policy change aimed essentially at the supply side - as in Dual France - does not address (or does so inadequately) the employment issues of the transition, which is particularly inequitable on the consumption side. Interventions in relation to demand and market organization thus seem to be a determining factor in attaining new market balances, creating a socially just and environmentally sustainable food supply for which there is a real demand (on both domestic and export markets).

On the demand side, current consumption dynamics in France and Europe are giving encouraging signals regarding the challenges associated with the transition (a reduction in the consumption of animal protein, an increase in the share of organic products, greater demand for local produce). However, changes to the average grocery basket conceal a wide range of food practices, which partly relates to a rise in the number of people living in food insecurity, for whom an increase in their food budget (both in money and time) would be difficult to envisage. Major initiatives are therefore necessary to encourage changes in practices and to make healthy and sustainable food more accessible. Although many possible measures have been discussed for years, their large-scale deployment is currently encountering significant opposition, particularly from the "consumer freedom" perspective.

Regarding the organization of markets, the challenge is twofold. Firstly, it is a question of bringing together the visions of various Member States to converge on a "standard pathway" to decarbonize the European food system, thus avoiding a situation where the implementation of strategies that are too different from that of the SNBC-A would lead to an increase in competitiveness gaps. Although the task is complex – particularly with regard to differences already present between Member States – the existing institutional frameworks could facilitate the discussion. However, going beyond this issue, there is also a challenge in harmonizing production conditions with non-European producers or, failing that, to at least temporarily protect the European market to avoid "carbon leakage" or to limit the development potential of sectors that are crucial for the transition - such as the protein crop sectors, which are currently struggling to take off due to seemingly insurmountable competition from North and South American soya. Current discussions on a carbon border adjustment mechanism could make it possible to resolve these problems, but there is no doubt that it is a complex issue to address.[8] More generally, since the European Union is the world's largest exporter and importer of food products, it can and should be a driving force in setting ambitious standards for more sustainable modes of production and consumption, and in pushing these issues forward not only through the bilateral agreements it signs, but also at the WTO level.[9]

In terms of supply-side agricultural policies, current Common Agricultural Policy reform should enable a convergence of Member State visions on the agricultural level via an accountability mechanism for the national strategic plans organized at the European Council level; however, to be truly effective, this must be accompanied by binding targets for States – a solution that the Council and the Parliament have so far rejected. Regarding the agri-food sector, the development of environmental labelling, currently being trialled in France, must be encouraged, along with the standardization of nutritional labelling throughout Europe: not only does such labelling have an impact on consumer choice, but it is also a powerful means of changing the supply itself through explicit benchmarking among producers, enabling the emergence of sustainable competition between economic operators.

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1 *See in particular: EC (2020). Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system. Brussels, European Union, 22 p.*

2 *Aubert, P.-M., Gardin, B., Aillot, C., (2021). Towards a just transition of food systems. Challenges and policy levers for France, Iddri*

3 *References include:*
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4 *See in particular the USDA analysis: Beckman J., Ivanic M., Jelliffe J.L., et al. (2020). Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies. Washington, Department of Agriculture, Economic Research Service, 51 p.*

5 *See for example: de Boer J. & Aiking H. (2018). Prospects for pro-environmental protein consumption in Europe: Cultural, culinary, economic and psychological factors. Appetite, 121, 29-40.*

6 *MTES (2020). Stratégie nationale bas-carbone. Paris, Ministère de la Transition écologique et solidaire.*

7 *See: Brasili C. & Fanfani R. (2006). The Italian food industry: structure and characteristics. In: Food Industry Enterprises Editors, The Food Industry in Europe–Erasmus Intensive Programme in Agri-Business Management with Emphasis.*

8 *Colombier M., Voituriez T. & Levaï D. (2021). Europe's Carbon Border Adjustment Mechanism: the need for an improved dialogue prior to project finalization. IDDRI – Note (February 2021), 7p.*

9 *This view has been expressed by the European Parliament's Committee on International Trade on the Farm to Fork strategy. See INTA (2021). Opinion on a Farm to Fork Strategy for a fair, healthy and environmentally friendly food system. Brussels, Committee of the European Parliament on International Trade.*

UN OBJECTIF DE RÉDUCTION DE MOITIÉ DES ÉMISSIONS DE L'AGRICULTURE D'ICI 2050
DEUX SCÉNARIOS CONTRASTÉS AUX IMPACTS DIFFÉRENCIÉS POUR Y PARVENIR

La trajectoire biophysique SNBC à horizon 2030

Efficience	Mix produit	Production bioénergie	Séquestration
• Surplus d'azote -30% • Fermentation entérique -15%	• Cheptel bovin -12%, porcin -14% • Grandes Cultures en AB 26%	• Méthanisation (production x60)	• Haies (surfaces +67%) • Techniques culturales simplifiées pour le carbone des sols (x6)

Les principales hypothèses des deux scénarios

France duale	Recompositions
Enjeu climat domine la décision Politiques ciblées sur l'offre agricole	Approche multifonctionnelle (climat, biodiv, santé) Politiques offre / demande / marché
Ré-équilibrage limité des régimes alim Part des aliments très transformés ↗	Régime plus sain : protéines animales ↘ Part des aliments ultra transformés ↘
Concentration du tissu agroalimentaire intensité en emplois ↘ compétitivité-prix ↗	Ré-équilibrage amont-aval Intensité en emplois ↗ Renforcement du tissu d'opérateurs moyens
Concentration et spécialisation des exploitations majoritaires	Diversification des systèmes Reconnexion culture-élevage

Les impacts dans les secteurs Bovins Lait et Grandes Cultures

France duale	Recompositions
Maintien du revenu si ↗ subventions	Maintien du revenu
Emploi agroalimentaire **- 12 %** vs 2015	Emploi agroalimentaire **+ 8 %** vs 2015
Emploi agricole **- 9 %** vs tendanciel	Emploi agricole **+ 10 %** vs tendanciel
Prix de l'alimentation **stable ou ↘**	Prix de l'alimentation ↗
Des régimes pas toujours équilibrés	Amélioration de la santé
Un peu de reconquête de la biodiversité	Très bonne reconquête de la biodiversité

Acronyms

AFI	Agri-food industries
AOC	Controlled designation of origin (Appellation d'origine contrôlée)
AWU	Annual working unit
CAP	Common agricultural policy
COP	Cereals, oilseeds and protein crops
DC	Dairy cow
DDE	Démographie des entreprises (Business demographics)
ESANE	Structural Business Statistics (Élaboration des statistiques annuelles d'entreprises)
FAO	Food and Agricultural Organization of the United Nations
FMCG	Fast-moving consumer goods
FTE	Full-time equivalents
IGP	Protected geographical indication (Indications géographiques protégées)
ISE	Intermediate-sized enterprises
LC	Large companies
MCL	Mixed crop-livestock farming
MoFOT	Model of food system transition
NAF	French activity nomenclature (Nomenclature d'activité française)
PL	Private Label
PRODCOM	Community Production (Production communautaire)
RICA	Réseau d'information comptable agricole (Farm Accountancy Data Network)
SO	Standard Output
SNBC	French National Low-Carbon Strategy (Stratégie nationale bas-carbone)
SME	Small and medium-sized enterprises
TF	Type of farming
UAA	Utilized agricultural area
UPF	Ultra-processed foods
VSE	Very small enterprises

TOWARDS A JUST TRANSITION OF FOOD SYSTEMS
Challenges and policy levers for France

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Foreword

When this research began in 2018, in partnership with the Ministries of Agriculture and Ecological Transition and ADEME (The French Agency for Ecological Transition), our starting point was a simple question: under what conditions could the low-carbon transition, as envisaged in the framework of the revision of the National Low-Carbon Strategy's agricultural component (MTES, 2020), be sustainable on the socio-economic level? Three years later, the relevance of this question has not diminished.

Indeed, the facts attesting to the impacts caused by the functioning of the food system in terms of climate (IPCC, 2019), biodiversity (IPBES, 2019) and health have continued to accumulate. The proliferation of prospective studies within the academic community has enable a convergence on which transformations are needed to maintain the food system within planetary boundaries (we return to this point later). Two major recently-adopted political strategies clearly point in this direction: the "From Farm to Fork" strategy (EC, 2020) as part of the Green Deal framework at the European level, and the National Low-Carbon Strategy, that was definitively adopted in France in 2020.

To say that these guidelines have generated concerns and, consequently, resistance would be an understatement: many actors have highlighted the risks to income, employment, food security, etc., that would be linked to an overly rapid implementation of measures that are fully consistent with these strategies (par exemple Beckman *et al.*, 2020). However, these concerns are based on methodological tools (supply-demand balance models) which, in the view of the authors and without becoming excessively technical, raises at least three types of issues:

- firstly, such models question the economic consequences of a tightening of constraints on agricultural production by implicitly assuming that production structures - i.e. farms, industries, distribution - will be structurally unchanged by 2030. Yet, as everyone has experienced over the past 10 years, both farms and factories can change considerably over such a time frame, and it therefore seems important to capture these changes in our analyses.
- secondly, they consider demand to be mainly driven by prices, through a process of endogenization, based on a double hypothesis: that demand depends mainly on prices; and that the evolution of demand in relation to price depends on the propensity of the consumer to continue to consume if a product's price rises or falls. However, current societal dynamics in terms of food are structured by many other aspects, not only prices, and it is important to consider these dynamics in greater detail.
- finally, they struggle to reconcile physical and socio-economic approaches, or in other words, to really take into account in their analyses the biophysical issues at the heart of the challenges of our time - whether we are considering climate change, biodiversity loss, or the degradation of natural resources (water or soil).

Faced with these limitations, we developed an innovative methodological framework to help us address our central problem – identifying the right political conditions for a socially just and environmentally sustainable transition – via the development and quantification of contrasting low-carbon transition pathways for the French food system. It has taken over three years of work to structure this methodological framework, and although it remains imperfect, we feel this framework is necessary to feed the complex political debates that revolve around the implementation of an environmentally ambitious vision for the food system.

This study has been carried out with the support of a scientific committee in order to challenge and validate, as and when it is developed, a novel analytical approach, ultimately leading to the publishing of a hybrid report that both presents an analytical approach that we hope can be replicated in other contexts and at other scales; and also presents findings from the French food system, in the dairy and arable sectors.

It would not have been possible to complete this work in its current form without having an open dialogue with stakeholders: farmer unions, civil society organizations, along with private sector representatives from the whole food chain, administrations and politicians. Nearly ten discussion workshops were organized between 2018 and mid-2020 in various formats, bringing together up to 70 people. This has provided the opportunity to present the process undertaken, to gauge opinions and hear proposals for improving the scenario, and above all to stimulate discussions between actors with contrasting visions on what represents a desirable future for the French food system. This work initially focused on France, before being extended to the European level in autumn 2020 through the organization of a series of workshops.

Finally, although this report marks the completion of a first stage, it represents only a milestone that will help feed an already lively debate. The pioneering approach that we are proposing must be both strengthened and extended to other key sectors of the transition as well as to other geographical scales. Indeed, the question of a just transition cannot be only a French issue: it is European and even global. This is our objective today, in association with other French (ASCA, Solagro, I4CE) and European (IEEP, Ecologic, TMG, SEI) actors, within the framework of Think Sustainable Europe, and with the financial support of a wide range of partners.

Box 1. The process of discussing the study.

Three discussion formats were set up during the course of the study with stakeholders and experts.

The most important role of the study's scientific committee was to support the methodological developments: is the scientific framework robust? Has the relevant literature been covered? The members met three times, in January and June 2019, and then in April 2020, and were all sent a draft of the study in January 2021 for their critical feedback.

Four workshops were held to bring all stakeholders together in a very inclusive way (up to 70 participants), these took place in: September 2018 at the launch of the study; February 2019 and September 2019 to work on the assumptions of the scenario; and then in June 2020 to present the main results from the modelling. Following a half-day format, the aim was to encourage actors to take ownership of the framework and the study's methodology and then, in small groups of 7 to 8, to gather proposals and criticisms to help develop scenarios and adjust assumptions.

Finally, a high-level workshop aimed at discussing the political implications of the study's main results was organized for July 2021, to bring together 20 elected representatives and those with important operational positions in the main stakeholder organizations.

1. Introduction

Given the challenge of climate change, the European food system must undergo profound transformation to simultaneously reduce its greenhouse gas emissions, increase the storage capacity of the land sector, and develop renewable biomass production to replace fossil fuels. Much recent work converges on three sets of solutions that need to be implemented concurrently in the OECD context to accompany the transition to carbon neutrality: a halving of the average consumption of animal protein; a halving of the amount of losses and waste; and a radical improvement in the climate efficiency of agricultural production systems (Odegard & van der Voet, 2014 ; Bryngelsson et al., 2016 ; Springmann et al., 2018a ; Willett et al., 2019 ; Clark et al., 2020).

However, this low-carbon transition of the food system must also take into account at least three other issues. Firstly, it must be socially *just*, from producer to consumer, i.e., it must ensure that jobs and income are maintained for those involved in the sector (Rosemberg, 2010) while guaranteeing access to food for all; it must ensure that this food is *healthy*; and finally, it must play its part in conserving and restoring *biodiversity* – that which is contained within agro-ecosystems and also that of uncultivated areas.

The effective inclusion of these issues in the dialogue is currently being obstructed due to considerable methodological difficulties. To put it simply, the models with the ability to capture socio-economic impacts are only capable of understanding marginal changes to the food system: in other words, they cannot deal with scenarios involving biophysical breakthroughs, although such scenarios are necessary if we are to achieve carbon neutrality. Conversely, models that provide a robust representation of the biophysical transformations that would keep the food system within planetary boundaries are unable to capture the socio-economic impacts. Furthermore, most biophysical models are incapable of accurately capturing the challenges of preserving biodiversity in agricultural landscapes, and generally focus on the challenge of decarbonization alone (e.g. Searchinger *et al.*, 2018 ; Lóránt & Allen, 2019). As a result of these methodological difficulties, the debate is dominated by single-issue visions (most focusing on climate), that are far removed from the concept of sustainable development, which by definition is a multi-issue subject (pour une analyse des arbitrages climat-biodiversité dans les scénarios de système alimentaire, on pourra se reporter à Aubert *et al.*, 2019).[10]

This state of affairs fuels serious concerns about the risks associated with the decarbonization of the food system. It prevents reasoned debate, which has now been replaced by a futile battle of entrenched beliefs. In economic terms, the supporters of an environmentally ambitious transition claim that it will undoubtedly lead to the net creation of jobs (WWF France, 2020) – at least to fewer job losses than with the current trend (Bâ et al., 2016); a claim that sceptics oppose, taking the view that the rise in production costs and the resulting fall in volumes[11] would lead to higher prices and catastrophic social and economic effects (voir par exemple pour une analyse de cette nature récente centrée sur les effets du Pacte vert et ne prenant pas en compte les enjeux environnementaux Beckman *et al.*, 2020). In most cases, the positions on either side are based on different and not very transparent arguments, limiting any possibility of discussion.

In this context, this study develops an original modelling approach to address its central issue: can the low-carbon transition of a food system be economically just, while contributing to the provision of healthy food for all and the preservation of all forms of biodiversity? The developed approach – that we will return to at length – combines biophysical modelling

10 The 17 Sustainable Development Goals adopted in 2015 by all UN Member States set a clear roadmap in this respect.

11 Most of transition scenarios compatible with carbon neutrality envisage significant decreases in the amount of animal protein in particular.

of the food system[12] with an understanding of market dynamics from two complementary angles: that of economic strategies at every stage in food chains (understood in particular through changes in production tools); and that of the policies that influence market equilibrium, targeting supply, demand or the ways in which the two come together.

This innovative approach allows us to address three complementary questions: (i) What changes to the economic strategies within food value chains are compatible with the decarbonization ambitions of the Paris Climate Agreement? (ii) What are the impacts of these changes on the other issues identified (employment, income, food, biodiversity) and the trade-offs or synergies involved? (iii) What policy changes (in terms of supply, demand or market organization) are necessary to ensure the economic viability of a sustainable transition for all of the issues considered, to have a win-win situation?

The study applies this approach to the French food system with two objectives: firstly, to show the usefulness of the method developed and thus encourage exchanges/discussions in countries across Europe, and also in Brussels; and secondly, to fuel the ongoing debates in the French context. It takes as its starting point the projections for agriculture contained in the National Low-Carbon Strategy (SNBC), published in 2020 by the Ministry of Ecology (MTES, 2020), which aims to halve greenhouse gas (GHG) emissions from the agricultural sector by 2050 (see **Box 2**). These projections are based on a physical/agronomic representation of French agriculture, on a 5-year time scale, in terms of surface area, livestock, yields and associated production.

Given the complexity of the system studied, the analysis was carried out with a 2030 horizon (rather than 2050) for two sectors: dairy and arable. These were chosen for their importance in the functioning of French agriculture: representing 70% of the Utilized Agricultural Area (UAA), 52% of value creation in agriculture, and 40% of value creation in the food industry.

Starting from the same indicative decarbonization pathway at the scale of French agriculture, that of the SNBC-A, this study develops two contrasting scenarios for the French food system: one explicitly and intentionally climate-centred, the other seeking to simultaneously address all of the issues outlined above. The comparative analysis of these two scenarios leads to three main conclusions.

Firstly, it shows that an ambitious decarbonization of the food system could effectively generate multiple benefits on the scale of the two sectors considered, namely: maintaining 10% more agricultural employment than in the current trend, despite the drop in volumes; maintaining agricultural income without increasing the price of agricultural raw materials; increasing employment in the agri-food sector by 7%; and contributing to the restoration of agrobiodiversity and diversified landscapes, all of which while also providing healthier food. The economic viability of such a scenario depends, however, on a simultaneous transformation of supply, demand and market organization - and therefore on major policy changes in these three areas. On the supply side, it implies aligning the instruments of the Common Agricultural Policy (CAP) with the environmental ambitions of France and Europe; while on the demand side it appears necessary to adopt an active policy to support food practices towards healthier and sustainable diets, while ensuring that such foods are economically accessible to the greatest number of people. Finally, in terms of market organization, the same social and environmental ambitions must be applied to all operators to avoid social and environmental dumping.

The second outcome is political. As the above mentioned policy changes are largely a European matter, they require an alignment of views on the transformation of the European food system among Member States in the European Council, which can only happen if there is a simultaneous push by the Commission, the Parliament and civil society. The establishment of a legislative framework for a sustainable food system,

12 From a purely physical point of view, such an approach makes it possible to test the validity of different decarbonization options according to their adequacy with the material and energy balances of a food system: between food demand and total production, between plant production and demand for animal feed/human food/biomaterials/bioenergy, between nitrogen inputs and exports, between cultivated areas and actually available areas, between water demand and available resources. Such a balance sheet approach leads to the characterization of a food system from a physical point of view: cultivated areas and sizes of different livestock herds, crop and livestock productivity, and total production. See Box 2.

Encadré 2. Agronomic scenario developed for SNBC-A
Study framework: the agricultural component of the French national low-carbon strategy

There are four levers for reducing GHG emissions in the agricultural sector:

- improving the carbon efficiency of production;
- adjusting volumes produced in favour of the most efficient products;
- developing biomass production to enable the substitution of fossil carbon (energy or material) with renewable carbon;
- promoting carbon storage.

Mitigation-focused approaches follow the same logic as land sparing strategies and can use all four of these levers: by maximizing yields of the most efficient and least land-consuming crops, they aim to free up agricultural land that can then be used to produce biomass or store carbon by afforestation. This is notably the approach taken by recently published scenarios in the United Kingdom by the Climate Change Committee (CCC, 2018), in Denmark by an organization bringing together representatives of agricultural stakeholders (Danish Agriculture & Food Council, 2019), and by the European Climate Foundation (ECF, 2018).

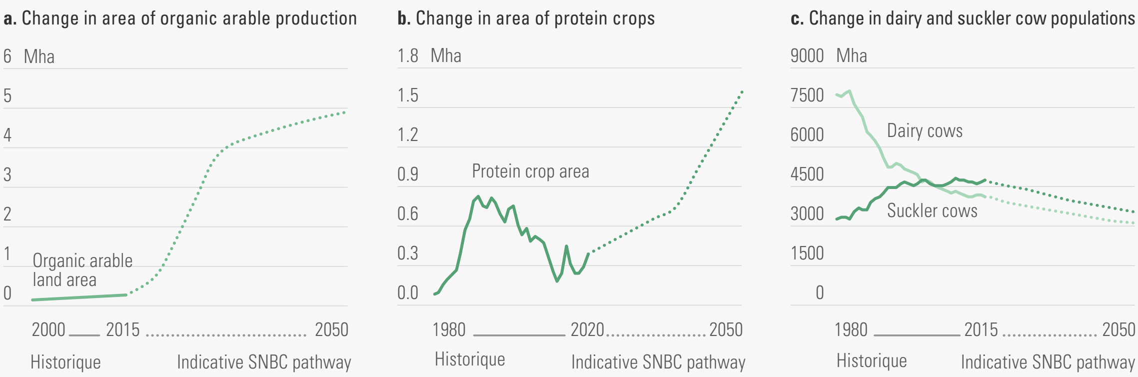
The SNBC-A differs from these scenarios by adopting a more agro-ecological perspective from the outset; it avoids making maximum use of all of the available levers so that other issues can be taken into account in a balanced way, particularly biodiversity and water quality. The assumptions made for each of the levers are as follows:

- Lever 1: improving production efficiency (i.e., reducing the tons of CO_2eql emitted/tonnes produced), which is reflected in the following assumptions:
  - a strong assumption of improvement in nitrogen use efficiency (NUE), with a nitrogen surplus that goes from about 40 kg/ha/year to 6 kg/ha/year on average across the whole territory. This increase in NUE enables a significant reduction of N_2O emissions;
  - an increase in leguminous crops to reduce fertilization needs and therefore associated N_2O emissions;
  - lipid supplementation of ruminant feed to reduce enteric fermentation;
  - a reduction of age at first calving for dairy and suckler cows and an increase in ruminant productivity (for meat and milk) to reduce the "unproductive" time of livestock;
- Lever 2: modification of product mix towards low-carbon impact production:
  - reducing animal production, especially ruminant livestock, in favour of an increase in plant protein production which has double benefits (agronomic and climatic);
  - increasing the area under organic farming despite its lower efficiency in climatic terms, in a balanced approach between climate and biodiversity issues (the development of low-input crops being key);
- Lever 3: development of biomass production: anaerobic digestion of intermediate cover and manure, development of dedicated biomass crops (miscanthus), etc.
- Lever 4: carbon storage: the SNBC-A does not envisage major land use change to increase forest carbon sinks. Additional carbon storage instead derives from agricultural soils, in line with the "4 per 1000" initiative: maintenance of permanent grassland, development of agricultural methods to promote soil conservation, diversification of crops and generalization of intermediate cover.

In terms of changes in livestock numbers, crop rotation and production, when making comparisons between the years 2050, 2030 and 2015, the main changes are in protein crops (very large increase), the development of field crops under organic production (extremely rapid), the decrease in ruminant numbers, and the maintenance of permanent grassland. **Figure 1** illustrates these changes.

Source: authors, based on the French Ministry of Agriculture and Food

Figure 1. Main changes envisaged by SNBC-A with regard to the 1980-2015 dynamics



Source: Authors, based on SNBC-A, Agreste and Agence Bio data anticipated by the “Farm to Fork” strategy by 2023, may provide the opportunity for such an alignment - in a context where the current negotiations on the post-2020 CAP show significant divergences.

Finally, the study shows that a climate-focused pathway based essentially on a change in supply-side policies – particularly improvement in the way that climate issues are addressed through CAP instruments – and minor interventions on demand and market organization, would be accompanied by significant socio-economic impacts: acceleration of the disappearance of farms and agricultural jobs by 15% compared to the trend between 2000 and 2015; a 10% loss of jobs in the agri-food industry compared to 2015; and major risks in terms of food and biodiversity.

The remainder of this study is organized as follows. Section 2 presents more detail on the methodological approach and the overall conceptual framework (without going into detail regarding the modelling tools developed, which are available in the technical appendix). Section 3 provides a review of the French food system in light of the conceptual framework developed. Readers with limited time should skip the detailed account provided in these two sections and go directly to section 4, which sets out the rationale behind the two scenarios developed. Section 5 presents the results in a comparative manner. Finally, section 6 puts these quantified results into perspective by considering the policy levers for a sustainable transition and the associated research issues.

2. A multidimensional approach to food system transition

2.1 *Modelling food systems to address the challenges of transition*

Logical structure of the model

The analysis developed in this study is based on an innovative and multidimensional conceptual model of food system dynamics: MoFOT (Model of FOod systems Transitions). MoFOT aims to explore the socio-economic impacts of ambitious food system transformation scenarios in order to identify the political and societal levers for a just transition. This original problematization led us to define the relationships between:

1. the levels of agricultural production and final consumption of a given food system, understood through biophysical modelling and set as a function of environmental objectives: reduction of greenhouse gas emissions, adaptation to climate change, biodiversity conservation (within and beyond agricultural systems), preservation of natural resources (water, soil);
2. the socio-political dynamics that guide the behaviour of economic actors, in reaction or in anticipation. These dynamics are characterized through storylines that describe, in particular, the interactions between the strategies of actors and the public policies governing agricultural supply, final demand (food and non-food), and market conditions;[13]
3. the strategies of actors at all stages of food value chains - farms, food industries, distributors, consumers - in line with biophysical constraints (see point 1 above) and socio-political dynamics (see point 2). These changes in the strategies of economic actors are characterized from an essentially techno-economic point of view, linking physical flows and economic equilibria at the different stages of food chains.
4. Ultimately, this approach enables the quantification of the socio-economic impacts of ambitious biophysical scenarios based on transparent assumptions regarding societal, political and techno-economic developments, using two complementary simulation tools concerning production systems (SPcalc) and agri-food industries (IAAcalc).[14] The proposed approach also makes it possible to shed some light on the impacts on food (basket price, nutritional quality) and on biodiversity. Regarding the latter, the MOSUT tool was used to regionalize the SNBC scenario to the scale of the 22 former French administrative regions (Solagro et al., 2016, p. 77). In general, however, major methodological challenges remain regarding the precise assessment of the impacts of contrasting scenarios on food and biodiversity issues, for similar reasons, which stem

13 Other social dynamics, not directly linked to public policies and affecting the strategies of actors, are also considered in the development of these storylines: the evolution of social norms and lifestyles in terms of consumption (voir par exemple Etiévant *et al.*, 2010 ; de Boer & Aiking, 2018). These changes in consumption practices obviously affect industrial actors and farmers in turn, who react or anticipate.

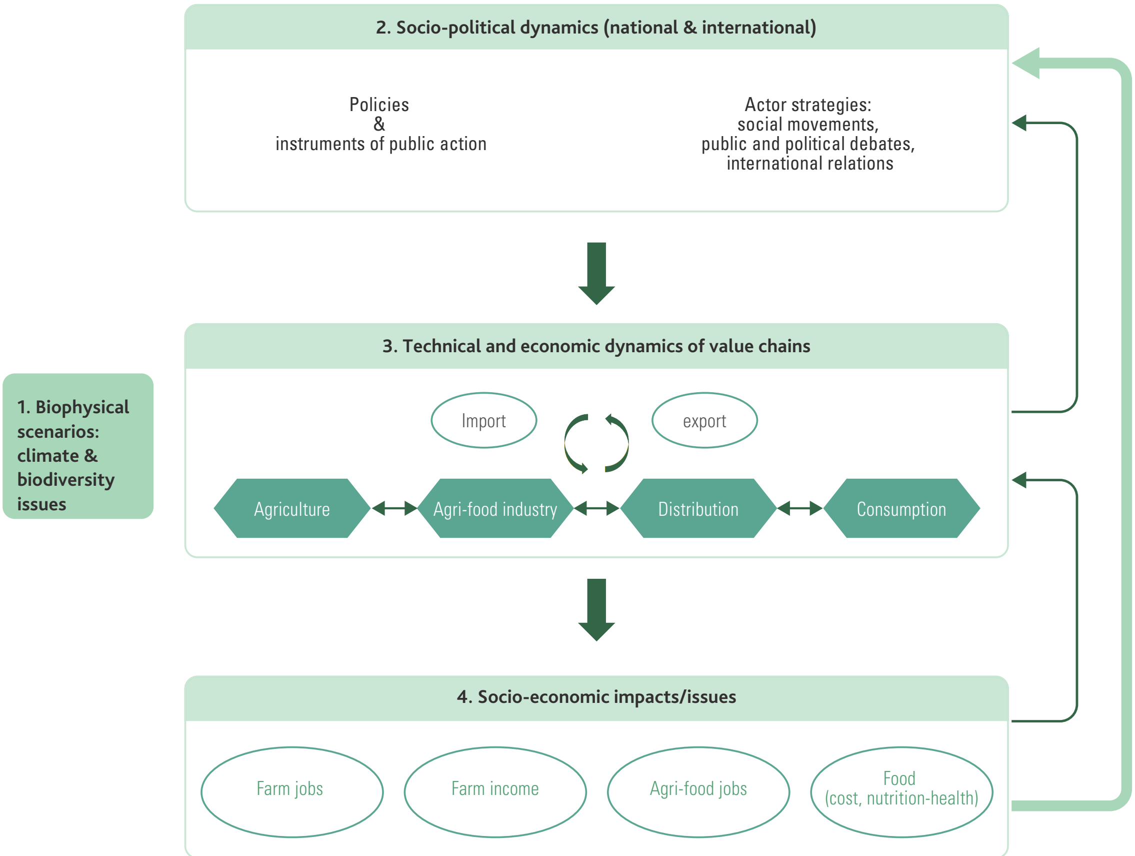
14 From an analytical point of view, the general MoFOT rationale is thus one of a supply model: our starting point is the evolution of agricultural supply under the constraints of decarbonization. There are, however, three important differences to be noted compared to "classical" supply models such as MagPIE or AROPAj (Galko & Jayet, 2011): (1) MoFOT is not an optimization model, but an exploration model, which combines quantification and narratives to show, simply and transparently, how certain impacts are associated with different strategy changes, thereby elucidating any trade-offs and synergies ((voir pour une revue récente d'initiatives similaires jusqu'à présent peu conclusivesKanter *et al.*, 2018); 2) MoFOT aims to understand, both qualitatively and quantitatively, the structural changes of production tools following the strategic choices of economic actors (where, for the most part, known models merely modify production functions under the assumption of technology adoption); (3) finally, like other supply-side models, we also pay particular attention to the characterization of demand.

from problems of metrics and heterogeneity (of both landscapes and consumers).[15]

Figure 2 presents these four dimensions of MoFOT in a stylized way and their dynamic and systemic links. Strategy changes by value chain actors have impacts on the issues under consideration (downward arrow from box 3 to box 4), and these strategic changes are themselves influenced by socio-political dynamics (downward arrow from box 2 to box 3). Feedback loops also exist: public policies can change as a result of strategic repositioning by economic actors, and they themselves can change in light of the impacts generated by their practices.

Figure 2. Logical structure of MoFOT

A simplified representation of the functioning of a food system, its determinants and its impacts



Source: authors

15 The nutritional and health impacts of “typical” diets are today evaluated by epidemiological models. These are based on the identification of statistical correlations between over/under-consumption of certain products or nutrients and the prevalence of non-communicable diseases (cardiovascular diseases, type 2 diabetes, cancer) in large cohorts (generally n > 50,000), which are then combined to assess differences in risk (positive or negative) between a given consumption scenario and a counterfactual scenario (voir pour un bon exemple Springmann *et al.*, 2016). Not only was the replication of these models not possible in this study, but by focusing on the risks associated with individual food groups, without taking into account and the level of processing , they offer a limited understanding of what a healthy diet might look like. In this work, as discussed later in this paper, we have sought to give greater importance to this issue of transformation, beyond the sole question of the composition of diets expressed in equivalent raw products (Fardet *et al.*, 2015).
In terms of biodiversity, studies seeking to quantify the impacts of agricultural scenarios tend to focus on biodiversity found outside of agricultural areas (Leclere *et al.*, 2018). However, it is known that agrobiodiversity itself plays a key role in the sustainable functioning of agrosystems (Dainese *et al.*, 2019); agrosystems represent nearly 50% of the world’s land surface and are an issue in their own right that must be taken into account (Garcia-Vega & Aubert, 2020). This is the direction of our own work (voir par exemple Poux & Aubert, 2018).

Importance of the challenges considered for France [16]

Direct employment in the agricultural and agri-food sectors represents 2.5% and 2.1% of the active population (AP) respectively, i.e. barely 5% of the current French AP (INSEE, 2019). However, the agri-food sector is one of the only French industries to have resisted deindustrialization, maintaining a constant level of employment since the late 1940s and generating considerable value added exports. More generally, the importance of the two sectors is best appreciated at the level of the particular territories where they are situated (pour un parallèle avec le charbon voir Spencer *et al.*, 2018). Not only is their relative importance greater in these areas (up to 5% of the AP for agri-food employment alone in many parts of the Grand Ouest), but they frequently play an important role as a stepping stone to unskilled employment for a precarious population, particularly young people from peripheral areas. Such employment, however, is often very physically demanding, which raises the question of how to improve working conditions in the sector. The aim of this study is to explore the conditions under which the current level of employment could be maintained, or affected as little as possible, even though the agronomic scenario defined by the SNBC-A envisages a reduction in production volume for most sectors.[17] The nature of the jobs at stake (particularly their arduousness) was not directly discussed, nor were the jobs at stake in the distribution sector. Indeed, these last two issues would have required specific developments that were not possible to include here.

The idea that farm income is too low in relation to the contribution farmers make to society has been part of the debate for many years (Piet *et al.*, 2020), and is becoming an increasingly important social issue: 66% of citizens consider that farmers are insufficiently paid for their work (Deloitte, 2020). Although recent research in Europe has shown that the income gap between the agricultural sector and the rest of society is smaller than most people think (Marino *et al.*, 2018), repeated crises in various sectors have put pressure on the cash flow of many structures. In such a context, maintaining a decent agricultural income is a prerequisite for farmers to continue producing up to 2030. This study will therefore attempt to assess the impact of transition scenarios on farm income at the smallest possible scale.

Challenges related to food are multifaceted, including the cultural and social aspects of "healthy eating", the importance of food as a social marker, questions of economic accessibility, and issues regarding health and nutrition. When questioned on this topic, the issue is certainly revealed to be a concern for consumers. A recent survey showed that more than 80% of consumers would consider adopting more sustainable practices for the benefit of the environment, nutrition or farmers' income (Max Havelaar, 2020).[18] However, the gap between what people say, and what they actually do, remains significant, particularly when economic constraints are an issue (Vermeir & Verbeke, 2006). And although the share of the household budget spent on food has recently stabilized (and even increased) following a period of continuous decline since the 1960s (Larochette & Sanchez-Gonzalez, 2015), the gaps between social groups are widening (Ferret & Demoly, 2019); nearly a quarter of French people surveyed in 2019 said they had experienced difficulty

16 It goes almost without saying that, regardless of the issue at stake, the empirical, methodological and theoretical problems raised by the questions posed here could in themselves be the subject of entire reports. The specificity and interest of this work lies not so much in the originality of the contributions we make on each point taken individually, but more in the fact that they are considered together. Furthermore, details of the methodological and theoretical approaches adopted to tackle these different subjects are provided in Part 2 of this report.

17 In this respect, we do not engage directly in a macro-economic discussion of the expected or desired role of the food sector in the functioning of the economy, particularly regarding its contribution to economic growth. More specifically, this study does not adopt the position that the loss of jobs in the primary and secondary sectors could (or should) be compensated by the creation of new jobs in the tertiary sector, as proposed by classical development theories (Timmer, 1988). We found that taking biodiversity and health-nutrition issues into account provides at least a partial justification of the objective to maintain relative employment in the sector, despite the physical limits to the development of production. A purely economic approach could challenge these objectives, especially since the material productivity of labour is considered to be necessarily increasing ((voir sur cette question notamment Dorin *et al.*, 2013).

18 Surveys of this kind have multiplied in recent years and have produced similar results. For example, see the 2018 survey by OpinionWay on behalf of FrenchFood Capital (Fench Food Capital & Opinion Way, 2018)

over the last 12 months in getting three meals a day (Ipsos & SPF, 2019) – a situation that is known to have worsened as a result of the Covid-19 crisis. In addition, rates of obesity and chronic diseases[19] associated with dietary habits – particularly the consumption of highly-processed foods (Schnabel et al., 2019) and fruit and vegetable deficiencies (Willett et al., 2019) – have gradually increased since 1990 (IHME, 2020).[20]
In this context, this study compares the agronomic scenario developed by SNBC-A with changes to the "average" diet, and focuses on the possible impact of changes to agricultural production methods on the cost and quality of food through the development of a set of detailed assumptions on changes in the agri-food sector.
Finally, maintaining (or even restoring) biodiversity is a key issue in any transition, given the negative dynamics underway, particularly in agricultural areas (ECA, 2020). Two types of biodiversity can be distinguished: that of wild ecosystems, the maintenance of which depends particularly on limiting the expansion of agricultural land (particularly in the intertropical zone) and therefore, for France, on the cessation of imported deforestation; and agrobiodiversity, which includes the diversity of species, breeds and varieties of cultivated plants and livestock, as well as the non-cultivated species that occupy and exploit different niches in agricultural landscapes at certain stages in their life cycles (FAO, 2019). Agrobiodiversity has a recognized existence value in Europe: 28% of the special environments that the European Union has committed to protect as part of its ratification of the Convention on Biological Diversity (CBD) are associated with and dependent on agricultural practices (Halada *et al.*, 2011). It also plays a key role as an agronomic production factor, providing crucial ecosystem services: pollination, pest regulation, contribution to the supply and recycling of nutrients (N, P, K), and the maintenance of soil health (pour une synthèse récente voir Dainese *et al.*, 2019). Maintaining agrobiodiversity will help ensure the resilience and adaptation of agro-ecosystems to shocks/disruptions due to global change (Lin, 2011). It will therefore be necessary to understand the conditions under which the transition envisaged by the SNBC-A could encourage the return of this specific type of biodiversity.

19 We refer here to cardiovascular diseases, type 2 diabetes and, to a lesser extent, colorectal cancers.

20 The prevalence of overweight and obese people in France increased significantly between 1982 and 2006 and has since stabilized. Thus, the obesity rate increased from 5.3% to 16.9% of the population, while the proportion of overweight (including obese) people rose from 23% to 49% (de Saint Pol, 2007 ; Verdot C *et al.*, 2017).

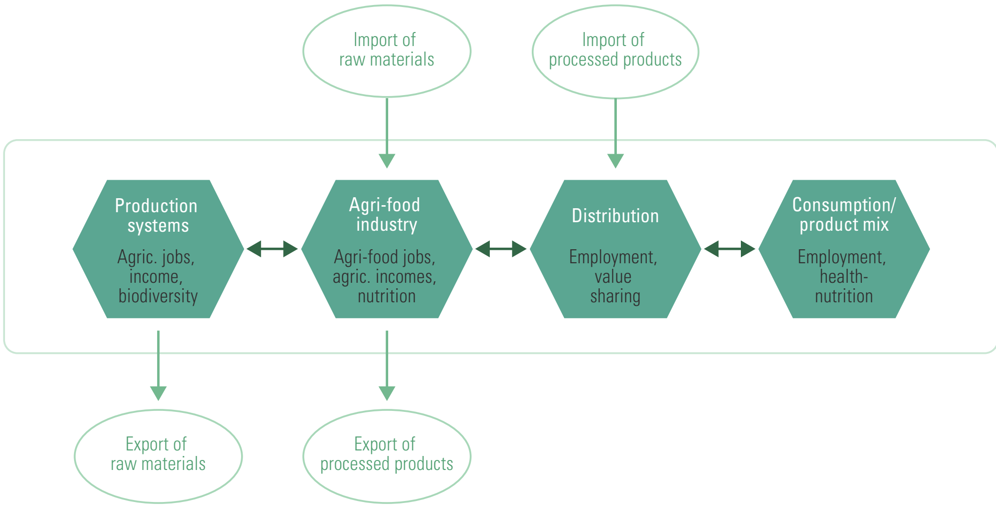
2.2 *Food value chains at the heart of modelling*

The technical and economic functioning of food value chains is at the core of this modelling. The model takes account of three components within which agricultural and food products are produced, processed, exchanged and consumed:

1. farming systems and the agrarian systems in which they are embedded, where the production of agricultural raw materials is carried out according to specific technical and social modalities and, therefore, with important socio-economic (employment & farm income) and environmental (biodiversity, natural resources, landscape) consequences;
2. agri-food and agro-industrial sectors, through which these raw materials are transformed into consumer products of varying degrees of complexity, which are then distributed to final consumers. Here, the production methods used largely determine the level of employment in the sectors and the nutritional quality of the products; they also have an important influence on the final price of the products for the consumer, but also on the "raw material" costs, which is the price paid to the farmers;
3. final consumers, of food or non-food products, in France and internationally.

Trade between France and the rest of the world (common market as well as third countries) is analysed at each link (raw materials, semi-finished and final consumer products). The arrows in **Figure 3** represent these exchanges. Similarly, spatial dynamics, both in the evolution of agricultural landscapes and in the organization of the agro-industrial complex, are analysed at each level.

Figure 3. Logical structure of food value chains



Source: authors

This conceptual model is equipped to address two issues:

- What changes in actor strategies, at each of the links considered (agricultural production, agri-food industry, consumers), could be compatible with the initial agronomic/biophysical assumptions (in that case, those of the SNBC-A) ?
- How do these strategic changes in turn affect the economic equilibrium of actors and, consequently, the way they manage employment, nutrition-health and agrobiodiversity challenges?

This conceptual framework and the associated modelling tools provide a detailed understanding of key transformations in the food system when considering the decarbonization objective. A brief presentation is provided here, which is expanded throughout the text (and also in the appendix).

At the level of agricultural production, the biophysical scenario used as a starting point (in this case the SNBC-A) sets targets for area/livestock, associated yields (thus determining production), and the rate of adoption of certain practices that are favourable to emissions reduction or sequestration. It does not, however, specify the type of agricultural structures that will be responsible for this production in the future: will they need to be larger than today and, if so, by how much? More specialized or more diversified? More capital-intensive? How diverse will farming systems be? Addressing these questions requires an analysis of the different strategies that farmers may adopt, along with the drawing up of scenarios involving the possible combination of these strategies to achieve the SNBC-A's agro-climate objectives by 2030. The scenarios on the evolution of farming systems thus created enable the assessment of the following, based also on a a series of assumptions on the evolution of production factor costs (that are detailed in the technical appendix):

- change of production costs;
- change in the numbers of farms and jobs;
- the potential impact on agrobiodiversity.

This analysis is also the first step in exploring the impacts on agricultural income; the completion of this exploration involves linking the scenario design of the agricultural component, with that of the "chain" component (a detailed presentation of the approach adopted, the associated calculator and the methods of its application to the two sectors considered can be found in the technical appendix of this study). The impact of a given change in production costs on farm income depends ultimately on the accompanying change in farm revenue, of which there is two types:

subsidies received (mainly) under the CAP; and the income from the sale of production, which is based on a volume and unit price. This unit selling price corresponds to the purchase price of agricultural raw materials for the agri-food industries. To define this purchase price, the industries rely on at least three parameters: the state of world commodity prices (an aspect we do not explore further here); the existence (or otherwise) of competition, particularly from imports; and the need to maintain a certain level of economic profitability for agri-food companies (in other words: the industry cannot pay above a certain price for raw materials without calling its economic model into question).

In the often proposed hypothesis, which we return to later in the text, where the decarbonization of agriculture leads to an increase in production costs at the farm level, the maintenance of farm income implies that the rise in production costs is offset either by an increase in agricultural subsidies, or by an increase in selling prices. Our conceptual model makes it possible to examine the implications of an increase in selling prices on the rest of the chain up to the consumer. The three options, that will be analysed in more detail below, are:

1. an increase in purchase price (i.e., an increase in raw material costs for the agri-food industry) is absorbed directly by the agri-food industry without repercussions on the rest of the chain. This may be the case if actors in the sector are able to compensate for this rise in raw material prices by reducing the cost of other production factors, or if they are able to reduce their margin;
2. the agri-food industry cannot reduce either the cost of other production factors or their profit levels; in which case, they pass on the increased cost of raw materials through an increase in the price to the distributors, but the latter is able to absorb the difference, which means the rise does not reach the consumer;
3. in a third situation, the increase in the cost of raw materials for the agri-food industry is passed on to the distributors, who pass it on to consumers, who have to reduce their budgets accordingly. This option may be acceptable to some consumers if the price change also reflects a change in the product and its qualities, perceived or intrinsic.

Option 1, 2, or 3 can be considered as the dominate one in a given scenario, depending on the complementary assumptions made regarding the other two components of our conceptual model: the food industry and consumer demand.[21] We take a brief look at these two points here:

Regarding the agri-food industry, the evolution of production costs excluding raw materials, as well as the quality of the products offered for sale, depends on the strategic choices made by companies whether in terms of renewing processing equipment, mobilizing human resources, product/market positioning, etc.

In the same way as the agricultural link, we identified different development strategies for the agri-food industries and devised several combinations, consistent with the volumes of raw materials from the agricultural link. These strategies are based on the characterization of two key components:

- the evolution of the "product mix", i.e., the final products offered to consumers and their qualities - which in turn affects the structure of the agrifood industry, the average employment intensity per sector, and ultimately the overall employment level (a detailed presentation of the approach and the calculator developed for this purpose can be found in the technical appendix);
- the evolution of the industrial fabric (labour intensity, capital intensity) which, together with the estimation of volumes and their qualities, enables to assess the on jobs (an attempt was made to analyse the impacts of these strategic changes on production costs excluding raw materials, but the issue proved too complex at this stage);

The assumptions that can be made about the product mix and the industrial fabric are highly dependent on the assumptions made about changes in consumer demand. Through the adjustment of consumer prices or by putting new products onto the market, producers indeed run the risk that the consumers will not "follow". Given a situation of no change in the apparent

21 The role and strategies of distribution, although an integral part of our conceptual model, could not be fully addressed in this study. Taking them into account in detail would have required developments that would have been impossible to carry out in the framework of this study. For recent work in this area, which could be coupled with the analysis conducted here, see (School, 2020).

quality of a product (perceived by the consumer at least), a price increase will most likely result in the substitution of a product by a competing product that is deemed equivalent, thus leading to a loss of market share. In terms of scenario design, the issue is therefore about ensuring consistency with regard to assumptions on demand and those on supply.

How supply and demand will meet depend, however, on a third aspect, namely competitive dynamics, whether in regard to agricultural raw materials or the products of the agri-food industry. Indeed, in the event of a rise in selling prices between two links (agricultural raw materials to the agri-food industry, processed products to retailers), economic actors may seek to obtain supplies from a more competitive supplier - both nationally and internationally. In the latter case, the buyer is no longer subject to the cost increase constraint - and neither is the consumer. On the other hand, it means the seller risks being unable to find a buyer at a price that covers the costs of production, potentially raising doubts over their investment viability. Our model addresses these issues by putting production cost changes in the scenario into perspective, firstly with assumptions on demand, and secondly with the current dynamics of the main international competitors - on the export and domestic markets.

Overall, the development of a set of assumptions characterizing actor strategies at each step in the food system makes it possible to parameterize two complementary simulation tools that characterize changes in farming systems (SPcalc) and the agri-food industry (IAAcalc) (presented in the Appendix). Taken together, these tools enable the analysis of the conditions under which the low-carbon transition, as envisaged by the French national strategy can be socially just; they also provide tangible elements – although not entirely conclusive ones, as discussed later – on the issues at stake in different pathways in terms of food (price and nutritional quality) and biodiversity.

The robustness of the proposed set of hypotheses results from the simultaneous understanding of (i) the mechanisms that link the techno-economic dynamics of food value chains to their impacts; and (ii) the recent developments in these value chains, resulting from the retrospective work presented in the following section.

3. Socio-economic challenges of the transition: key findings of a retrospective analysis

In this section, the functioning of the French food system and its recent dynamics (over the last 20 to 50 years depending on the data sources) are analysed through MoFOT. For every link considered in the food value chains (agricultural production, agri-food industry, consumption), we present (i) the current situation (in terms of the dominant strategies and technical-economic functioning) and its recent developments; (ii) the impacts of these developments on the issues considered, and (iii) the main socio-political dynamics at stake in the observed developments,[22] ultimately enabling the initial identification of pathways towards change or breakthroughs for the development of scenarios. This retrospective work makes it possible to illustrate MoFOT's ability to account for recent dynamics and their impact on the issues under consideration, and to identify the main challenges that can be addressed by sustainable transition scenarios that allow for breakthroughs of different magnitudes.

3.1 Data sources

The analysis proposed here is based on the linking of heterogeneous data sources (which are not always easily interoperable) to quantify changes at all levels of food value chains.

The analysis of the evolution of farming systems is based on the complete *Réseau d'information comptable agricole* (RICA, Farm Accountancy Data Network)[23] and the *Recensement général agricole* (RGA, General

22 Given the complexity and scale of the changes that have taken place in the French food system as a whole over the last three decades, the analyses that follow are highly selective and only trace the dynamics directly related to the questions posed by this study. More detailed elements relating to the two sectors analysed are presented in a box in Part 4 to enable the reader to fully grasp the assumptions made.

23 The RICA database is a European statistical database that focuses on large and medium-sized farms (Standard Output (SO) above €25,000). In France, the sample includes 7,284 farms extrapolated to 296,800, representing about 70% of the total number of farms (450,000 in 2013) but 95% of the production potential and 90% of the surface area. The RICA analysis focuses on the year 2015, which was chosen as the reference year for the scenarios. Although 2015 was rather favourable for crop production and more difficult for pig and dairy farming, the cyclical variations are considered negligible in view of the envisaged overall structural determinants.

Table 1. Data sources used to reconstruct the system's past dynamics

System component	Data source mobilized (and reference year where relevant) / *Data type*
Agricultural link	RICA – *Réseau d'information comptable agricole* (Farm Accountancy Data Network, 2015) *Accountancy data from a network of 7,284 farms, representing French medium and large farms* RGA – *Recensement général agricole* (General agricultural census, 2010) *Comprehensive data on all French farms (area, livestock, workforce, production and marketing methods, etc.)*
Agri-food link	ESANE – *Élaboration des statistiques annuelles d'entreprises* (Structural business statistics, 2012-2017) *Accounting and socio-economic data aggregated according to the French activity nomenclature (NAF)* DDE – Démographie des entreprises (Business demographics) *Demographic data: number of legal entities and number of jobs by company size and NAF code* PRODCOM – PRODuction COMmunautaire (Community Production) *Level of production and trade in volume and value, by product class*
Consumer link	INCA 3 *Data on food consumption representative of the French population (presentation of typical diets from the perspective of different social indicators)* FAOstat *Food consumption data by country based on supply balances*
Trade	FAOstat & COMTRADE *Trade data in volume and value by major product categories*

Source: authors

Agricultural Census), which provide detailed technical and economic information at the farm level.

For the agri-food industries, the Élaboration des statistiques annuelles d'entreprises (ESANE, Structural Business Statistics) database was used, which provides aggregated/consolidated data at the activity sector level, grouped according to the *Nomenclature d'Activités Françaises* (NAF, French activity nomenclature) at its most detailed level (the so-called NAF 5 level); the business demography database, which provides the number of legal entities of each size for each activity sector; and the PRODCOM (*PRODuction COMmunautaire,* Community Production) database, which for each NAF code provides the production levels in terms of volume and value for French industries.

For consumption, the basic data of the INCA 3 survey and the consolidated food balance sheets of FAOstat were used.

Finally, for the analysis of international trade, the COMTRADE database (United Nations International Trade Statistics Database) was used, which lists all trade in volume and value, recorded according to the consolidated codes of the United Nations, partially covering the NAF codes.

The quantitative analyses from these databases were put into perspective using academic and grey literature to qualify the observed dynamics.

Box 3. Key concepts used to understand the evolution of farming systemfarming systems

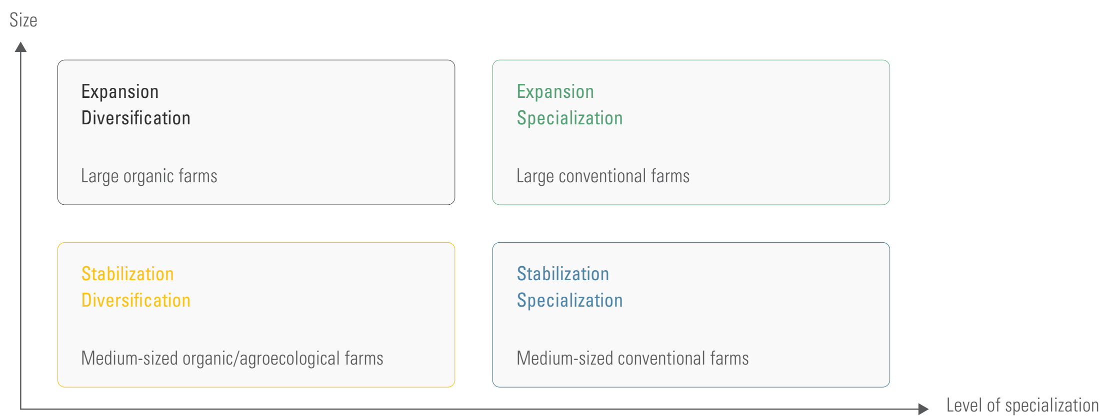
MoFOT looks at farm dynamics from the perspective of the "système de production" (farming system) concept, which originated in French-style comparative agriculture (Cochet *et al.*, 2007 ; Cochet, 2012 ; Darnhofer *et al.*, 2012). This concept enables the analysis of the strategies governing the development of farms from a dual agri-environmental and socio-economic point of view, and thus to address their impacts on, firstly, employment and farm income, and secondly on biodiversity*. Three key indicators structure the analysis: the degree of concentration (and relative importance) of the different production factors (land, labour, capital); the level of specialization of the farming systems, which results from the choice of allocating the available factors of production to one or more activities; and the degree of intensification of the factors of production**.

Source: authors

* This framing deliberately distances itself from exclusively economic approaches, especially those based on the concept of "total productivity of production factors" to understand/predict the profitability or economic performance of farms (e.g. Fuglie et al., 2019). Although these approaches have recently attempted to integrate certain agri-environmental aspects (e.g. Coomes et al., 2019), it remains difficult to link them with finer agrarian dynamics, which are fundamental to the approach proposed here, and they suffer from significant methodological difficulties (particularly concerning the monetary equivalence of all factors of production).

** The level of land intensification is considered in terms of yields per hectare or per animal; that of capital in terms of value added/fixed capital; and that of labour in terms of value added/farm labour unit.

Figure 4. Four possible development strategies for farming systems



Source: IDDRI inspired by (Cerfrance, 2019)

3.2 *A strong trend towards the intensification/specialization of farming systems due to competitive pressure*

A triple concentration-specialization-intensification dynamic with major social and environmental impacts

In very general terms, two strategic pillars can be considered to characterize the development of farming systems: their concentration and specialization levels, which reveal four potential strategies.

Recent decades have been dominated by strategies that combine the concentration, specialization and intensification of production factors[24] – which are shown in the top right quarter of our diagram. Other strategies, based particularly on the differentiation of production (with or without growth in size) have developed, but their numerical significance remains low (in terms of both farm number and utilized agricultural area (UAA)) and they do not impact on the generic pattern outlined above shown here.

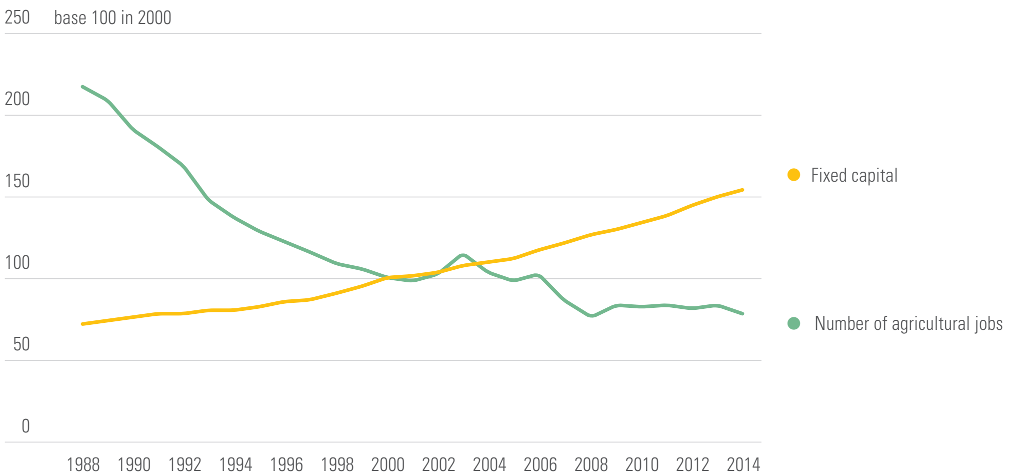
This triple concentration/specialization/intensification dynamic is fundamentally based on the development and adoption of technical/technological innovations, which have led to a radical increase in the material productivity of farms: firstly, the productivity of land and livestock, for almost all types of production; and secondly, the physical productivity of labour, which can be approximated by comparing the total production of French agriculture, expressed in terms of calories (FAOstat data), with the change in the number of agricultural jobs (INSEE data). The increase in land productivity has led to an unprecedented increase in the total production of French agriculture, for a constant surface area. The increase in labour productivity has led to an equally significant reduction in the

24 Intensification of labour and land factors, and not capital factor - see below.

25 In this respect, it can be noted that the development of animal production since the 1970s (and, to a lesser extent, of biogas more recently) has enabled the mitigation of the impact of the increase in the material productivity of labour on employment. Indeed, strictly from the perspective of the volume of activity - and therefore of employment - intensive animal production enables the multiplication of the number of operations for the production of a single kilogramme of consumable calories: while crop production for direct human consumption requires a single production cycle, its use for animal feed (or the production of biogas on farms) entails the addition of one or even two production cycles.

26 The so-called "MacSharry reform" of the CAP, conducted in parallel with a renegotiation of the trade rules concerning agricultural raw materials, put an end to the policy of guaranteed prices (through which producers were assured of receiving a certain price per tonne or per litre of milk for the majority of products) and to a strong protection of European markets based on significant customs duties. Farmers are therefore exposed to the dynamics of international competition. Although the amount of subsidies paid has decreased very little, there has been a significant change to the underlying rationale, becoming more closely linked to new trade rules.

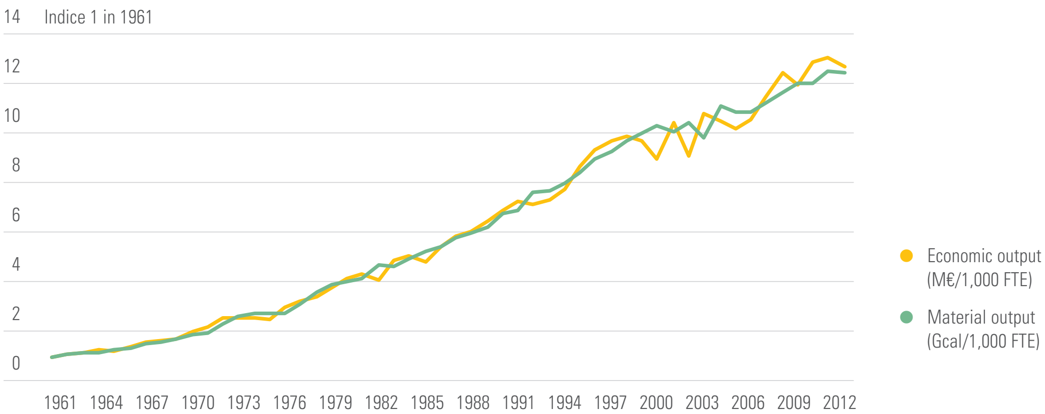
Figure 5. Capital-labour substitution in French farms between 1988 and 2014 (all sectors combined)



Source: Authors, based on RICA data

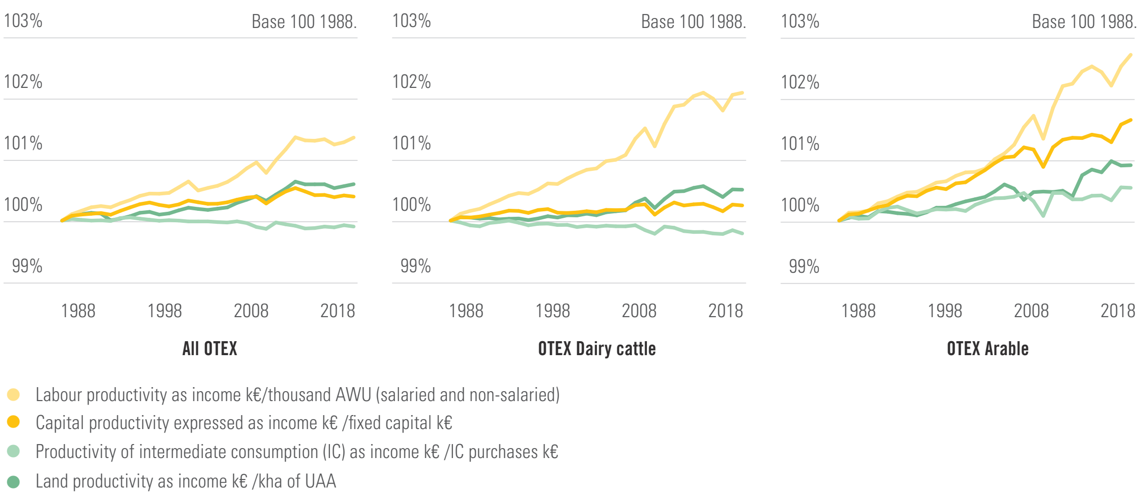
number of farms and jobs (salaried and non-salaried) in the agricultural sector, through a vast movement of substitution of labour by capital (see **Figure 5**).[25] These gains in physical productivity, particularly labour, have made it possible to increase production while reducing employment, and thus to "stay in the race" in an agricultural sector that is increasingly exposed to competitive pressure following the liberalization of agricultural markets (with the 1992 MacSharry reform and then the successive changes to the CAP)[26] and also the increasing concentration of downstream industrial operators (Sexton, 2013). Increasing physical productivity thus appears to be a response to increase price competitiveness in the face of growing competitive pressure, in highly commoditized markets where differentiation and innovation have historically played a lesser role (see below). Competitive pressure and demographic decline are thus contributing to the transformation of the farming systems, which can be seen in the emergence of a new type of farming, known as "corporate farming" (which currently represents 10% of farms, 28% of employment and 30% of SO) (Purseigle *et al.*, 2017). In contrast to traditional family farming, where the majority of production factors are concentrated in the hands of the farmer, corporate farming is characterized by new forms of governance where land and/or capital owners are often no longer the ones who work in the fields.

Figure 6. Similar growth in the material and economic productivity of agricultural labour



Sources: FAOstat, INSEE, processed by IDDRI

Figure 7. Labour productivity, the driving force behind the evolution of total factor productivity in agriculture, but with strong contrasts between TFs



Source: authors, based on RICA data

In this process, the simultaneous decrease in farm number and the number of agricultural jobs has facilitated a gradual increase in average farm income (Piet *et al.*, 2020), with physical labour productivity growing at a similar rate to economic productivity (all sectors combined – see **Figure 6**). However, a more detailed analysis of changes in economic productivity shows that there are significant differences between sectors, with particularly evident contrasts for the two sectors analysed in this study: dairy and arable (**Figure 7**).

Over time, however, a significant proportion of the productivity gains obtained in agriculture have been captured downstream, either by the agri-food industries (which have in turn used the decrease in material costs to invest) or directly by the consumer via a fall in consumer prices (Butault, 2008). These developments partly explain why the - albeit real - improvement in farm income has not been sufficient to fully converge with the average non-farm income (EC, 2017, p. 14). On this point, however, recently presented work in the Agr'Income project (Piet *et al.*, 2020, p. 17) has highlighted the complexity of the issue: the existence of social transfers and tax measures specific to agriculture, as well as the development of non-agricultural income sources, makes it possible to significantly reduce the gap shown in the public statistics between the income of agricultural households and other households.

In parallel with this concentration/specialization/intensification dynamic, strategies based on production differentiation and non-price competitiveness have emerged and developed. Based on publicly recognized quality labels (organic farming, Geographical Indications, red label, etc.), these strategies prioritize the economic productivity of labour above physical productivity. While farms adopting these strategies show rather better economic performance, with higher employment intensity, their viability frequently (though not exclusively) depends on the level of premium[27] associated with the differentiated nature of their production (van der Ploeg *et al.*, 2019). However, the increase in the supply of differentiated products has historically led to a gradual decline in the premium for food products (this has particularly been the case for organic products, see Bâ, 2016), thereby weakening the strategies that depend on them.[28]

Between competitive pressures and changing market demands, what are the challenges for the transition?

Changes in French agricultural systems were initially determined by the Common Agricultural Policy. At its outset, this policy promoted the movement towards concentration/intensification/specialization through market protection and investment support measures. The gradual liberalization of trade after the 1992 reform and the 1995 Marrakech Agreement at the WTO, followed by the signing of numerous free trade agreements (Copenhagen Economics, 2016), then exposed farmers to increasing competitive pressure, which only strengthened the triple concentration/specialization/intensification dynamic. The exposure of producers to strong competitive pressure/price competitiveness increased further with the growing concentration of downstream agro-industrial operators from the 1990s. In this context, the "literal" application of European competition law in the agricultural sector has progressively limited the role of the tools of collective organization that were implemented in France in the 1980s and, as a result, has worked to the disadvantage of producers – even though these collective organizations, both horizontal (producer organizations) and vertical (inter-professional associations), now receive greater recognition in Brussels.

The emergence of the CAP's second pillar (Pillar II) in the mid-1990s subsequently accompanied the development of more extensive production methods, with the pursuit of market value through quality standards.[29] This has been encouraged, both within Europe and internationally, by the European Union's active policy to promote quality and origin labels (*Les signes officiels de la qualité et de l'origine,* SIQO) and

27 The term *premium* is used to designate the price difference between a "standard" product and a differentiated or "quality" product (the notion of quality requires inverted commas, given the importance of the qualification of goods in the market adjustment).

28 The issue of the market share "threshold" for differentiated products, beyond which the premium is significantly eroded remains largely ambiguous: is it 10, 15 or 30%? In any situation, this threshold varies according to product and sector type.

29 Pillar II of the CAP was introduced by the so-called "Agenda 2000" reform in 1999. It aims to finance the European Union's rural development policy through subsidies to agriculture. Pillar II subsidies particularly focus on improving the management of natural resources and maintaining or promoting employment through agriculture or agri-food in less-favoured areas.

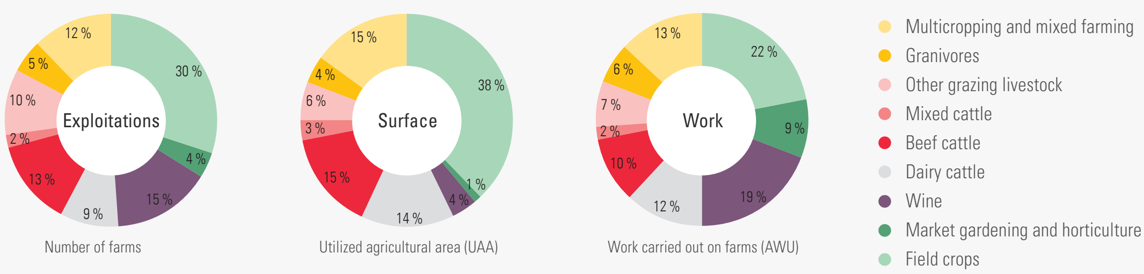
Encadré 4. Overview of the French agricultural sector

- Agricultural farming systems are divided into major specialization types, grouped into statistical categories known as TF (type of farming)*. The arable sector is the leading production sector, particularly in terms of agricultural area (38% of the UAA). Combined with dairy cattle/mixed cattle farming and mixed crop livestock farming sectors, which are the focus of this study, this accounts for 70% of agricultural land. Other sectors with smaller territorial footprints nevertheless occupy an important place in terms of employment at the national level. This is the case for wine growing and market gardening/horticulture, which are more labour intensive and account for 29% of the national agricultural workforce.
- Jobs and farmland are concentrated on large and very large farms, which account for 73% of total farmland and 67% of jobs. Conversely, small farms account for almost a third of the total number of farms, but only 7% of the total area and 12% of the total jobs.
- Disparities in farm income (calculated from the indicator of current income before tax per non-salaried worker) are significant between the different production types. On average, vineyards have higher incomes than other specializations. Cereal, oilseed and protein crop farms also have higher incomes on average than the other specializations, although in recent years these have been marked by great variability due to price fluctuations and exceptional climatic events. This variability has also been considerable for pig farms, due to highly volatile pork prices in a poorly regulated market. Incomes for cattle farms are more stable, but lower on average. Moreover, these average incomes conceal a wide range within each specialization, between the most efficient and the least efficient farms.

* The type of farming (TF) is defined based on the standard gross production (SO), which describes the production potential of farms. A farm is considered specialized in a type of production when its main production represents more than two thirds of the farm's SO. The farm is then designated with one of the 64 types of farming from the detailed nomenclature.

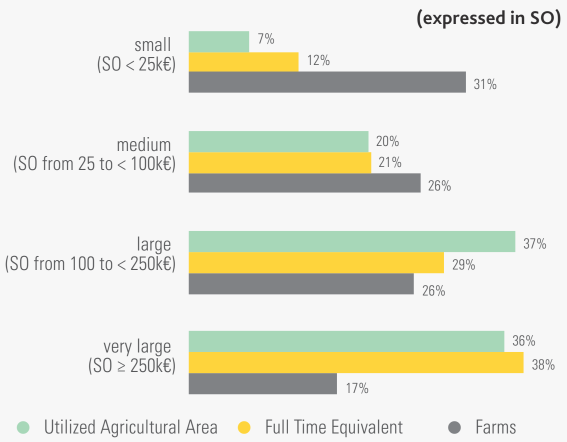
Sources : Auteurs, d'après données INSEE & MAA

Figure 8. Proportion of farms, areas and jobs according to farm type



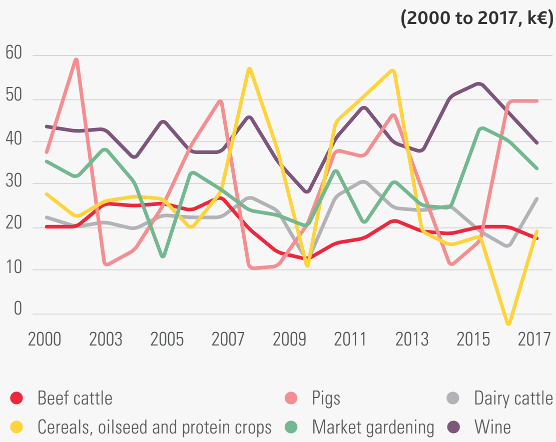
Source Agreste ESEA 2016, processed by IDDRI

Figure 9. Proportion of farms, jobs and areas according to farm size



Source: Agreste ESEA 2016, processed by IDDRI

Figure 10. EBIT (Earnings Before Interest and Taxes) per non-salaried worker by farm type,



Source: RICA

to foster their recognition. However, the very limited budget of Pillar II (compared to Pillar I) has limited the possibility of major developments in these strategies. In a context where the indicative trajectory of the SNBC-A envisages a stabilization, or even a decrease, in production volumes by 2030 – and even more so by 2050 – (depending on the sectors considered), maintaining such a policy framework, favouring a continued increase in the physical productivity of production, would lead to the loss of farmers from the agricultural sector through an amplification of recent trends. In the same way, an increase in strategies based on differentiation and premium would raise the question of the market balances necessary for their economic viability.

Furthermore, there are also environmental challenges related to the adoption of strategies favouring physical productivity rather than the economic productivity of agricultural labour, particularly regarding the biodiversity of agricultural landscapes. In many sectors, especially the two studied here (arable and dairy farming), the search for greater physical productivity of labour has led to an increasing simplification of farming systems, which has itself had a negative impact on agrobiodiversity, through two key processes (Gonthier *et al.*, 2014) 2014: a simplification of the landscape and a reduction in the level of spatial heterogeneity; and an increase in the total amount of synthetic inputs applied to the land (entre 2009-2011 et 2017-2018, les ventes de produits phytopharmaceutiques en France exprimées en NODU ont augmenté de 21 % – voir MAA, 2020).

In arable farming, the simplification and enlargement of farms have mainly concerned two aspects: a shortening and simplification of rotations; and a reduction in the proportion of agro-ecological infrastructure on farms (especially permanent grasslands) (Schott *et al.*, 2010 ; Meynard *et al.*, 2018). In the case of dairy cattle, the combination of a complex land situation in many regions and the continuous increase in herd size has led to a reduction in the amount of forage in typical livestock rations, and a de facto increase in the use of concentrate feeds (maize silage and soya) for animal feed (Posseme & Seuret, 2011) – a dynamic that is not, however, specific to French livestock farming (cf notamment sur l'intensification des systèmes laitiers en général Clay *et al.*, 2020).

In contrast, emerging strategies based on differentiation and the prioritization of economic productivity of labour over physical productivity have produced positive results for agrobiodiversity. This is particularly the case for self-sufficient dairy systems (Devienne *et al.*, 2016) or organic field crop systems or, under certain conditions, conservation agriculture (Bengtsson *et al.*, 2005 ; Pelosi *et al.*, 2009).

Ultimately, the impact of the agricultural sector's decarbonization on agricultural income, employment and biodiversity, will depend on the relative importance or even hybridization between both strategies (concentration/specialisation/intensification *vs* differentiation/valorization) and how they rekate to market dynamics. The evolution of the policy framework will play a key role in this respect.

3.3 *The French agri-food industry, between issues of competitiveness and the consideration of societal expectations*

Concentration, segmentation and lengthening of agri-food chains

Based on the analytical framework presented in **Box 5** and the literature (see in particular Traill, 2000), two key areas can be considered to characterize the strategies of the agri-food industry, the combination of which reveals six main strategic positions in a double-entry table (**Table 2**). The first area concerns the geography of target markets – from local/regional markets to international markets, via the national space. The second key area specifies the nature of the products on the market by combining two variables: the type of processing[30] and the type of differentiation. It thus distinguishes:

- primary processing products, resulting from the conversion of heterogeneous and perishable agricultural

30 The existence of several processing "types" results from the progressive organization of the agri-food industry towards dealing with heavy, heterogeneous and perishable agricultural raw materials, around two movements: a movement of conversion, which transforms raw materials into stable and homogeneous ingredients; and a movement of recomposition, which assembles these ingredients to make finished products (Soler *et al.*, 2011).

Box 5. Key concepts for understanding change in the agri-food industries

MoFOT accounts for changes in the agri-food industry at the sub-sector level of economic activities (at the level of NAF 5 codes), at two interdependent levels:

- The level of production tools, which can be characterized by the relative importance and level of intensity in the use of the different production factors: labour, capital, externally purchased goods and services. The intensity of the use of production factors is interpreted in physical and economic terms – regarding the labour factor, for example, the physical intensity of employment relates to the number of jobs required to transform 1,000 tonnes of raw material into final products, while the economic intensity of employment refers to the number of jobs generated by a turnover of €1,000. This dual approach, physical and economic, enables agri-environmental dynamics – how should French production change to reduce agricultural sector emissions by 50%? – to be linked with economic dynamics – what are the economic impacts of the planned transformations, particularly in terms of employment?
- The level of the product mix, which can be characterized by the respective proportion of the various final products obtained for a given quantity of raw material entered into the process - for example, for dairy products, the proportion of cheese, liquid milk or milk powder produced for 1,000 litres of milk. At the company level, the product mix is defined by the type of processing implemented and the nature of products that "leave the factory": ranging from standard to highly differentiated products, lightly or heavily processed. It depends on the markets targeted and the comparative advantages of the companies.

These two levels - intensity in the use of production factors and product mix - are highly dependent. Indeed, the level of employment intensity depends to a large extent on the type of product that dominates the mix. For example, cheese production is much more labour intensive than milk powder production; however the production of AOC/AOP type cheese at small facilities is more employment intensive than the production of mass produced Emmental cheese.

For statistical reasons, MoFOT analyses these developments at the sub-sector activity level in an aggregated manner, whereas the agricultural link has been examined at the farm level (particularly as a result of using RICA data, which enables the analysis to be conducted at the level of individual farms). Conceptually, our approach makes the company the elementary unit of analysis* (voir Hirsch et al., 2014 ; Rastoin, 2016) and considers that companies searching for competitive advantages is thus the main determinant of (i) their economic profitability/viability and (ii) the evolution of the sector in which they operate.

The evolution of volumes, product mix, jobs and, to a lesser extent, the competitiveness of the industries resulting from the changes implemented by these companies was analysed quantitatively using official statistics and served as a basis for subsequent modelling (see appendix). The evolution of product quality from a nutritional point of view and the impact of food industry strategies on the price paid to producers were addressed qualitatively via second-hand data (Monteiro et al., 2017; OFPM, 2020)**.

Source: authors

* Here we have considered companies in the sense of legal entities in official statistics. A legal entity is one under public or private law which, according to European Regulation 696/93, includes "legal persons whose existence is recognised by law independently of the individuals or institutions which may own them or are members of them; [or] natural persons who are engaged in an economic activity in their own rights." The dynamics of groups, which bring together tens or even hundreds of companies (Tozanli, 2015), also play an important role which has not been dealt with here. It is indeed at this level that structuring decisions are taken in terms of brand portfolio, productive or R&D investments, supply strategies, decisions on remuneration of labour or capital, etc., (voir par exemple Pérez, 1996 ; Palpacuer & Tozanli, 2008).

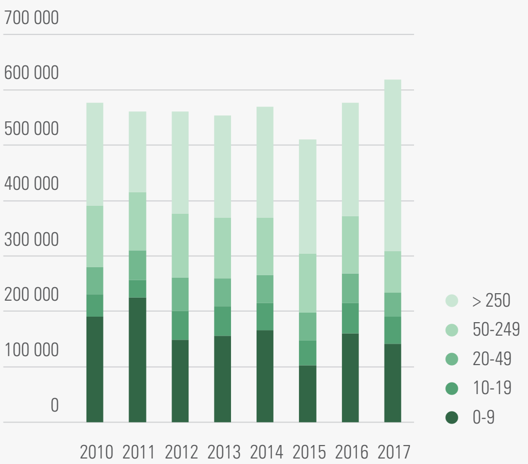
** At the agricultural level it was possible to interpret the strategies of producers and their quantitative impact at the level of individual production systems, due to the highly detailed public statistics, however, this was not possible at the agri-food level. All quantitative analyses were conducted at an aggregate level according to NAF sub-sectors. Fifty NAF-5 codes were considered, covering all codes 10 (food) and 11 (beverages), as well some codes 46 (agri-food wholesale trade). These quantitative analyses were coupled with qualitative analyses of companies or clusters of companies based on the literature.

Box 6. Structure of the French agro-industrial complex

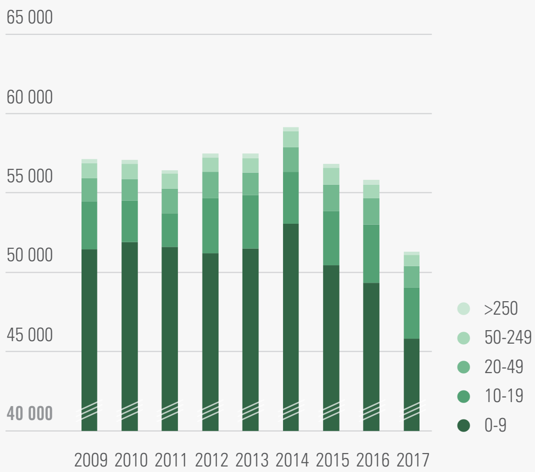
- The French agri-food sector is characterized by the significant importance of small businesses in the total number of companies, but also by the decisive role of large corporations in terms of the total number of jobs. These large corporations therefore partly concentrate the physical production flows.
- The sector is also characterized by the importance of the animal production and primary processing sector. Land-based animal production (dairy and meat processing sectors) accounts for more than a third of the sector's employment and value creation.

Source: Authors, based on INSEE, Eurostat, PRODCOM data

Figure 11. The agri-food industry is dominated by VSEs/SMEs, while employment is concentrated in ISEs and large companies



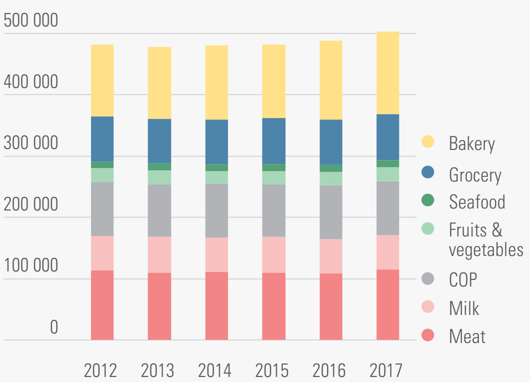
Total number of persons employed, according to company size



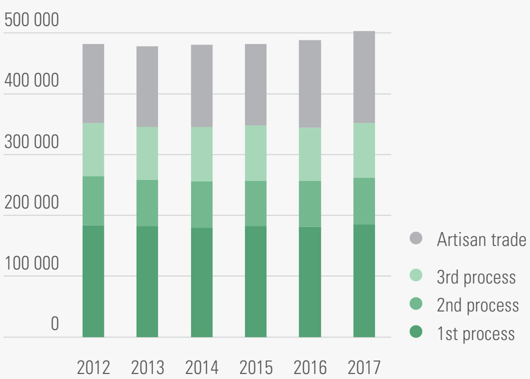
Number of companies according to company size

Sources: Eurostat, processed by IDDRI. Scope: all NAF 10 and 11 codes (including commercial crafts)

Figure 12. Un secteur de la production animale déterminant pour l'emploi agro-industriel en particulier en première transformation



Employment changes in main sectors, in FTE



Employment changes according to level of processing, in FTE

Sources: INSEE-ESANE

Note: differences in total number of employees between Figure 13 and Figure 14 are due to the calculation method: in terms of total number of persons employed for Eurostat data, and in terms of full-time equivalents (FTE) for ESANE.

Table 2. Possible strategic positionings for companies in the agri-food industry (AFI)

	Local markets	National markets	European markets
Standardized products from first stage processing	Ø	IAA_{amont} – type **A** (PME à GE)	
FMCG sold under private label	Ø	IAA_{aval} – type **B** (PME/ETI)	Ø
FMCG sold under national brands	Ø	IAA_{aval} – type **C** (ETI/GE)	
"Ultra-processed" FMCG (corresponding to class 4 NOVA)	Ø	IAA_{aval} – type **D** (ETI/GE)	
Minimally-processed, "terroir" type products	$IAA_{amont\text{-}aval}$ – type **E** (TPE/PME)		$IAA_{amont\text{-}aval}$ – type **F** (PME/ETI)

Ø : means that the strategic positioning is not really meaningful.
TPE : very small enterprises (0-9 employees); SME: small and medium-sized enterprises (10-249);
ETI : intermediate-sized enterprises (250-4,999 employees);
LC : large companies.

Source: authors, based on INSEE and (Traill, 2000)

raw materials into stable, homogeneous and transportable, highly standardized ingredients;

- fast-moving consumer goods (FMCGs) obtained by the recomposition of converted ingredients, usually differentiated "downstream", i.e. through attributes that are symbolic and not particularly related to the intrinsic qualities of the product (the addition of a brand, specific packaging, etc.). Within this category, we can single out so-called "ultra-processed" products within the meaning of the NOVA classification,[31] i.e. composed of ingredients that have undergone a series of transformations, often only for industrial use rather than for use alone in food, such as additives, supplements, etc.
- and products whose "upstream" differentiation is based on the specificities of the agricultural raw material or the production/processing method (related to the terroir) and which are generally obtained from the raw material directly.

Generally speaking, the last few decades have been dominated by a trend of specialization in production, which has simultaneously brought about an increasingly marked dissociation between $AFI_{upstream}$ and $AFI_{downstream}$ and the progressive marginalization of $AFI_{upstream\text{-}downstream}$;[32] an increase in the average amount of processing of food products and a lengthening of agro-industrial chains (more processing stages = more operators involved). We can also observe a trend towards the *concentration* of production tools and companies (Nefussi, 1990), particularly for $AFI_{upstream}$ (position A in **Table 2**), to allow (in particular) economies of scale in an increasingly competitive environment – although this trend has largely slowed down over the last ten years, at least in France (see **Figure 11**). However, these general trends conceal a high degree of heterogeneity in the individual strategies of companies, which **Table 2** enables us to understand in part.

Large companies producing national brand consumer goods (FMCGs) and those producing ultra-processed foods (UPFs) (types C & D in the table) have initially progressively concentrated the bulk of the volumes, in line with the already mentioned progressive concentration in the sector (FCD, 2020). The economies of scale allowed by their large size have made it possible to address the double pressure of price competitiveness: firstly on the domestic market, due

31 There are 4 classes in the NOVA classification (Monteiro *et al.*, 2017): (1) unprocessed foods, (2) processed ingredients (salt, sugar, animal and vegetable fats), (3) processed foods (which result from the alteration of category 1 foods through the use of category 2 ingredients) and (4) ultra-processed foods (composed of ingredients that have undergone a series of transformations, often only for industrial use rather than for use alone in food, such as additives, supplements, etc.) This last class of food groups together the so-called ultra-processed foods.

32 $AFI_{upstream}$ (or primary processors) include all primary processing companies, whose main purpose is to convert agricultural raw materials into ingredients that are stable (more or less), standardized and "transportable". $AFI_{downstream}$ (second and third processors) produce finished products using ingredients derived from the first processing. $AFI_{upstream\text{-}downstream}$, often small scale, carry out all primary and secondary processing operations, aiming for strong differentiation of production by anchoring it in the territory.

to the competition between distributors to lower FMCG prices (Moati, 2010); and secondly on the international market, with the development of increasingly fierce competition with the "traditional" exports of French operators.

Although these companies are key players in the French agri-food sector, they lost market share between 1990 and 2010, to the benefit of operators producing FMCG products sold under private label (PL) (type B of **Table 2**).[33] The growth of PLs, linked to the market power of distributors over the other actors in the agri-food sector and to their increasing concentration (Burch & Lawrence, 2005), has since stabilized at a market share of around 30% (in some countries such as the UK, PL penetration has reached over 50%), contrary to what some had anticipated (Moati, 2010). Their product offer is increasingly distinguished by the search for specificities (quality criteria, labels and claims of all types). Agri-food companies that manufacture products in this PL segment, mostly SMEs or ISEs, are also developing a growing supply of *premium* products as part of their own branding, characterized by an increasing distinctiveness of products and an anchoring in regions, approaching to some extent the type E indicated in **Table 2** (FCD & FEEF, 2018).

Companies that have invested in upstream differentiated products have been particularly successful in recent years - despite their higher employment intensity.[34] Many of these companies are VSEs (0 to 9 employees) and SMEs (10 to 249 employees), corresponding to types E & F in **Table 2**. These trends should be linked to the development of consumer demand (see section 3.4) for more sustainable products - although the physical volumes involved seem relatively low at this stage (see also **Figure 15**).[35] With more than 40% of their products positioned at the top end of the market, PL and own-brand products from VSEs and SMEs sold in supermarkets accounted for 88% of the growth in value in 2018 – even though they are clearly under-represented on the shelves in relation to their importance in the retail sector's overall turnover (FCD & FEEF, 2018).

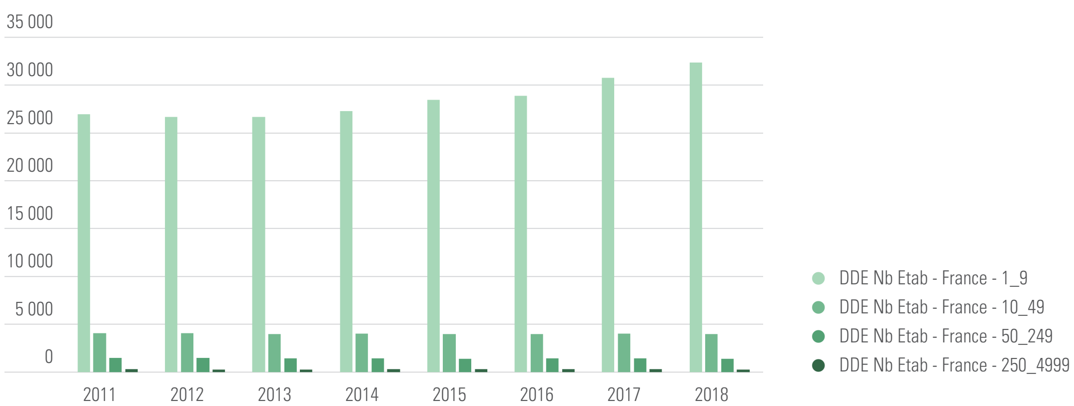
Conversely, SMEs that have not been able to invest in differentiated products have found it difficult to maintain their operations, as they are unable to compete with large companies in commoditized/standardized markets (on pourra se reporter pour des

33 Some manufacturers are also developing "mixed" activities, producing under both their own brand and private label, either structurally or marginally/opportunistically.

34 In this respect, products to which symbolic qualities are not directly linked to their intrinsic properties, but where these qualities are attached downstream of a standardized production process, and that fall under a logic of conversion-recomposition, will not be considered as "differentiated" (e.g. dans le cas du café Daviron & Ponte, 2005).

35 It should be noted that, from a statistical perspective, we do not have disaggregated flows between size classes of companies (i.e. volumes passing through small, medium and large companies), but only volumes aggregated firstly by NAF codes, and secondly by company demographics (i.e. the number of companies per size class for each NAF code).

Figure 13. French agri-food trends for VSEs 2011-2018



Source: authors, according to INSEE, Business demography - NAF codes 10 & 11, excluding craft bakeries données détaillées à Aleksanyan, 2015).[36] The result is a type of dualization of the agri-food industry, which is particularly noticeable in the brewing sector (Xerfi France, 2020). Structural changes in the industrial fabric (increase in the number of very small enterprises, stabilization of companies with 10-49 employees, decline in companies with 50-249 employees, and stabilization of ISEs and LCs - see **Figure 13**) seem to indicate that this dualization is well underway in a large part of the agri-food industry.

Finally, a number of companies have invested mainly in the development of what is known as "ultra-processed" products according to the NOVA classification (Monteiro *et al.*, 2017), products that are intended either for the national market or for export (type E in **Table 1**). The R&D and marketing needs associated with such a strategic positioning mean that this option is mainly accessible to large companies. Its growing importance clearly reveals the major tensions that exist today in the AFI sector between – in particular – the creation of value (and therefore the maintenance of employment) that is facilitated by the development of these products in a saturated food market, in an OECD context (Monteiro *et al.*, 2019), and the consideration of health issues, because there is a clear correlation between the consumption of ultra-processed products and a declining nutritional status (voir dans le cas de la France Schnabel *et al.*, 2019).

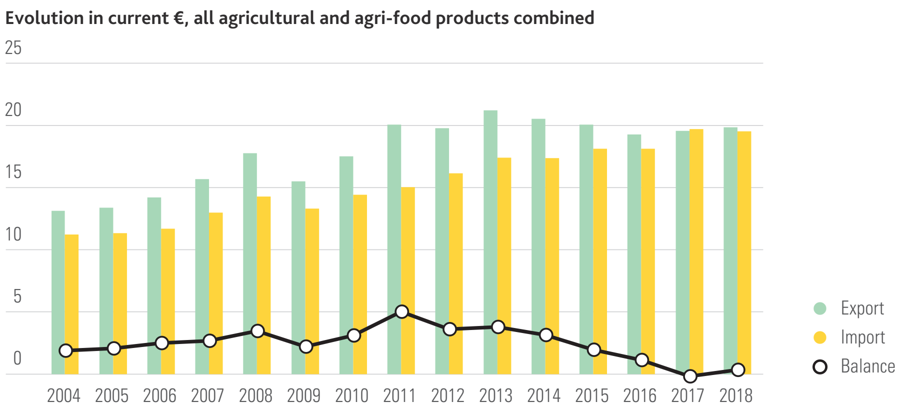
36 Aleksanyan (2015) showed that between 1998-2012, SMEs (companies with up to 249 employees) in the French agro-industry saw a deterioration in almost all of their economic indicators: turnover, value added, margin and profitability, whereas intermediate-sized companies (up to 4,999 employees but with a turnover of less than €1.5 billion) and large companies (other companies) are in a much better situation.

Socio-economic impacts of ongoing transformations

Over the past 60 years, employment in the agri-food sector has been remarkably stable. While significant physical productivity gains were achieved until the mid-1980s, causing a decline in the sector's employment intensity, this decline was more than offset by the increase in the volumes processed by the industry, which allowed employment to be maintained. In the 1990s, processed volumes have grown more slowly and then stagnated, but investment was redirected from capacity development to R&D and marketing. The reverse mechanism then came into play: the stagnation of volumes did not lead to a loss of jobs due to the maintenance of employment intensity. This maintenance of employment intensity is the result of contrasting and sometimes even contradictory dynamics.

- Factories were first automated (bien que de manière plus lente que dans la plupart des autres industries, cf. Ilyukhin *et al.*, 2001), leading to a reduction in the number of workers in large organizations (and to a lesser extent in small organizations, due to high initial costs making it less accessible). The associated job losses were offset by three other trends.

Figure 14. Erosion of French trade balance



Source: Authors, based on COMTRADE data

- The increase in the level of processing of food products has led to a general increase in the number of processing operations, and associated jobs – as shown by the example of the development of ready meals, which involve the mobilization of an increasing number of ingredients (powdered milk, powdered egg, pea proteins for emulsification, etc.) which are then reassembled into standardized products.
- The growing segmentation of markets and the increasing complexity of processing methods has led to a significant development of "new" jobs in marketing and R&D (movement from "blue collar" to "white collar" jobs).
- Finally, the development of employment-intensive artisanal production (typically in the beer (Xerfi France, 2020), biscuit or artisanal pasta markets) has also helped to counterbalance the automation of large processing units.

For many actors (Rouault, 2010 ; Bontemps *et al.*, 2012 ; Duplomb, 2019), the capacity of the French agri-food industry to maintain its level of employment in the years ahead is however threatened by its gradual loss of competitiveness, both on the domestic market (with the penetration rate of imported products steadily increasing for a significant proportion of production) and on the export market (where French exporters are losing market share, in value as well as in volume, in production sectors where historically they have been very present) – see **Figure 14**. These dynamics are particularly noticeable in the two sectors on which this study focuses, arable and dairy.

Several factors can explain thes evolutionq (voir pour une synthèse récente Gaigné *et al.*, 2020). The small size of French operators and industrial tools in relation to their competitors – which mainly concerns the $\text{AFI}_{\text{upstream}}$ – is very often advanced as the main limiting factor, for two reasons. Firstly, smaller operators are less able to significantly increase productivity (less opportunity for economies of scale, and fixed costs per unit of product are too high), which limits the capacity of actors to position themselves in markets where price competition is very strong. Secondly, there is reduced capacity for operators to innovate and differentiate themselves, and therefore to move into (or remain in) fields of non-price competitiveness. Encouraging the creation of larger French organizations to increase productivity could help address the competitive pressures being experienced today; this is a recurring recommendation in the reports submitted by politicians (e.g. Rouault, 2010 ; Duplomb, 2019). In the context of a low-carbon transition, envisaging targeted volume reductions in the most problematic production areas, particularly meat, which accounts for a significant proportion of employment, such a development should be accompanied by significant product innovation and a lengthening of production chains to avoid excessive job losses. However, such a development could also intensify the impact on agri-food companies with regard to two other issues: the nutritional quality of food and the price paid to producers.

In addition to sector-specific employment issues, the transformations of the agri-food industry have also led to increased pressure on the prices paid to agricultural producers, who are poorly organized in a context of an increasing concentration of buyers, who are themselves involved in complex negotiations with distributors. Moreover, although a large proportion of processing companies are owned by cooperatives, which were once in the hands of farmers, this does not always lead to better remuneration for producers, particularly in market segments exposed to strong national or international competition and in which cooperatives are not always the best positioned.

Finally, the development of growth strategies in the food industry based on so-called ultra-processed products has an impact on the nutritional quality of diets – although this issue is quite controversial. While there are no exhaustive studies available – the NOVA classification is not currently recognized by French public authorities – a certain amount of data enables an assessment of the current situation. Davidou et al. (2020) for example, indicated that more than 50% of the food sold in French supermarkets falls into the ultra-processed products category, while the share of calories from such products reached 35% on average for BioNutriNet participants.[37]

37 UPFs account for an increasing share of the average food basket in OECD countries, reaching up to 60% of calories consumed in the US (Martínez Steele *et al.*, 2016) and 48% in Canada (Moubarac *et al.*, 2017). In France, the average value for the entire French population is probably higher than the 35% mentioned here, given the very specific profile of BioNutriNet consumers who are interested in, and committed to, organic food.

Dynamics driven by the internationalization of trade in a context of strong competitive pressure

The French agri-food industry appears to be experiencing difficulties as a result of European and world dynamics, which are increasingly internationalized (particularly through the globalization of supply strategies). This is a consequence of the growing liberalization of agricultural and food markets, which have progressively favoured (very) large operators and the commodification of agricultural and food production. The regulation of large-scale distributors, particularly in France (voir Messerlin, 2008), has also led to increased pressure on and between manufacturers, limiting their margins and pushing them towards increasing their productivity.

The regulatory framework for food safety has also done little to curb the development of highly processed products, the health impact of which remains the subject of much debate as a result of work such as NOVA. In fact, the emphasis placed on product safety tends to support these processing methods. By guaranteeing a very high degree of homogeneity and precise control of industrial production methods, such operations are able to comply with stringent health standards. This context has favoured agri-food strategies that focus on these products as drivers of growth, which indirectly favours larger companies with the ability to invest in R&D and marketing to develop and market such products. In cases where public criticism (or investor pressure) has forced companies to limit the use of certain ingredients through reformulation strategies, the underlying rationale of their strategy (and market position) has not been fundamentally altered (Scrinis, 2016).

In this context, it appears that the low-carbon transition as envisaged by the SNBC-A would be difficult to implement without having major impacts on employment and agricultural income. Indeed, for the transition to be sustainable in terms of employment, the D & E type strategies presented in **Table 1** should be encouraged (comme suggéré dans Rastoin, 2016) due to the high employment they offer, B & C type strategies would have to better valorize agricultural raw material (both at the level of producers and of the manufacture of the product itself), while D type strategies based on UPFs should be discouraged.

In addition to policy changes that target the industry itself, and the organization of markets, such evolutions also imply major changes in consumption practices. The next section of this study examines food demand in order to (i) understand the role it has played in the changes observed so far and (ii) identify how it could change in future, to help foster the type of sustainable pathways described above.

Box 7. Key concepts used to understand the development of dietary practices

Conceptually, three dimensions of consumption trends are distinguished in our modelling to understand their evolution and their (i) environmental, (ii) socio-economic, and (iii) health-nutritional impacts:

- Diets expressed in of "raw product equivalent", which enable to apprehend (i) the adequacy between agricultural supply and food demand; (ii) the environmental impacts of food consumption patterns; (iii) their potential health impacts through an analysis of their adequacy with nutritional recommendations;
- Diets expressed in terms ofproduct types (see the typology in **Table 2**), which provides information on both (i) the number and nature of the processing stages, and therefore indirectly on the level of employment provided by food practices (also a function of the organization of the agro-industrial complex, see below), and (ii) the potential impact on health, due to the observed correlation between processing types and health problems;
- changes in food expenditure, especially in relation to consumption trends - in particular the relative importance of out-of-home food services and highly processed foods in dietary practices - which affects both the accessibility of food for consumers and the remuneration of all those involved in production (and is also a function of the distribution of value throughout the chain).

The available data most often provide information on average values for all these indicators, despite the fact that social heterogeneity is increasing and undergoing strong polarization. We therefore describe the dynamics underway initially at an aggregate/average level, and then provide more detailed information where possible.

Source: authors

3.4 *Diets with less meat and more processed foods, accompanied by increasing social fragmentation*

Seemingly contradictory dynamics

The average French diet expressed in terms of gross product equivalents has evolved over the last three decades. However, it remains marked by two key aspects in the perspective of a low-carbon transition and towards a healthier diet (voir pour une présentation détaillée ANSES, 2017).

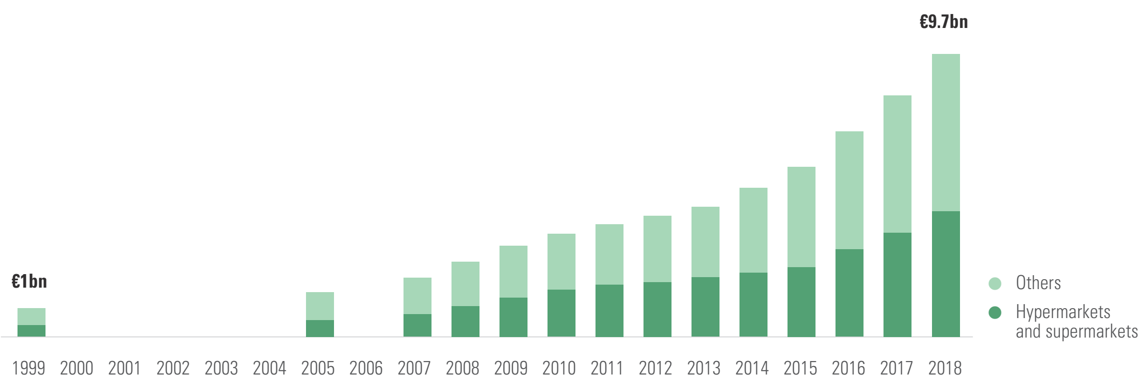
The first aspect relates to the fact that the current consumption of animal products greatly exceeds nutritional needs. Animal protein now accounts for almost two-thirds of the total daily intake, amounting to about 100 g/day, while nutritionists consider that 50 g/day is sufficient to cover the nutritional needs of an "average" individual.[38] The quantity of animal protein consumed increased in the post-war period partly as a result of public incentives – particularly as a way to address a major increase in production capabilities due to considerable progress in terms of physical productivity. The level has stabilized since the early 2000s, even beginning to fall slightly on average, due in particular to a decrease in the consumption of meat products. Although this is a general trend, according to CREDOC it is more noticeable among managers and workers than among the rest of the population (Tavoularis & Sauvage, 2018). Above all, this trend takes extremely different forms according to age groups and dietary practices, with highly processed meat consumption tending to increase overall.

The second point concerns the low consumption levels of legumes, fresh fruit and vegetables with respect to nutritional guidelines (almost 40% of adults consume less than 3.5 portions/day, as opposed to the recommended 5), despite communication campaigns aimed at increasing this consumption. This low level contributes to fibre deficiency, which is itself harmful in terms of the development of colorectal cancers (sur l'ensemble des données de consommation voir Esen, 2017).

As regards the types of products consumed, there is a coexistence of two contrasting dynamics, reflecting a growing fragmentation of dietary practices in the social space. Firstly, the proportion of ultra-processed foods in the average calorie intake is tending to increase, mainly in the less affluent social categories. This increase can be seen, in the short term, in the surveys based on the NOVA classification (en comparant deux sources récentes en la matière, on constate que la part des produits ultra transformés dans la prise calorique totale est passée de moins de 15 % en 1991 à au moins 35 % aujourd'hui – cf Monteiro *et al.*, 2011 ; Davidou *et al.*, 2020); in the longer term this increase is also visible through the rise in the consumption of vegetable oil/capita (which almost doubled between

38 This figure corresponds to a requirement of 0.66 g/kg body mass for an "average" 75 kg individual (EFSA, 2017, p. 24) – this value is also used by Westhoek *et al.* (2011) – or a protein intake equivalent to 10% of the caloric intake of 2,300 kcal/day (ANSES, 2016, p. 23).

Figure 15. Rapid growth of the organic market in terms of value over the last 20 years



Source: (FCD, 2020)

1960 and 2015), due to the fact that it is an essential component of ready meals and highly processed products more generally (Corley, 2009).

Secondly, the market for quality products (organic, terroir and various quality labels) is growing – with double-digit growth for organic food (see **Figure 15**). This change is mainly being driven by social categories for whom the price of food is not a major issue - i.e. the middle and upper classes - on the basis of cross-cutting concerns for health and the environment (Allès *et al.*, 2017), but also due to taste preferences (Mathé & Hebel, 2015).

The work carried out with the BioNutriNet cohort also shows significant correlations between dietary composition, in gross product equivalent, and the nature of the products consumed. Thus, "committed" organic consumers are also those who consume the least highly processed products, and also the lowest amounts of animal protein (Baudry *et al.*, 2019).

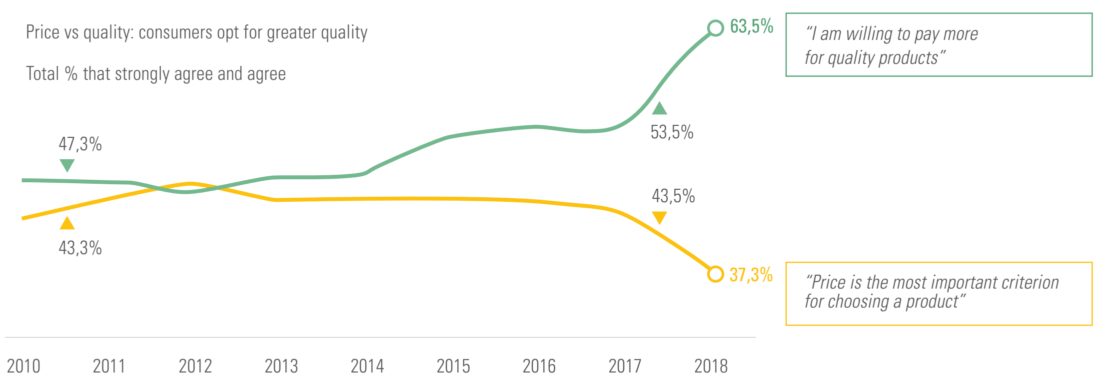
The contrasting dynamics of dietary practices reflect equally contrasting economic realities. On average, the share of the household budget devoted to food fell steadily between the immediate post-war period and the early 2010s; it has since stabilized at around 15% (not including alcohol), and has even risen slightly for some households (Larochette & Sanchez-Gonzalez, 2015). While these changes are a result of the fact that the most precarious social categories have undergone a loss in their total purchasing power (and thus an increase in the relative significance of food in their budget) (Ferret & Demoly, 2019), on the other hand, this trend also seems to be a consequence of a symbolic revaluation of food by households which are less exposed to economic constraints (Mathé & Hebel, 2015). This is also reflected in an increased willingness to pay more for "quality" products, that was discernible prior to the coronavirus pandemic (see **Figure 16**).

All of the developments described above paint a picture of a "food landscape" that is increasingly fragmented and even polarized, essentially between practices that focus more on the environment and health, made possible by a certain degree of economic comfort and a greater time budget; and practices that are more constrained economically and in terms of time, where environmental issues are secondary and for whom the very fact of eating organic/local food, due to the social indicator it represents ("hipsters"), generates a form of mistrust.

Multiple drivers and a wide range of possibilities

The determinants of the above-mentioned dynamics are of a "societal" nature, understood here in the broad sense (cf. Hérault *et al.*, 2019): the individuation of social practices, the acceleration of the pace of life, or the affirmation of new representations of nature (particularly with regard to the consumption of animal products). Moreover, while manufacturers and distributors spend considerable amounts of energy trying to anticipate consumer trends and offer "the right

Figure 16. Un accroissement considérable du consentement à payer (pré-pandémie de COVID-19) pour des produits de qualité



Source: (FCD, 2020)

product at the right time to the right consumer", they also play a key role in structuring consumer practices, both through marketing and through what they put (but above all, do not put) on the shelves.

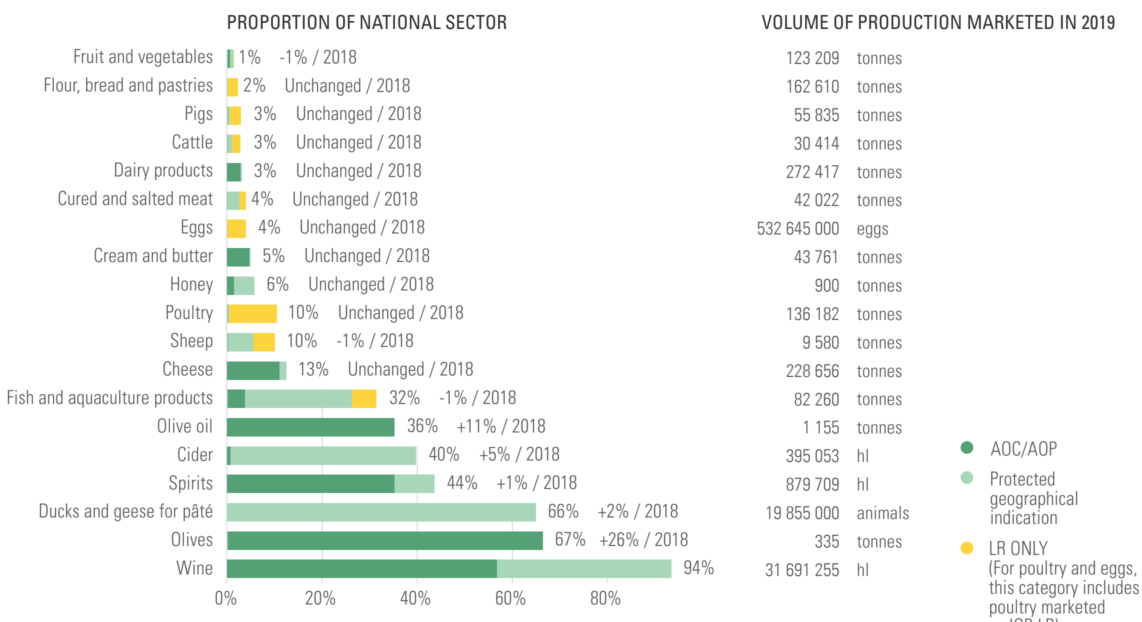
Politics is largely absent from these determinants. Most of the existing policies focus on informational measures, which have limited resources (particularly compared to marketing expenditure by the agri-food industry) and limited effectiveness (Capacci *et al.*, 2012). The emphasis on consumer responsibility also limits the use of measures that aim to intervene more directly on the supply itself, or in the ways in which food supply and demand meet (through marketing regulations, for example). Boubal (2019) shows, however, that this state of affairs results from, among other things, the activism of economic operators in reducing the scope for public intervention in dietary practices.

In this context, a sustainable low-carbon transition for food probably requires significant policy innovations to simultaneously encourage the adoption of quality products, along with changes to the average food basket. The issue of the differentiated targeting of social categories arises to support dietary practices that do not begin from the same starting point (with regard to sustainability and nutrition), and also do not have the same resources (in terms of time and money).

3.5 *Intermediate conclusion: do we have a dual food system?*

Taken together, the current dynamics of value chains contribute to a fragmentation of the food system into two polar archetypes: one, "conventional", which is structured according to competitiveness strategies based mainly on price and volume; the other, "alternative" (a term for which the use of inverted commas is very much needed), structured by differentiation strategies based on the characterization of products on multiple criteria. However, the barrier between these two poles is by no means impermeable, and an increasing number of actors are developing strategies to take part, at varying degrees (in terms of volume and value) in these two dynamics (Sonnino & Marsden, 2006). In terms of volume, the fact however remains that conventional chains largely dominate most sectors, at least those most directly concerned by this study. Products with quality and origin labels, a good proxy for understanding these product differentiations, thus in 2019 represented barely 3% of dairy products (not including cheese), 13% of cheese, and 2% of milled products by volume (see **Figure 21**). In terms of value, so-called "quality" product (all sectors combined –excluding wine) represent 3.4% of the marketed production in France, to which can be added the 5.8% from organic farming sectors - i.e. a

Figure 17. For most sectors, quality labels represent a minority of products in the food chain



Source: (INAO, 2020)

Table 3. Actors and public policies involved with the structure of supply, demand and market organization

	Key policy instruments
Supply	Agriculture: CAP, environmental regulations Agri-food: health standards
Demand	French National Nutrition and Health Programme (PNNS), French National Food Programme (PNA)
Market organization	Common market: CMO (CAP) Organization of chains: competition policy (with exemptions for the agricultural sector + UTP directive) International: WTO rules + FTA

Source: authors

Table 4. Variables determining the impacts of value chains on the issues considered

Component	Variables	Quantitative indicators used (relative to 2030 vs 2015)
Dietary practices	Dietary composition	g/d of gross product equivalent consumed
	Product type	Proportion of ultra-processed products in average food basket as % of total kcal consumed Proportion of "terroir" or labelled/lightly-processed products, in value
	Willingness to pay	Not modelled
Organization of agrarian systems	Degree of farm concentration	Farm size (mean and standard deviation)
	Degree of farm specialization	Relative proportion of main production in the farm's business model
	Degree of crop-livestock linkage, and level of territorial specialization	Proportion of permanent grassland in UAA Share of Organic in total UAA LU/ha of UAA
Agro-industrial complex	Relative importance of $AFI_{upstream}$/$AFI_{upstream-downstream}$/ $AFI_{downstream}$	Employment intensity (no. of FTEs/kt of processed gross product equivalent) % of volumes passing through each organization size % of volumes allocated to different types of final products (specific to each sector)
	Relative importance of small/medium/large units in processing AFI volumes	
	Composition of the product mix and, in particular, the proportion of production based on a differentiation of the agricultural commodity	
Large-scale distribution	Private label product mix Private label development strategy Purchasing policies	Not modelled
Trade	Coverage rate Export rate Penetration rate	Not modelled

Source: authors

total of just under 10% of French production in value terms - excluding winemaking.

This situation is largely the result of a policy framework that:

i. essentially targets the supply side (both agriculture and food) through the CAP and various health and environmental regulations;

ii. organizes markets according to a logic of competition based on environmental, social and nutritional standards that fall short of the issues that need addressing - thus leaving companies and consumers with the responsibility of going beyond public standards;

iii. takes (very) little action on the demand side, apart from the dissemination of information in a poorly targeted and low-intensity way (see **Table 2** for a summary of the current policy framework).

The resulting environmental, socio-economic and nutritional impacts of the food system are not improving, or are even deteriorating, as the preceding sections have shown. While this observation is not new, the retrospective study provides solid foundations for structuring and extending the two low-carbon transition scenarios envisaged in this study. Indeed, it enables the definition of (i) the set of variables which, at each link of the food chain, determine its impacts on the issues considered (see **Table 3**); and (ii) the structuring dynamics of the two scenarios.

3.6 *From retrospective to scenario design: the process and its challenges*

Based on the retrospective work, the scenario design has two main objectives. Firstly, it enables the integration of the system's different dimensions into a systemic and coherent narrative in a "natural language" that can be appropriated by actors ((voir pour une présentation détaillée du rôle des scénarios Poux, 2005). Secondly, it supports public and political debate by providing information on the desirability or feasibility of a given option, and as such informs the issues at stake in the short or medium term.

Two normative scenarios have been constructed for this study, taking the 2050 decarbonization objective set by the SNBC-A as a starting point – which in this respect represents a departure from current trends. Indeed, recent developments in the French food system are either contradictory to the direction set by the SNBC-A, or insufficient to achieve its objectives.[39]

The "Dual France" scenario explores the consequences on the other challenges considered that would result from a decarbonization that is carried out only by the strictly necessary modifications in the political framework and the technical-economic organization. The "Socio-territorial Recompositions" scenario sets ambitious objectives from the outset on all of the issues at stake in order to examine the changes that would be entailed, both in the technical and economic functioning of food value chains and in socio-political dynamics.

On this basis, the narrative allows the sets of assumptions and the results obtained from the two scenarios to be made consistent and presented in a comparable manner. In sections 4.2 and 4.3, each scenario is presented according to the same sequence.

Firstly, the socio-political dynamics underlying the scenario are explained, between politics (i.e., the interplay of actors, power relations and ideas that dominate the political debate) and policies (i.e., the policies and instruments of public action).[40] Three types of policy changes[41] are considered in particular: policies that target food demand (information, taxation, marketing regulation, etc.); those that regulate agricultural and agri-food supply (subsidies, production rules); and those that organize the ways in which supply and demand meet, i.e. the organization of markets (common market, competition policy, trade agreements).

The changes in the strategies of economic actors associated with these adjustments to the socio-political framework, and the resulting technical and economic transformations in the different links in the food value chains are then characterized at a fairly general level as hypotheses that allow the simulation tools developed for this study to be parameterized, and based on the retrospective work carried out in section 3.

The impacts of technical and economic transformations on the four issues of this study (employment and agricultural income, agro-industrial employment, biodiversity, and food) are specified for each link and for the specific example of the two sectors considered,[42] in a comparative and concise manner in section 5.

39 Although by no means an exhaustive list, the following developments can be mentioned: a reduction in the legume area between 2013 and 2018, a loss of permanent grassland (compared to a projected increase), an increase in pesticide dependency (despite the requirement for a reduction), an insufficient improvement in nitrogen use efficiency, etc. (voir pour plus de détails Rüdinger *et al.*, 2018).

40 Here we consider changes in public policies as the result of a joint dynamic of ideas, of actors' interests/interactions, and of institutions, according to an approach that has become a classic in public policy analysis (Heclo, 1994 ; Palier & Surel, 2005), without prejudging the relative importance of any of these three variables.

41 The scenarios are based on assumptions of broad changes in public policy. They do not go into the precise details of the modalities of public action. While such work would obviously be useful, it is beyond the scope of this study.

42 As seen below, this detailed analysis of the impacts is based on a *specification* of the assumptions made in a general way for each link in the specific case of the arable and dairy sectors.

4. Two contrasting scenarios for a low-carbon transition

4.1 "Socio-territorial Recompositions"

The socio-political narrative

The "Socio-territorial Recompositions" scenario gives serious consideration to the announcements made in the framework of the European Green Deal, particularly the "Farm to Fork" (EC, 2020) and "Biodiversity" strategies. The ambitious approach to climate issues is thus accompanied by public policies that give greater attention to health and nutrition, and also to biodiversity. These political changes are made possible through the concerted action of actors from the fields of climate, biodiversity and nutrition-health, and through the scale of social mobilization around food issues, both in France and at the European level.

In terms of health and nutrition, the shifts introduced following the French Citizens' Climate Convention and the proposals contained in the "Farm to Fork" strategy have resulted in a proactive policy with significant resources in two areas:

- consumer awareness/information, including social marketing and major developments in environmental and nutritional labelling;
- stricter monitoring of the consumer's food environment through the imposition of tighter regulations on the food supply with regard to marketing, and nutritional and health standards (limiting the degree of food processing and use of additives).

This double regulation-incentive approach facilitates a slowing down and then a ceasing of the growth in the consumption of ultra-processed products, and supports access to healthy and sustainable food for all categories of the population. At the same time, an expansive support plan for the agri-food industry is implemented to reinforce a network of "medium-sized" companies (with 20-49 or 50-249 employees) capable of producing differentiated foodstuffs linked to territories, but also with controlled production costs giving access to a large market.

The objectives in terms of the circular economy/nixtrogen recycling and the maintenance of biodiversity also lead to the emergence of robust measures framing agricultural production and encouraging a relative territorial despecialization: the 10% agro-ecological infrastructure objective contained within the "Farm to Fork" strategy is raised to 20%, while the target of a 20% reduction in nitrogen inputs is also stepped up, raising it to 30% in line with the recommendations of the European Environment Agency (EEA & FOEN, 2020, p. 10). Completing the system is the development of payments for ecosystem services (PES) that cover all environmental issues according to a multifunctional rationale, notably helping moderate-sized farms to continue being a part of the landscape.

These developments in supply and demand measures are also accompanied by a harmonization of production and marketing conditions at the European level, due in particular to the establishment of effective CAP accountability mechanisms between Member States, the Commission and the Council. Competition law is evolving to allow more leeway for the challenge of meeting social and environmental demands, following the explorations launched by DG COMP in the framework of the Green Deal (voir l'appel à contribution lancée en octobre 2020 DG COMP, 2020). At the same time, the European Union succeeds in revitalizing trade negotiations within a multilateral framework and in gaining acceptance for the idea of border adjustment mechanisms based not only on the carbon content of production but also, more generally, on the environmental and social impact of production methods (voir sur la question des normes attenantes aux modes de production dans les négociations commerciales Gaines, 2002).

These different developments lead to the following policy framework changes (see: **Table 5**).

Table 5. Policy framework evolution

	Key policy instruments
Supply	Agriculture: the CAP integrates and strengthens the "Farm to Fork" strategy's objectives on agro-ecological infrastructure, on the reduction of nitrogen inputs and the development of organic farming + development of PES to support multi-functional practices. Agri-food: nutritional norms for food are reinforced; and support is provided to SMEs and ISEs to develop a food supply with closer links to territories while controlling production costs.
Demand	Information instruments are developed with significant resources, backed up by a multi-functional environmental campaign; Development of support measures for the poorest households.
Market organization	*Common market*: strengthening of the CMO (CAP) with major harmonization of social, environmental and fiscal production conditions among countries through the establishment of strong accountability mechanisms. *Organization of sectors*: competition policy is evolving to better integrate environmental and social issues. *International*: relaunching a multilateral framework consistent with multilateral environmental agreements, allowing food products to be identified according to ambitious social and environmental production criteria, moving beyond a single carbon measurement.

Technical and economic assumptions

Changes in consumption practices accompanied by public action that drives the transformation of the system

The development of an ambitious policy framework to support changes in dietary practices, driven by environmental and health concerns, helps to amplify the current dynamics and reduce the polarization of dietary practices with regard to three aspects.

Firstly, composition of the average diet continues to evolve towards less animal protein (from 62 g/day to 50 g/day) with an increase in legumes (from 4 g/day to 8 g/day). Following more than 15 years of stagnation (Esen, 2017), the consumption of fresh fruit and vegetables is increasing, rising from 265 g/day to 300 g/day due to social marketing that particularly targets the "low eaters" of fruit and vegetables (i.e. those consuming less than 200 g/day) who now represent nearly 40% of adults.

Secondly, the share of highly processed products (category 4 of the NOVA typology) is stabilizing (following a period of strong growth) and then decreasing to less than 30% of calories consumed, due in particular to a return to a diet based on fresh produce and to more "home cooking". The increase in the time budget required to develop these dietary practices, a critical element for the poorest families (Mancino & Newman, 2007), is conditioned under this scenario by broader societal assumptions about the "improving stability" of the working poor. For the more affluent social categories, the increase in the proportion of minimally processed products consumed is linked to the development of food deliveries, which have exploded with the COVID-19 pandemic.[43]

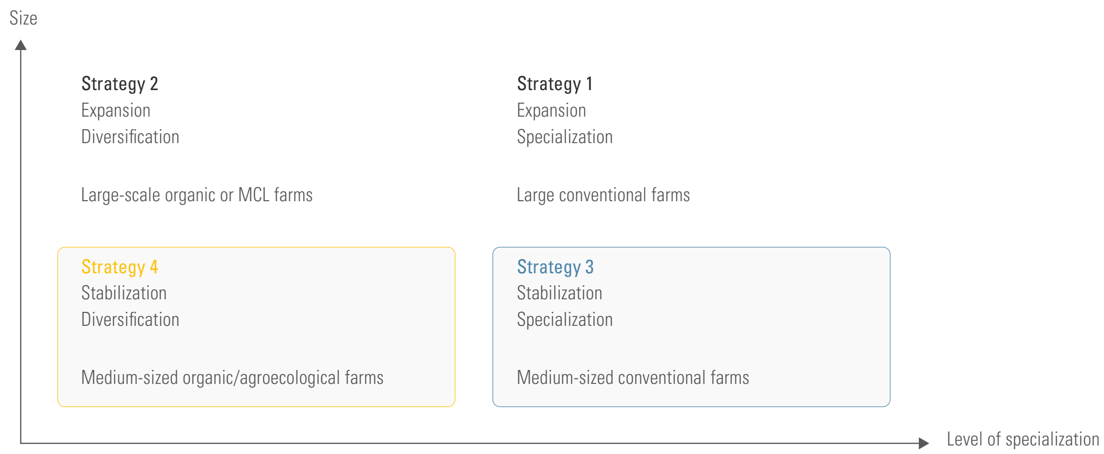
Finally, the proportion of the household budget spent on food remains stable at the beginning of the period (thus continuing to increase in absolute terms) and then gradually increases by 2 to 3% – resulting in a significant increase in constant euros by 2030. For the most affluent families, this trend reflects a continuation of the symbolic revaluation of "healthy eating" that started in the 2010s. For less wealthy social categories, the emergence of a food voucher policy, which is inspired by the American model (Shenkin & Jacobson, 2010) but improved to ensure environmentally sound practices, makes possible this budget increase.

Towards an increase in farm diversification strategies and the stabilization of concentration

The Territorial Recompositions scenario proposes a structural change to the agri-food system in line with sustained consumer demand for quality products and a renegotiation of trade rules. In this scenario, the majority of farmers turn to diversification and more

43 It is worth noting that such a development *also* presupposes that sourcing practices in out-of-home food services are at least partially relocated and made more sustainable.

Figure 18. Dominant evolution strategies of farming systems in the Socio-territorial Recompositions scenario



Source: IDDRI inspired by CER France, 2019

upmarket strategies to respond to the new developments in the agri-food system. **Figure 18** presents the two dominant evolution strategies of this scenario.

The most developed strategy in the scenario consists of the inclusion of the farming system in a chain dynamic that brings together labelling and proximity (strategy 4). The main objective is to maximize the economic productivity of labour (thus moving away from considering productivity in terms of volume). To achieve this, the producer firstly considers the potential for production differentiation, for example by producing organic milk or field crops. The volume of production decreases, but has a higher value, particularly through the recognition and payment of the ecosystem services provided by the farm (biodiversity conservation, carbon storage, etc.). Levers for change are then available regarding technical modifications linked to changes in practices, such as the introduction of legumes and the lengthening of crop rotations for arable farms. Beyond the adoption of new techniques, changes in farming systems are of a systemic nature and the entire rationale of production evolves towards maximizing the use of ecological processes. Training, particularly through information exchange groups among farmers, is a key issue for producers who become part of the overall functioning of agro-ecosystems. These farming systems are supported by local authorities in particular, who seek to ensure local and quality supplies. The territorial redeployment of production is then promoted by a political will at the national and European levels (especially in the framework of environmental standards, such as the nitrates directive, which favours territorial redeployment due to, for example, the constraints relating to spreading manure).

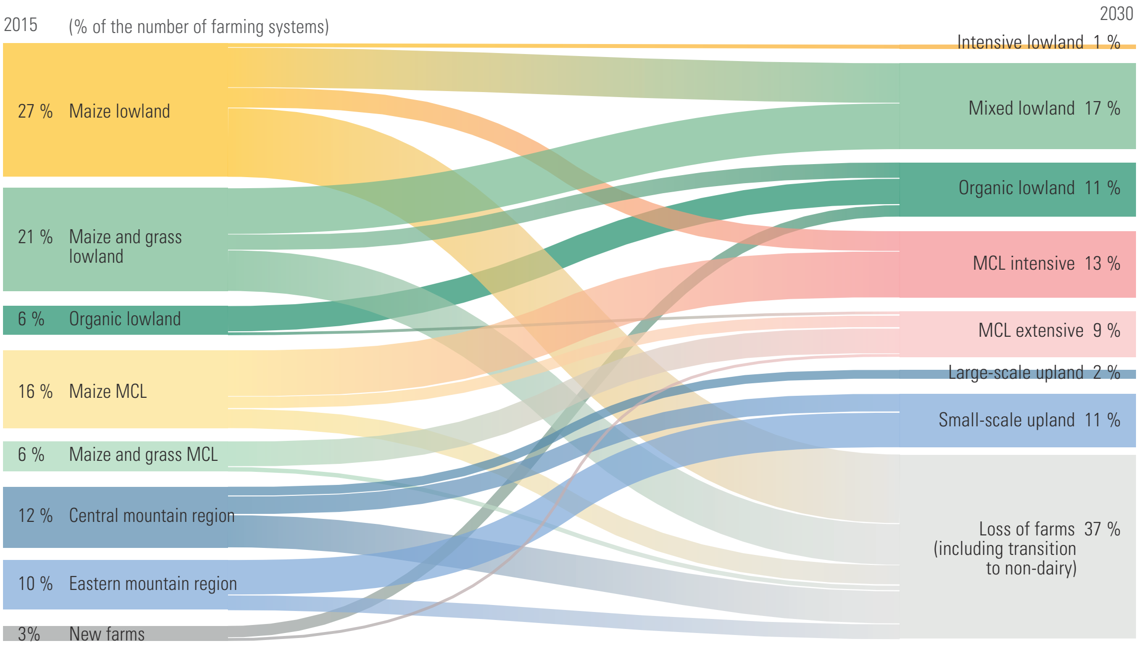
At the same time, other farmers continue to favour a production specialization strategy while slowing down the current concentration dynamics (strategy 3). In this case the farmer's objective is to maintain a high production potential while integrating environmental objectives as income supplements. The measures adopted are primarily technical, such as adjusting feed strategies to reduce enteric fermentation, or adopting no-till approaches to improve soil carbon storage. These measures are adopted under the impetus of new support and subsidies that are earmarked for these practices. The recognition of the role of farmers in the production of biomaterials and energy allows farms to acquire additional income, and the development of anaerobic digestion plays a major role in this context. These new income sources enable this type of farming system to be profitable without entering into a race for expansion, which in turn enables a significant number of farms to be maintained in the territories.

In practice, these assumptions translate into strategies for the development of typical farming systems from 2015, towards the farming systems defined for 2030 in the dairy (**Figure 19**) and arable (**Figure 20**) sectors.

A more labour-intensive agri-food processing system that better valorizes the specificities of agricultural production

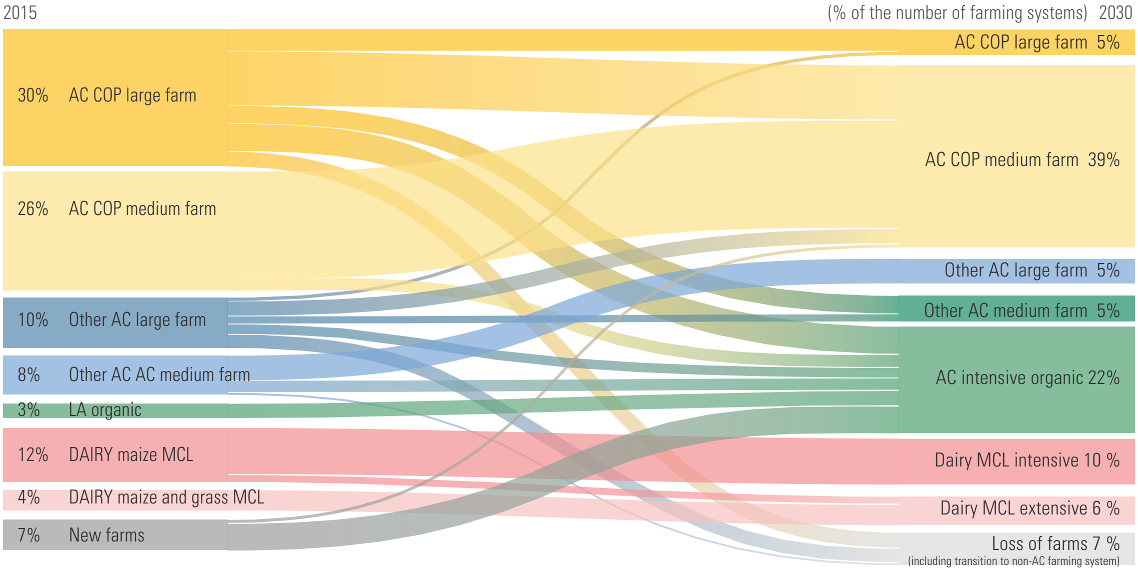
In the Socio-territorial Recompositions scenario, the combination of effective local marketing techniques, small-scale innovations and consumer interest in rediscovering local products enables a wide range of VSEs and SMEs to gain market share, at the expense of large industrial groups that operate solely on price competitiveness. These VSEs and SMEs, on the basis of an industrial model of differentiated production, continue to segment the markets and are becoming

Figure 19. Schematic diagram of estimated changes in dairy cattle farming systems, Socio-territorial Recompositions scenario



MCL: mixed crop-livestock farming Note: the definition of the farming systems considered is changing over the period 2015 - 2030 *Source: IDDRI*

Figure 20. Schematic diagram of estimated changes in arable crop farming systems, Socio-territorial Recompositions scenario



MCL: mixed crop-livestock farming; AC: arable crops. COP: cereals oilseed and protein crops Note: the definition of the farming systems considered changes over the period 2015 - 2030 *Source: IDDRI* increasingly important throughout the country. Simultaneously, due to the stricter regulatory framework on product composition, there is a slowdown in the growth of agri-food companies oriented towards ultra-processed products. Similarly, the dominant strategy of separating upstream and downstream agri-food companies is challenged in favour of more integrated production processes, often at the local level, encouraged by processing standards that lead to labelled products.

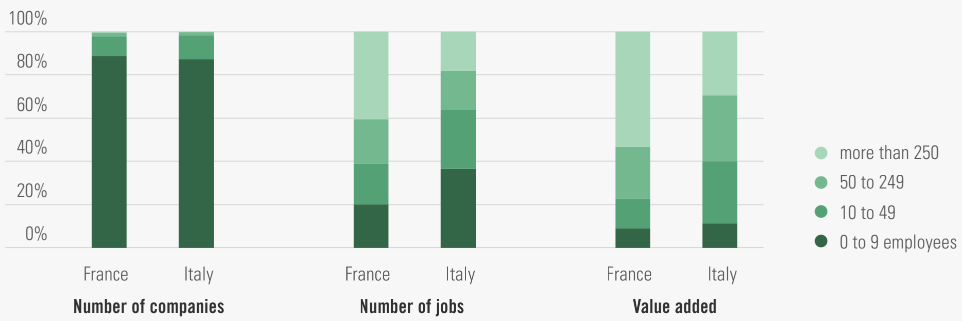
At the technical level, this translates into a decrease or stagnation of labour productivity (and therefore into higher overall employment intensities) and a strengthening of the downstream agri-food companies. In terms of product mix, there is a better valorization of agricultural material, resulting in increased value added products. There is a decreasing export of products in an unprocessed or semi-finished state after initial processing. At the same time, secondary and tertiary processing companies (artisanal bakeries, craft breweries, local cheese dairies), which are labour-intensive and often linked to their locality, become key players in this new territorial restructuring.

Changes in eating habits enable an increase in the sales of fresh and local products, driven by artisanal bakeries, patisseries, local beers and cheeses. The consumption of protein crops, in their traditional form (unprocessed pulses, hummus, soups, etc.) increases significantly.

Box 8. Italy's agri-food sector, an example of a successful, less concentrated, sector

Unlike the French agri-food industry, where almost 50% of the value and employment are concentrated in companies with more than 250 employees – which however only represent 1% of the total number of companies – the creation of value in the Italian agri-food industry is much less concentrated. Thus, while the industry's structure (in terms of number of companies) is relatively similar, with companies of over 250 employees representing less than 1% of the total number of companies, employment and value are distributed much more homogeneously, particularly among small companies: companies with 0 to 9 employees account for 36% of employment and 11% of value (compared with 20% and 9% respectively for France), and those with 10 to 49 employees account for 27% of employment and 29% of value (compared with 19% and 14% respectively for France). This much less concentrated organization has proved very successful from an economic perspective, with a 30% growth in value over the 2008-2018 period (in constant euros) compared with barely 10% for France.

Figure 21. Comparison between French and Italian industrial systems



Source: Eurostat

4.2 The Dual France scenario: decarbonization under price competitiveness pressures

The socio-political narrative

Following the publication of the Green Deal and the increase in climate ambition (enshrined in the European framework), climate change mitigation issues have taken centre stage in European policy discussions. Stakeholder groups targeting climate change are gaining influence, while alliances with biodiversity and health stakeholders, although sought after, are failing to emerge. In terms of agriculture and food, the domination of this climate-centric perspective reinforces the prominence of the "sustainable" intensification of agricultural production as the main solution, with the support of key Member States such as Denmark and the Netherlands. This land sparing approach is also supported by the upstream agricultural industry (crop protection and agricultural machinery), which is lobbying to accelerate the deployment of large-scale conservation agriculture through the granting of massive investment aid to farmers. Carbon efficiency indicators for production are chosen for their ease of implementation in order to organize the evolution of the entire sector.

Food demand continues to be regarded as an area where public action is illegitimate. The prevailing idea is that market mechanisms for providing greater consumer awareness/information will be sufficient to change practices, along with proposals for substitutions, particularly to replace animal protein (Rolland et al., 2020). In this respect, the issue of health impacts resulting from the level of food processing remains largely ignored in the public/political arena, and efforts are focused on how to reduce the amount of animal protein in the average basket, rather than on the nature of the products consumed.

The dominance of the climate issue is reflected in the approach to market organization. While the EU adopts a carbon border adjustment mechanism by 2025, allowing imports to be differentiated according to their carbon content, other social and environmental standards that form the basis of international trade are not implemented. In general, however, food and agricultural issues remain largely overlooked on the political and strategic agendas of the EU and of major Member States. These socio-political dynamics lead to the following changes in the policy framework.

Technical and economic assumptions

Consumption assumptions

While the policy framework for dietary practices remains relatively tame, the societal dynamics that have been underway for the last twenty years are continuing and leading to an increased polarization of dietary practices. While the general decline in animal protein consumption continues – reaching an average

Tableau 6. Les hypothèses d'évolution du cadre politique dans le scénario France Duale

	Key policy instruments
Supply	The CAP and recovery plans include massive support for investment in precision agriculture; the utilization of PES for carbon storage is developing for all structures. Agri-food: health standards remain stable, but significant funds are made available to put the French agri-food industry back on the road to price competitiveness.
Demand	Information instruments remain predominant (PNNS), with a strong development of environmental labelling essentially based on a "carbon" score.
Market organization	*Common market*: regulations regarding Common Market Organizations remain stable. *Organization of sectors*: competition policy is not substantially modified in terms of the environment, but exemptions for the agricultural sphere are confirmed. *International*: the WTO's Marrakech Agreement (especially the Blair House Agreement for protein crops) remains the common framework, but it becomes less structuring; Europe introduces a carbon border adjustment mechanism and continues to develop bilateral free trade agreements that are not very binding regarding other environmental issues associated with the agri-food sector.

Source : auteurs

Figure 22. Dominant evolution strategies of farming systems in the Dual France scenario

Source: IDDRI inspired by (Cerfrance, 2019)

in 2030 of 55 g/day, which is, however, higher than in the Recompositions scenario – the practices of the upper middle classes and the most affluent change in a very different direction to those in less well-off categories. The dual constraints of financial and time budgets, together with a differing symbolic value attributed to food, largely explain this polarization. For the upper-middle classes and above, the propensity to pay more for labelled, fresh and local products does not change over time.

However, changes to the average food basket are ultimately determined by less affluent social categories, the demographic weight of which will increase by 2030 due to the difficulties of resolving the social crisis caused by the COVID-19 pandemic. For these populations, the consumption of fresh fruit and vegetables stagnates or even falls slightly, while the consumption of highly processed products continues to grow. More specifically, while the consumption of legumes is also increasing among these populations, it is mainly in the form of ingredients/textures used in highly processed products.

Dominant strategies and technical-economic assumptions at the agricultural farming system level in the Dual France scenario

The Dual France scenario shows a trend of increasing competitive pressure coupled with an imperative for ecological performance (part 3). In this context, the trends towards the concentration and intensification of farming systems identified in the retrospective work (3.2.1) continue, while environmental imperatives are integrated into farm growth strategies. **Figure 22** illustrates the two dominant evolutionary strategies.

The main strategy for the evolution of farming systems is to produce larger volumes at lower costs (strategy 1). The search for economies of scale is carried out above all on labour productivity (reduction of labour costs per volume produced). Indeed, labour productivity appears to be the main factor of competitiveness within the single market in the Dual France scenario.

The second dominant strategy consists of pursuing the expansion dynamic while seeking better differentiation of production (strategy 2). Key drivers are the contractual agreements with companies or large-scale distributors seeking to secure large volumes of differentiated production (local, organic, etc.). This strategy can also be employed by conventional farms, which expand while diversifying their production to be more resilient to market fluctuations. This is referred to as “large-scale multi-specialization”, where farms combine several production units within their farming systems that are sufficiently large to be considered as “viable” by the market (Aigrain *et al.*, 2016).

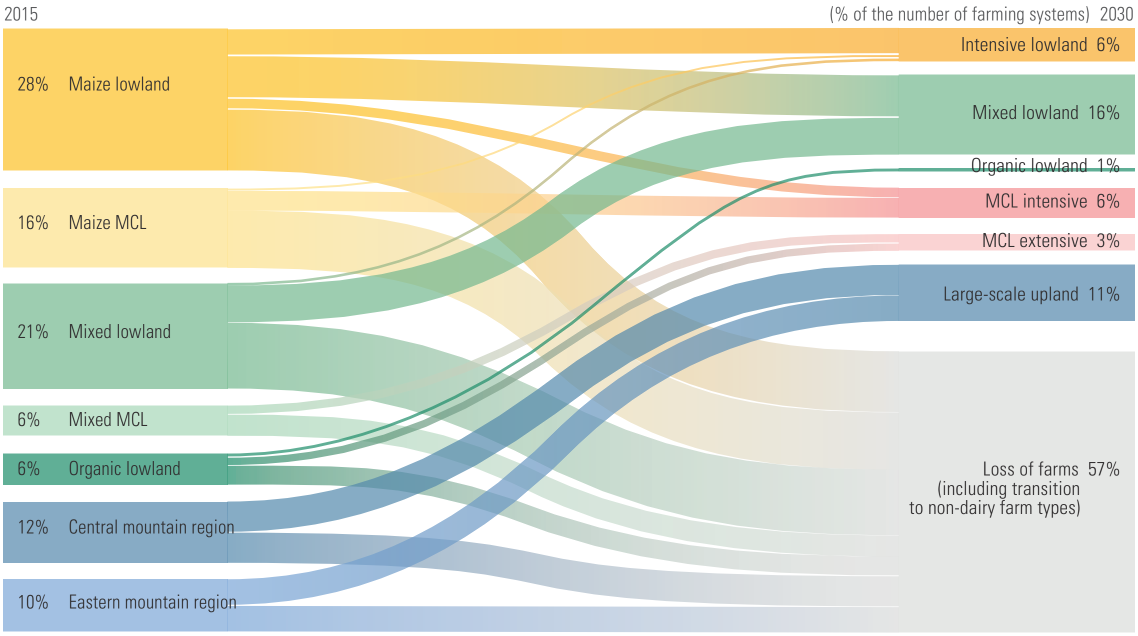
A secondary trend is ensuring the maintenance of smaller farms (strategies 3 and 4), particularly in areas where geographical constraints limit significant increases in the size of farming systems (particularly mountains for dairy cattle) or in the context of the diversification of the farmer's activity (direct sales, tourism, etc.).

The evolution from 2015 farming systems to 2030 ones following those hypotheses are represented in **Figure 23** for the dairy sector and **Figure 24** for the arable sector.

Dominant strategies and technical-economic assumptions at the agri-food level in the Dual France scenario

In the Dual France scenario, the current trend of polarization of the agrifood system intensifies. While

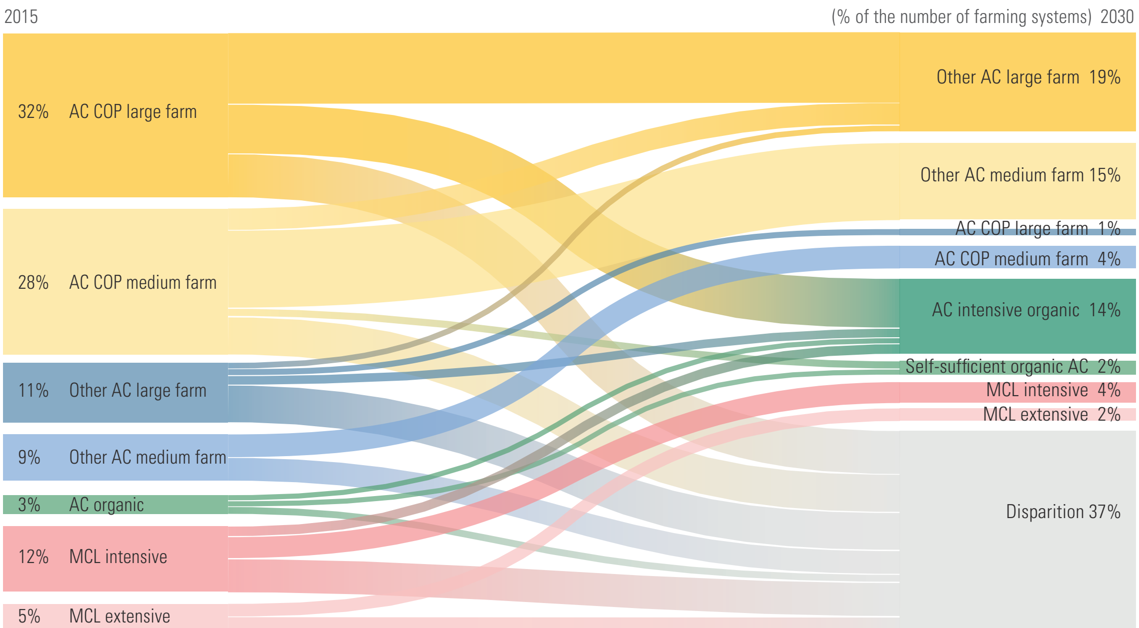
Figure 23. Schematic diagram showing estimated changes in dairy cattle farming systems, Dual France scenario



MCL: mixed crop-livestock farming. Note: the definition of the farming systems considered changes during the period 2015 - 2030

Source: IDDRI

Figure 24. Diagram of the evolution of arable crop farming systems in the Dual France scenario



MCL: mixed crop-livestock farming; AC: arable crops. Note: the definition of the farming systems considered changes over the period 2015 - 2030

Source: IDDRI

niche markets linked to organic production or territorial labels maintain their position, the dominant system continues to follow the pathway towards increased specialization that has been underway for the last decades. To reduce average costs and develop economies of scale, the dissociation between primary processing and secondary processing in the agri-food industry increases, with secondary processing actors continuing to concentrate and increase volume of standardized production. At the same time, companies continue with efforts towards internationalization, especially agri-food companies that produce Fast-Moving Consumer Goods (FMCGs) sold under private labels. Due to lower production costs, such companies gain market share at the expense of medium-sized companies often producing own-brand products, which are unable to be sufficiently differentiated to enter niche markets or to maintain price competitiveness through the creation of economies of scale. Agri-food businesses involved in the production of "ultra-processed" foods also see a continued growth in profits.

From a more technical perspective, these developments in the food sector have two types of consequences. Firstly, by being based mainly on price competitiveness, companies increase the physical productivity of labour (and therefore reduce the labour intensity compared to the volumes processed). Secondly, the product mix evolves towards the production of food-ingredients following a conversion/recomposition rationale, to the detriment of more labour-intensive production.

Table 7. Overview of the assumptions of the scenarios

Component	Variable	Recompositions	Dual France
Dietary practices	Dietary composition	Sharp reduction in proportion of animal protein from 63% to 50%, increase in fruit and vegetables	Small reduction in animal protein intake (from 63% to 55%), stagnation in fresh fruit and vegetable intake
	Product type	Decrease in proportion of ultra-processed food, increase in proportion of local and region-specific food	Continued increase in proportion of ultra-processed foods, limited emphasis on local production
	Willingness to pay	Slight increase	Decline
Organization of agrarian systems	Level of farm concentration	Stabilization	Continued concentration
	Level of farm specialization	Re-diversification	Specialization continues
	Level of crop-livestock connection and of territorial specialization	Relative reconnection of crop and livestock farming on territories (or even on the farms)	Territorial specialization stabilizes at the 2015 level
Agro-industrial complex	Relative importance of the $AFI_{Upstream}$/$AFI_{Upstream-Downstream}$/$AFI_{Downstream}$	$AFI_{Upstream-Downstream}$ become more important, employment intensity increases in some sectors	Continued strong separation of $AFI_{Upstream}$ / $AFI_{Downstream}$, employment intensity decreases due to specialization
	Relative importance of small/medium/large entities in processing agri-food volumes	Rebalancing of the relative importance of small businesses in terms of employment and total output	Continued polarization of the agri-food complex;

Source: authors

5. Results summary: pathways with very different impacts

In this section, the set of parameters and assumptions defined for each scenario allows us to present their impacts on the challenges considered by MoFOT: (i) agricultural income and employment, (ii) employment in the agri-food industry; (iii) food-health and biodiversity issues. A final sub-section analyses the sensitivity of these simulations to alternative hypotheses to test the robustness of the proposed framework.

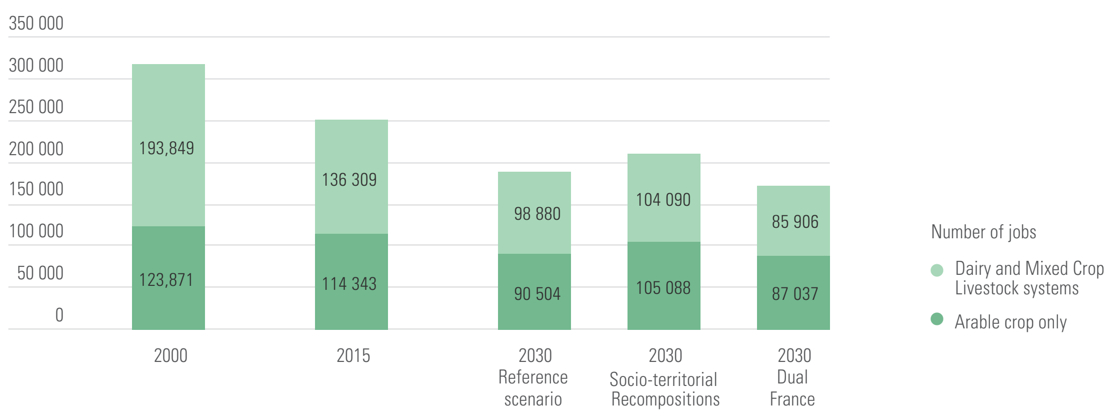
5.1 *Impact on agricultural sector by 2030*

The first major result of the study is that a low-carbon and agro-ecological transition could maintain more jobs than a continuation of the current trend by reducing the rate of farm loss, without a decline in income – despite the reduction in total production. About 28,000 farms and 20,000 jobs could be maintained in the two sectors studied compared to the current trend. This is possible in the Socio-territorial Recompositions scenario due to the evolution of the global context, which is more favourable to the development of new strategies for diversification and for more upmarket products.
On the other hand, in a context where price competitiveness is strengthened, where political support focuses on the mitigation of climate change, the majority of strategies would lead to a highly significant reduction in the number of jobs through a reinforcement of capital/labour substitution, with risks for income levels. The increase in labour productivity is the main factor of competitiveness in this context. It is estimated that the Dual France scenario would lead to the loss of 9,500 farms and 16,500 jobs compared to current trends.

Employment dynamics

Changes to job numbers in the sectors are presented in **Figure 25**, in comparison to recent developments and the current trend.
Beyond the number of jobs, it is the evolution of the agricultural model that is above all at stake in the two scenarios.
The emphasis on smaller farms in the Socio-territorial Recompositions scenario favours the maintenance of family-type agriculture, insofar as the majority of production factors remain in the hands of the farmer. Salaried work increases slightly in the arable sector to the extent that the majority of new farms are of medium size with little recourse to outsourcing (**Figure 26**). The development of salaried employment on dairy farms continues to increase slightly, with a noticeable rise in the number of qualified workers who can support farmers to lighten their workloads.

Figure 25. Change in job numbers in farming systems in 2030

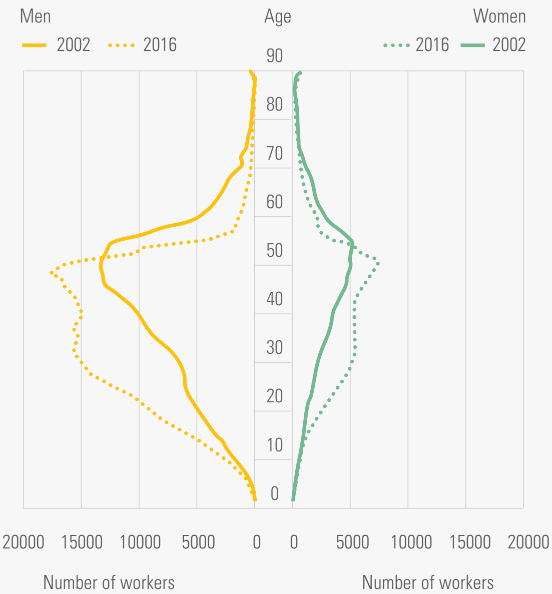


Source: RICA, processed by IDDRI

Box 9. Demographic constraint: recent dynamics, the framing of scenarios and the challenges of new entrants

In addition to the physical framework of the SNBC-A and the criteria for the demographic composition of farming systems in these scenarios, the assumptions for projecting the number of agricultural farming systems were structured according to demographic constraints and the renewal of generations. Projections for the number of farms in 2030 are thus based on the consideration of current trends in retirement and the establishment of new farms, in a context where farm managers represent an ageing population (from 2010 to 2016, the proportion of farmers aged 60 and over rose from 10% to 17% of the total agricultural population).

Figure 26. Changes to the population pyramid of farmers and co-workers between 2002 and 2016



Source: MSA (Mutualité Sociale Agricole) data, CEP process; (Forget et al., 2019)

More specifically, projections were carried out for the dairy and arable sectors, based on farmer age data and the number of farms.

For the dairy sector, approximately 50% of current farmers are over 50, while the current average number of new farms/ per year is 1,200*. In addition, an increasing number of existing farms are shifting from livestock production to cereal production for many reasons: favourable price ratio for crop production, specialization of territories and agglomeration economies, search for improved working conditions, etc. (Schott et al., 2018). Thus, around 4% of dairy farms are lost each year, due to their non-replacement following retirement or the transition to other specializations, a trend that would bring the number of dairy farms to around 35,000 by 2030 (Reference scenario).

In the Dual France scenario, the fall in farm numbers corresponds to a significant reduction in the number of new farms (around 700/year compared to 1,200 today).

Conversely, the Socio-territorial Recompositions scenario has a new farm establishment rate close to the highest rate observed in recent times (1,800 new farms/year in 2008), leading to a figure of 43,000 farms in 2030. The slowing of capitalization is therefore crucial in encouraging the taking over of farms by limiting the debt of the acquirer. The territorial development of dairy production in farms that are less intensive and more numerous thus raises major demographic challenges in addressing the retirement of large numbers of farmers, and to enable the establishment of newcomers in non-specialized areas. The set-up of local production, collection and processing networks are then key issues in this scenario for coping with the decline in the "dairy environment" (lack of suitable service providers with expertise in dairy production: veterinarians, consultants; less possibilities for joint work and exchange or mutual support with neighbouring farms, which exacerbates the limitations that are perceived to be linked to production constraints).

For the arable sector, 60% of farmers in 2016 were over 50, with an average new farm establishment rate of about 2,100 farms in 2014 (CEP 2019).

The Dual France scenario falls short of meeting the challenge of generational renewal in the arable sector, with a slowing down of the new farm establishment rate (1,300 establishments/year) due to the concentration of existing farms.

In the Socio-territorial Recompositions scenario, there are significant challenges in terms of new arable farms. Indeed, the establishment of this type of new farm will have to increase to maintain a sufficient number of jobs. In our scenario, the number of average annual new farms in this sector is estimated at 3,400 farms compared to 2,100 in 2014 (65% increase). The development of small, diversified and territorialized farming systems is then a key factor, as these small systems make it possible to limit the challenges arising from the difficulty of financing the set-up of new farms.

* More than 1,700 young farmers (under 40) started work in dairy production each year between 2010 and 2013. Of this number, if we assume that 500 people are spouses or people of the same age working with the farm manager, we can estimate that there will be around 1,200 new farm establishments per year (Forget et al., 2019).

In contrast, the Dual France scenario forecasts an ending of the domination of traditional family farming in favour of a significant development of salaried employment (**Figure 26**). The methods of labour management are strategic: there are two main options, autonomous associates or a manager with employees. In contrast to the large specialized farms in northern countries, which rely on salaried labour or subcontracting and a high degree of automation, large French farms are currently mainly based on partnerships, with several partners and few salaried employees (the so-called "GAEC"). Other forms of salaried employment are also likely to develop in the context of the scenario, given the increasingly important place they currently occupy, particularly in the arable sector (53% increase in outsourcing contracts from 2000 to 2016, while 12% of arable farms outsourced all cultivation work in 2016 (Forget et al., 2019))[44].

Conditions for generating sufficient income

Changes in the average profit and loss accounts in the two scenarios reflect two contrasting strategies for seeking profitability at the farm level.

The Socio-territorial Recompositions scenario puts the emphasis on obtaining good value from production while reducing costs. Investments and supply costs are limited in "self-sufficient" type systems, but labour income is high compared to the level of production, and the monitoring of new standards can lead to significant costs for the farmer. Having a high premium is then fundamental to ensuring a farm's economic viability (for a typical example see **Box 10**).[45]

The share of value added[46] dedicated to labour remuneration increases from 48% to 58% for the dairy sector and from 51% to 64% for the arable sector.

If wages remain constant,[47] dairy farms would generate a surplus of 0.55 billion euros, which represents an increase in wages of 28% (from 1.2 to 1.5 times the minimum wage), or the hiring of 24,000 workers at constant wages (1.2 times the minimum wage).

Contrastingly, in the Dual France scenario, the dominant strategy is to increase competitiveness through a reliance on economies of scale and high-volume production. The increase in production capacity leads to significant investment needs which take up a large

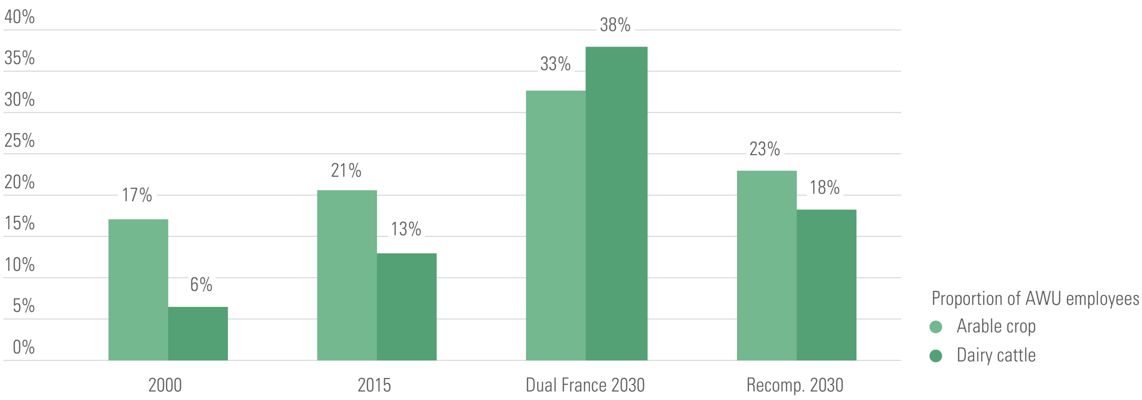
44 It is important to emphasise that the methodology used here, which is based on data from individual farms, is in fact limited in terms of revealing all of the underlying factors in the evolution of farming styles. The ongoing concentration trend and the emergence of corporate agriculture are particularly reflected in the emergence of holding companies that control several farms to make up very large areas of farmland (over 1,000 ha) (Purseigle *et al.*, 2017). As each farm within a holding declares its area separately and is counted as a distinct entity, aggregation within the same holding is currently concealed.

45 Prices and premiums used correspond to real price averages over the period 2013-2019, €337/1,000l for conventional milk and €437/1,000l for organic milk, i.e. a 30% premium (source: Enquête Mensuelle Laitière SSP/FranceAgriMer)

46 Value added is defined here as the difference between all products (including subsidies) and all intermediate consumption and structural costs (excluding staff remuneration, which is included in the wage part).

47 Target income levels correspond to the average annual income of the dairy TF over the period 2000-2018. €22,800 for non-salaried AWU (EBIT/non-salaried AWU) and €20,000 for salaried AWU (personnel costs/ salaried AWU) (source: RICA)

Figure 27. Change in the proportion of employed persons in 2030



Source: authors, based on FADN & AGR data and own calculations part of the expense account (amortization and depreciation). The viability of the system then depends on maximizing the volume produced per AWU, which makes it possible to limit wage costs (see typical case in **Box 11**).

The proportion of value added dedicated to labour remuneration falls from 48% to 38% for the dairy sector, and from 51% to 45% for the arable sector.

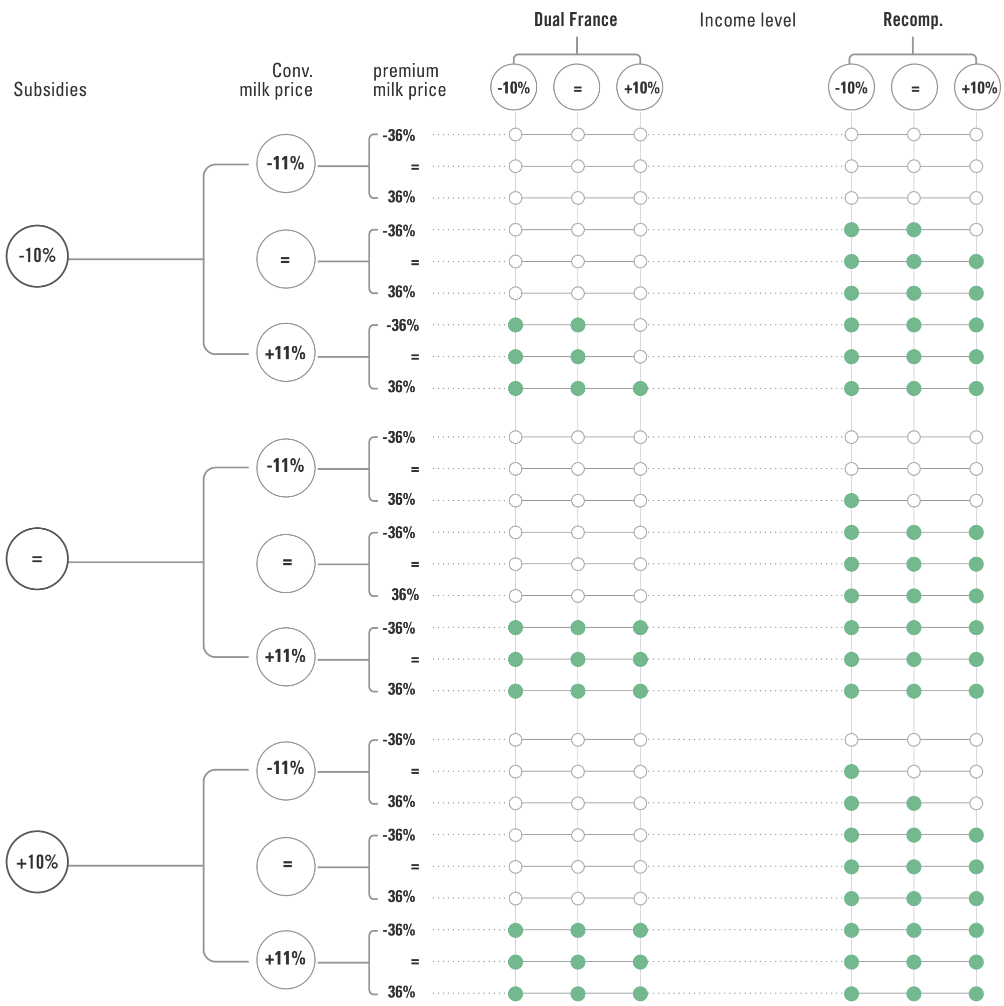
At constant wages, dairy farms will have to mobilize an additional 0.54 billion euros to ensure the transition and to finance the major investments – according to our reconstruction. This corresponds to a 6% increase in milk prices or a 25% increase in subsidies.

The conditions under which farmers could generate sufficient income to meet investments while ensuring a satisfactory wage level are analysed through combinatorial matrices presenting different configurations of the amount of subsidies, the premium allocated to production and the income level.

The matrix can be read as follows: for a given income level (constant or + or - 10%), it presents the combinations of the subsidy level and milk prices that would enable farmers to ensure a sufficient level of investment to make the transition. Thus, the matrix shows which economic levers can be activated so that farmers are able to meet their investment needs, to ensure that their farms can undergo the necessary transformation within the scenario's framework.

Figure 28. Socio-economic possibilities for a 2015-2030 transition

Key: Each box represents a combination of milk price, subsidy level and wage target.
A green box means that the combination generates a surplus that is sufficient to cover the investment costs of the transition.



Source: authors, based on RICA data

Figure 28 shows that changes in the price of milk play a decisive role in the viability of transition pathways. According to the Dual France scenario, farms are unable to ensure a satisfactory income without an increase in the price of milk, as indicated above. In contrast, the Socio-territorial Recompositions scenario provides greater leeway for maintaining or increasing income while making investments possible.

5.2 *Impacts on the agri-food sector: employment, international positioning and tangible investments*

Changes in employee numbers vary according to company strategies

By placing greater value on products derived from artisanal producers who implement strategies of differentiation, combined with an increase in investment for secondary and tertiary industrial processing, the Socio-territorial Recompositions scenario forecasts an increase in the number of jobs in the agri-food industry for the cereals, oilseeds and protein crops (COP) sector (6%), and in the dairy sector (12%).

In the cereals sector, the reduction in exports of raw agricultural materials and in the use of cereals for the manufacture of biofuels helps to maintain production volumes entering the agri-food industry at fairly stable levels compared to 2015 (1% decrease). Due to the change in the product mix at the primary processing stage (greater orientation towards flour production rather than starch production or malting) there is an increase in job creation in the milling sector, along with an increase in the volumes of flour available for secondary and tertiary industrial processing (given the relatively stable level of flour consumed or exported). As a result, there is an increase in the number of jobs in the secondary and tertiary level food processing sectors, which improves the position of France in the production of bakery and patisserie products, pasta and beer, particularly artisanal. The only sector where the workforce decreases is that of cereals for animal feed, as a consequence of the reduction in French livestock numbers (and its requirements), as anticipated by the SNBC-A. The volumes of oilseeds and protein crops entering into the agri-food industry increase relative to the reference year. This increase is particularly noticeable for protein crops, where volumes more than double as a result of an increase in agricultural production, while gross exports decrease. The number of employees in the sector of oil and protein crops for human consumption thus increases relative to 2015.

There is an increase in employment in the dairy sector, despite the decrease in the volume of milk collected in the Territorial Recompositions scenario. This is mainly due to a change in the product mix. Processing companies move towards an increase in cheese production (which is highly employment-intensive in comparison to other processed products) mainly at the expense of butter production.

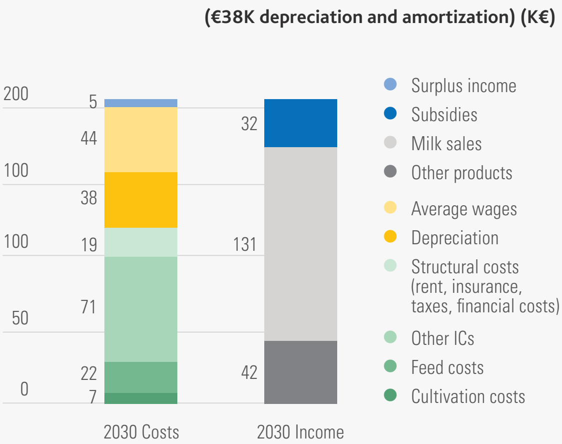
While the Recompositions scenario shows an increase in the labour requirement of the agri-food industry, Dual France shows the opposite trend. The increased specialization of the French agro-industrial fabric leads to a reduction in the number of agri-food jobs in the COP sector (10% decrease) and the dairy sector (11% decrease). This decline in the number of jobs is the result of two trends. Firstly, there is a decrease of between 5% and 10% in the employment intensity of all sub-sectors compared to 2015, due to the large-scale adoption of strategies of concentration and economies of scale. Secondly, the product mix evolves towards productions that are characterized by lower labour intensities because they are less linked to production in VSEs and SMEs. A third factor at work, but only in the COP sector, relates to a marginal decline (4%) in the volumes of agricultural production entering the agri-food sector, which is not compensated for by the reduction in gross exports.

For products derived from cereal production, all sub-sectors are affected by the decrease in employment except for starch production, the malting industry, industrial bread production and breweries, which see an increase in production volumes in a scenario which favours the industrial processing of these highly standardized or high value-added products. The oilseed and protein crop sector is the only one where the number of employees increases, which is due to the increase in agricultural volumes and the emergence of outlets in the food and animal feed sector. This net creation of employment enables these industrial

Box 10. Socio-economic impact assessment of the establishment of a lowland organic dairy farming system in 2030

Our calculations found that setting up a lowland organic dairy farming system in 2030 would involve an investment of around €380,000 at the time of establishment. The economic viability of the system in 2030 depends on the production being valued in such a way as to enable this investment cost to be met (€38,000 of annual depreciation with an assumed depreciation period of 10 years) along with additional costs, while ensuring a satisfactory income for the labour force.

Figure 29. Profit and loss account of a lowland dairy organic farming system in 2030 in an establishment pathway



Source: RICA, processed by IDDRI

A lowland farming system in 2030 undergoing an establishment pathway is primarily characterized by high milk valorization; the producer follows a logic of differentiation of production. The assumption adopted here is the maintenance of a premium that corresponds to the average of previous years.

At the same time, the farmer is turning to a strategy of cost reduction: firstly, feed costs, by seeking to make the system self-sufficient in terms of fodder, and by feeding the herd mainly on grass. Feed costs now represent only 9% of expenses, compared to an average of 17% in 2015. Economies of scale are favoured, in particular through the search for integration of animal and vegetable production at the farm or territorial level and therefore the development of mixed crop-livestock farming (Perrot *et al.*, 2012). Farmers are pursuing strategies aimed at the autonomy of the farming system and a more extensive management of soil and livestock. Veterinary costs are also reduced due to fewer animals inside buildings and by the moderation of production levels (6,000 l/DC).

The search for economies and self-sufficiency in grass-fed dairy systems has already been described (Devienne *et al.*, 2016). Nevertheless, it can be seen that structural costs remain substantial and constitute the major part of operating costs.

The impact of investments, visible through the depreciation costs, is under control. The reduction in the length of time the animals are kept in stalls and the increase in the amount of grazing allow for a reduction in expenses related to buildings and equipment, with a stock of equipment that is smaller and in less demand (less cultivation and harvesting of fodder, in particular with regard to silage maize, which is costly in terms of inputs and labour), with storage and silage also being less important.

The reduction in the share of value added dedicated to the remuneration of capital (40%) thus allows farmers to generate more income for their own remuneration and that of their employees (60%).

Thus, it can be seen that, if current subsidy and price levels are maintained, this system would generate a surplus of income, compared to the average income reference hypotheses used in the analysis (€9K of additional income compared to the average income). In a context of growing recognition of environmental issues, support for agro-ecological production methods could also consolidate the economic viability of this type of system. For example, innovations in the payment of subsidies, such as the introduction of a bonus-malus system for the maintenance of permanent grasslands or the introduction of an asset-based payment, would make it possible to support this type of farm (Fosse, 2019).

The higher income generated per asset could then be used to remunerate the new skills developed by the farmer in the context of systems based on ecosystem services, for example in terms of more diversified crop rotations or pasture management, (technique de pâturage tournant dynamique par exemple, voir Duru, 2000 ; Roca-Fernández *et al.*, 2016), or to support adaptation techniques for greater resilience to climate change. In this context, the support of other innovative livestock farmers in the framework of producer groups is also crucial.

Box 11. Socio-economic impact assessment of the 2015-2030 transition from a lowland dairy system to an intensive dairy system

The transition pathway from the typical 2015 lowland dairy farming system to a typical 2030 intensive farming system, which is prominent in the Dual France scenario, is particularly illustrative of the significant investment needs for the development of large farms.

The "transition pathway" at stake here means the merger of several farms to reach the capital levels of the 2030 farming system. This can occur in different ways: either by setting up a producer group, such as the *Groupement Agricole d'Exploitation en Commun* (GAEC) for dairy farming, or by the acquisition of the capital of neighbouring farms by a single farmer. In **Figure 28**, the transition from a typical farm type in 2015 to the one in 2030 reflects an increase in fixed assets of €3,6m.

The economic viability of the resulting farming system depends on the production being developed in such a way as to enable it to cope with new investments and costs while ensuring a satisfactory income for the labour force. The larger size of the resulting farm type firstly enables an increase in milk production income (a more than five-fold increase from €160K to €910K), linked to the greater production capacity.

Higher labour productivity also makes it possible to limit the share of wage costs (which only represent 10% of costs in the 2030 system). Controlling other costs is also a crucial issue, as intermediate consumption, particularly feed costs, increase significantly (which is particularly linked to our assumptions on the increase in the price of animal feed)*.

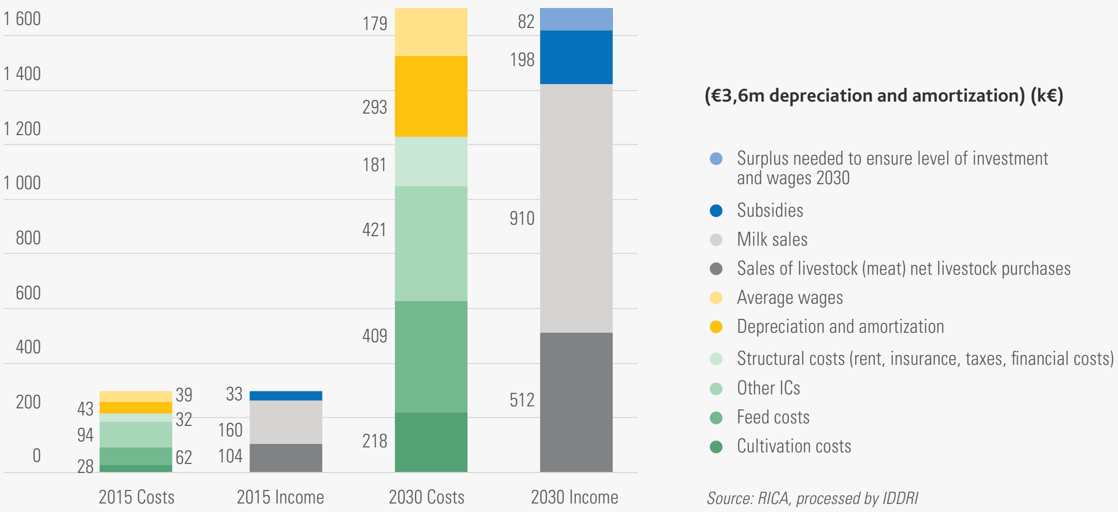
Above all, it is depreciation that has a major impact on the profits of the 2030 farm, thus reflecting the significance of the investments made. In other words, the proportion of the farm's value added dedicated to the remuneration of capital increases significantly (from 50% in 2015 to 70% in 2030), while the proportion dedicated to the remuneration of labour decreases (from 50% to 30%).

The profit and loss account shows a lack of balance: growth in the income does not enable the increased costs to be met, with the objective of ensuring both investments and a wage level that is at least the same as current averages. **Figure 30** shows (in yellow) the surplus needed to cover the level of depreciation and wages in 2030.

This surplus can be envisaged in different ways: it can be covered either by subsidies (which in our configuration would require a subsidy increase of 40%), or by an increase in the selling price of production (in this case an increase of 9% in the selling price). The increase in subsidies and selling prices can be combined at various levels. Nevertheless, it can be seen that there is much less room for manoeuvre in this pathway type, if the farmer wishes to both invest for expansion and to maintain the level of wages (both for the farm manager and the employees).

* Animal feed represents a major cost for dairy farms. The SNBC's hypotheses in terms of protein self-sufficiency forecasts a reduction in feed imports of 70% by 2030. The relocation of plant protein production in France, where current production costs are higher (and are likely to remain so between now and 2030), compared to soybeans imported from the Americas in particular, is thus likely to result in an increase in feed costs. The modelling was therefore carried out assuming a 20% increase in feed costs

Figure 30. Evolution of the profit and loss account resulting from the 2015-2030 transition from a specialized maize-type farming system to an intensive lowland dairy system



Source: RICA, processed by IDDRI

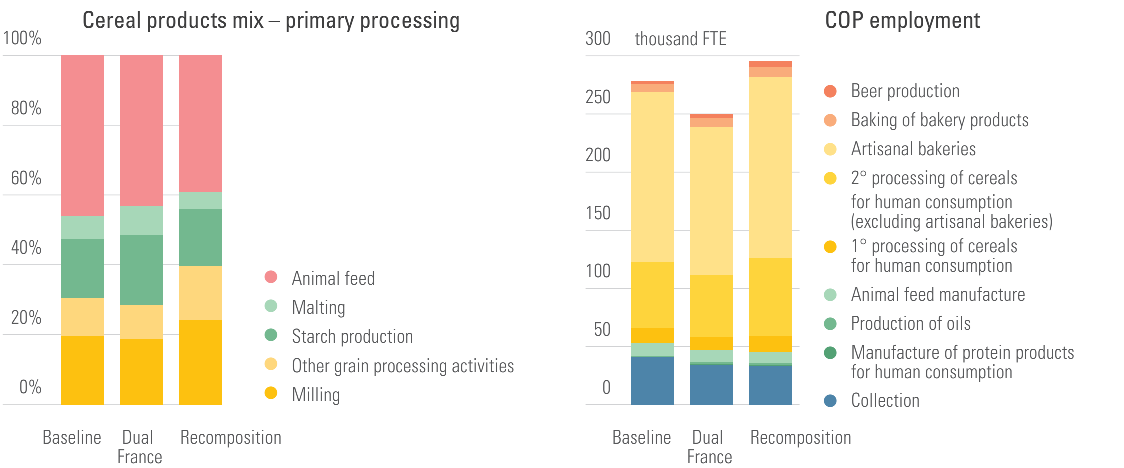
sectors to develop and to counterbalance (although only weakly) the job losses in the other industrial sectors.

In the dairy sector, despite an increase in milk production and the volume of milk going through the agri-food industry, there is a fall in the number of jobs. There are two reasons for this trend. Firstly, there is a particularly strong reduction in the employment intensities in this sector; and secondly, producers decide to focus less on cheese and more on butter, relatively, the latter having a much lower employment intensity.

Artisanal versus industrial exports

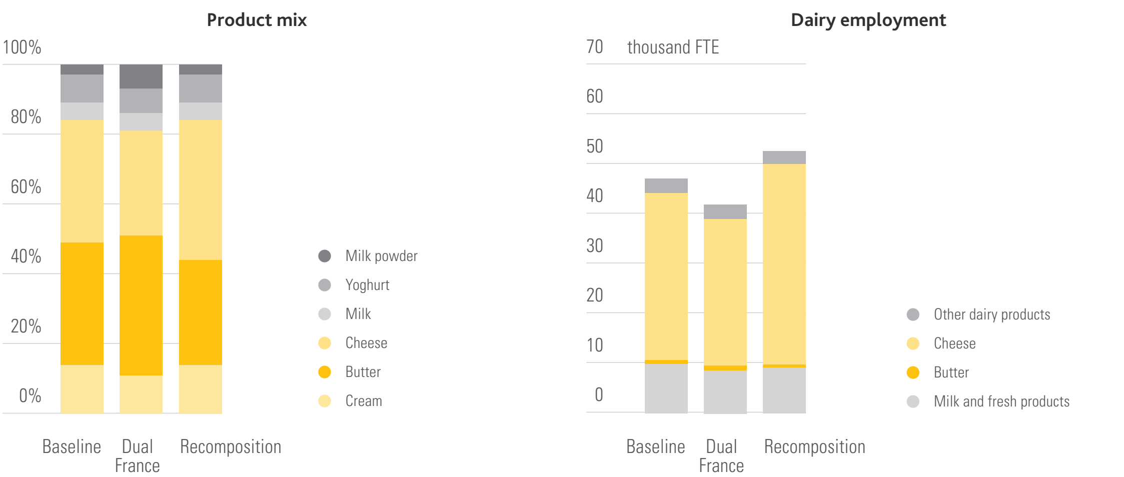
Due to a sharp reduction (25%) in the export of raw agricultural materials, the Recompositions scenario shows relative stability in the agricultural production of COP that goes through the French agri-food industry. The greater quantity of durum wheat flour and semolina produced by the French milling and semolina industry increases exports of these commodities and the trade balance of their by-products (industrial bakery, biscuits, pasta). Similarly, beer exports increase as a result of a rise in malt production and a reduction in its raw

Figure 31. Evolution of product mix and associated jobs in the arable sector for the two scenarios France Dual and Socio-territorial Recompositions



Source: authors

Figure 33. Evolution of the product mix and associated jobs in the dairy sector for the two scenarios Dual France and Socio-territorial Recompositions



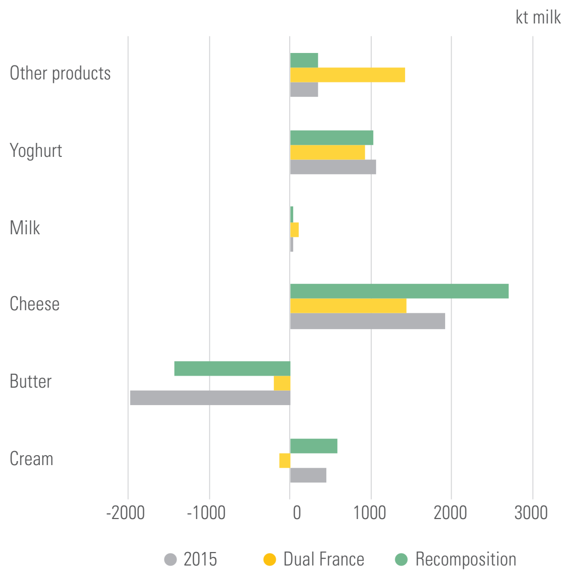
Source: authors

form exports. Conversely, there is a reduction in the trade balance of starch products and compound feed for animals, the former due to the transformation of the industrial complex to become more oriented towards VSEs and SMEs, which cannot deal with this type of activity due to reasons of size, while the latter is due to a decline in the import of oilseed cakes and therefore a decrease in compound feed production, in line with the reduced demand for animal feed. In the oilseed and protein crop sector for human consumption, despite the increase in the quantities of protein crops consumed (20g/person/day), the increase in the volumes produced enable a commercial surplus to be generated, particularly in the protein ingredient sector. In the dairy sector, the trade balance remains almost identical for most products except for butter and cheese. As mentioned above, in the Recompositions scenario, companies produce relatively more cheese than butter. As cheese consumption remains constant in the scenario, this leads to an increase in export volumes. Conversely, for butter, a decrease in domestic consumption offsets the lower volumes produced and reduces the trade deficit.

In the Dual France scenario, strategies are concentrated on capital-intensive sectors in which French actors already have a certain advantage in terms of exports: starch production, malting, beer and animal feed manufacture. These results are due to changes in the product mix linked to primary processing (the increase in starch production and malting compared to milling). Similarly to the Recompositions scenario, in the oilseed and protein crop sector for human consumption, the increase in the quantities of agricultural material produced enables these sectors to find export outlets even against a background of an increase in domestic consumption, which is expected to reach 16g/person/day (compared to 5g/person/day in 2015). Despite this, the volumes of raw material equivalent traded remain very low in comparison to the cereal trade. In the dairy sector, the increase in milk collection has a positive effect on the variation of the balance for butter and milk powder, favoured in particular by a product mix that is more oriented towards these two types of processed products. In this scenario, France comes close to no longer being in a butter deficit. On the other hand, despite the increase in the volumes of milk collected, the trade balance for cheese deteriorates due to industrial production becoming relatively less focused on this type of product.

Figure 33. Evolution of the trade balance (in kt) for the main products derived from arable crops

Figure 34. Evolution of the trade balance (in kt) for the main products of the dairy sector



Investment needs for the industrial transition

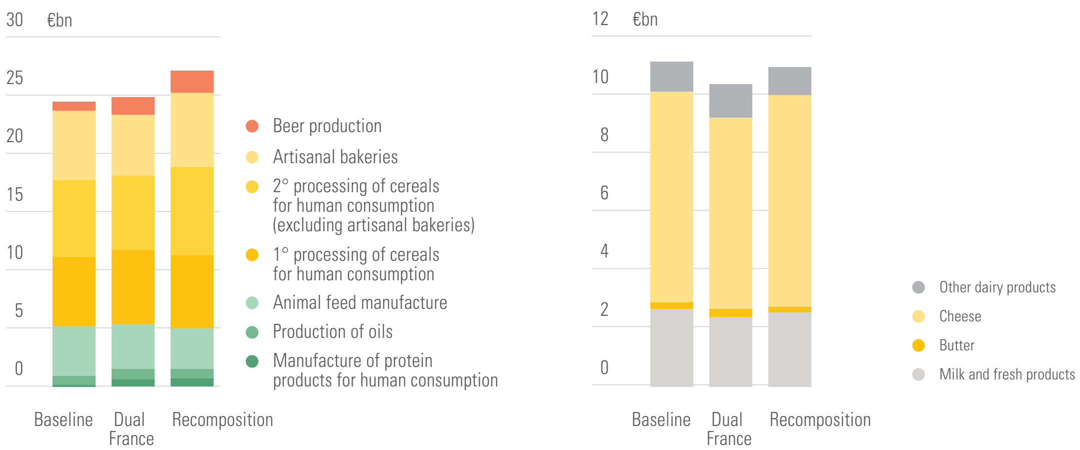
The assumptions of the Recompositions scenario affect the need for additional tangible assets in an ambivalent way depending on the sector. There is an increased need (11%) in the COP sector, and a slight decrease (2%) in the dairy sector. This shows that while the situation in the dairy sector remains stable overall, the situation in the COP sector is different. In this sector, to achieve the industrial transition based on the segmentation of production and a better valorization of raw materials, companies have to generate a surplus to invest in new production tools. This surplus can come from higher payments by consumers for products or from an investment support policy.

A more detailed analysis of the issues at stake is possible when we look at the impact of the scenario within the sectors. In the cereals sector, there is an increase in the need for investment in all value chains except for the starch industry (reduction in quantities produced) and animal feed (reduction in livestock requirements). The increase in investment needs is particularly significant for the secondary and tertiary industrial processing sectors, which gain importance in this scenario (artisanal and industrial bakeries, pasta production, commercial biscuit and patisserie production). In particular, in the brewing sector, the growth of local microbreweries increases the capital intensity of the sector. These dynamics, combined with the increase in processed volumes, lead to significant additional investment needs. The industrial sector of oil and protein processing for human consumption also has an increase in investment needs. In the dairy sector, the lower volumes of milk collected lead to lower investment needs in all sectors except cheese making. Despite the reduction in capital intensity (due to the technological progress induced by the growing demand for cheese), the cheese dairy sector increases its investment needs. Indeed, due to the considerable increase in volumes produced, this sector maintains the same need for tangible assets as it did in 2015.

Given constant capital intensities, the Dual France assumption regarding product mix and production volumes have little impact on the need for tangible assets in the COP sector (1% increase) and in the dairy sector (7% decrease). This means that, overall, this scenario does not require a strong investment policy to evolve from the current system by placing itself more in a business-as-usual rationale in terms of the industrial complex. Despite this general observation, the situation is more heterogeneous when analysed sector by sector.

For cereals, the lower volumes of agricultural raw material production passing through the factories

Figure 35. Evolution of fixed asset requirements in both COP and dairy sectors for the two scenarios



Source: authors, from ESANE data

contribute to the limiting of additional investment needs in malting, starch and beer production – capital-intensive sectors which become more significant in this scenario. Conversely, a result of the closure of many VSEs that can no longer compete with industrial bread and patisserie manufacturers, the artisanal bakery sector risks being left with potential stranded assets. As in the Recompositions scenario, the development of the oilseed and protein crop sectors for human consumption is leading to an increase in the need for investment in industrial protein crop crushing and processing plants. This is particularly true for companies operating in the highly capital intensive ultra-processed foods market. In the dairy sector, driven by high fat diets and by the consumption of high-protein ultra-processed foods, there is only an increase in investment needs in the sectors of butter production and other dairy product manufacturing (e.g. casein, milk powder). On the contrary, despite the increase in the volumes of milk collected, the cheese, milk and other fresh product sectors are reducing their investment needs and will have to, at least partly, repurpose their production tools.

5.3 Impacts on food and biodiversity

Unlike employment and agricultural income, the impacts of the scenarios on food (basket price, nutrition-health) and biodiversity could not be fully quantified and conclusively assessed (see section 2 for a short discussion of the methodological issues involved). Nevertheless, the hypotheses of the initial biophysical modelling, the breakdown into two contrasting scenarios and their socio-economic and biophysical quantification make it possible to bring several elements to the debate.

A food basket caught between quality, health and price

Firstly, on the physical level, the indicative pathway of the SNBC that is common to both the Dual France and Socio-territorial Recompositions scenarios, envisages dietary changes (in raw product equivalent) that would lead to better nutrition for consumers, and in particular: an increase of almost 50% in the daily consumption of fresh fruit and vegetables due to an increase in market gardening area, an increase in the consumption of pulses (lentils, chickpeas), and a reduction in the total consumption of animal protein, particularly meat. The economic stakes associated with these changes in dietary habits for the average basket as a whole, have not, however, been asssessed here.

Looking at the two sectors studied, arable crops and dairy products, the benefits/risks attached to the two scenarios, Socio-territorial Recompositions and Dual France, appear contrasted - in line with their respective rationales. While a detailed analysis of the developments in these two sectors is not sufficient to draw definitive conclusions regarding food,[48] the following elements can however be highlighted.

In the Socio-territorial Recompositions scenario, the composition of the average food basket for the two sectors studied evolves towards less processed products, slightly more pulses and less dairy products - all of which are consistent with a better nutritional status. Although the production costs for the agri-food sector have not been precisely evaluated, the increase in employment intensity, as envisaged for most products, will probably lead to an increase in average product prices. While this increase in certain products could be counterbalanced by a change in the overall composition of the food basket – with a reduction in meat and dairy products in particular (WWF, 2017) – there remains a need for a detailed assessment. While the question must at least be raised regarding the implementation of political measures to counterbalance these effects and thus minimize the consequences for less affluent consumers.

48 Due not only to the heterogeneity of the initial situations, but also to the strong interdependencies between the different products in a basket (c'est-à-dire le fait que ce qu'on mange comme produits laitiers a un effet sur ce qu'on mange comme fruits et légumes et vice-versa ou comme céréales – ce qui implique que des changements de consommation sur les produits laitiers se traduisent nécessairement dans des changements sur les autres postes, qui n'ont pas été représentés ici – voir pour plus de détail Irz *et al.*, 2016).

In the Dual France scenario, the structuring assumption is that of an exacerbated polarization of food practices. However, the impossibility of modelling the diversity of both food processor strategies and consumption patterns has led to the impacts of the scenario being assessed on the basis of an "average" basket (once again, only for the two sectors considered). This basket reflects the coexistence between:

- firstly, a predominant basket, where the share of more processed products continues to increase, animal protein from dairy products remains stable, and the relative price of products tends to decrease due to the reduction of employment intensities in the agri-food industry (itself a consequence of a major proportion of industries adopting price competitiveness strategies);
- secondly, a more diversified and localized basket, where the proportion of highly processed products and of animal protein significantly decreases, with average product prices tending to increase.

The average basket that emerges from this dualization process ultimately contains more highly processed products than today – and more than in the Recompositions scenario – with a more limited increase in the consumption of pulses, which could lead to health risks. However, the associated average price is lower.

Impacts on biodiversity

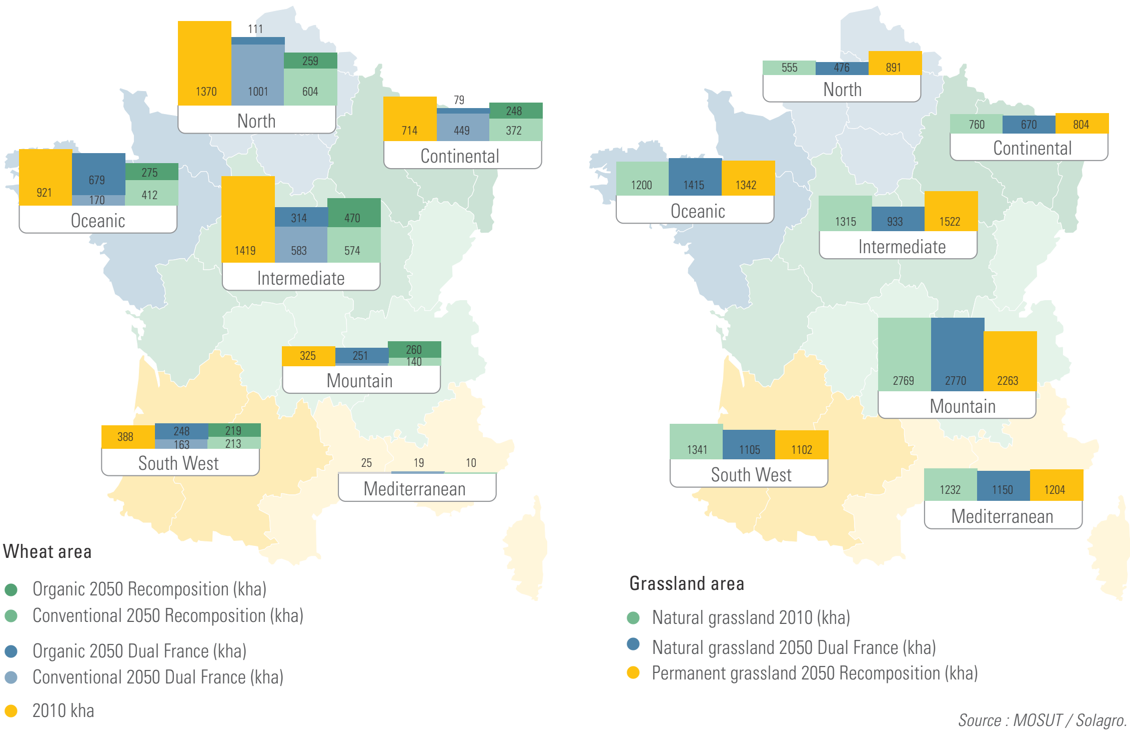
Similarly to nutritional issues, it can be noted that the indicative biophysical pathway provided by the SNBC-A already proposes a number of important advances in terms of biodiversity by 2030: halving of the pesticide treatment frequency index, halving of the nitrogen surplus (from 40 kg N/ha in the three-year average 2014-2017 to 21 kg N/ha), the near maintenance of permanent grassland area (5% loss), an increase in the proportion of organic farming to 25% of arable crop areas in 2030, and the gradual halting of imported deforestation via a significant increase (30%) in protein self-sufficiency for livestock farming. In relation to these advances, the Socio-territorial Recompositions scenario proposes going one step further, in particular by ensuring that these biodiversity benefits are distributed as evenly as possible across the French territory. To do this, the scenario combines three levers, the effects of which have been partially quantified using the MOSUT (systemic land use modelling) tool (Solagro *et al.*, 2016, p. 89):

- A territorial despecialization, based on two complementary dynamics: (i) the re-connection between crops and livestock and (ii) the redeployment of permanent grasslands in all regions so that they cover at least 15% of the useful agricultural area in each region. This double dynamic makes it possible to guarantee that at least 20% of the useful agricultural area of each region is taken up by semi-natural vegetation in 2030 (Garibaldi *et al.*, 2020); while also ensuring the efficient recycling of nitrogen and phosphorus via the crop-livestock reconnection (Dumont *et al.*, 2018).
- The development of extensively managed permanent grasslands in lowland areas (30% more than 2015) through a greater development of farming systems based on grass-feeding strategies – these permanent grasslands play a key role in maintaining many ecosystem services at the scale of small agricultural regions (Isselstein *et al.*, 2005 ; Pärtel *et al.*, 2005 ; Habel *et al.*, 2013).
- A homogeneous distribution of organic farming areas across French agriculture, ensuring a homogeneous distribution in the French agricultural regions of the benefits for biodiversity associated with organic farming. The reduction of pressure on insects and weed diversity, linked in particular to the absence of synthetic inputs, as well as the diversification of organic crop rotations, allow for an overall increase in the complexity of trophic chains and landscapes favourable to biodiversity (Bengtsson *et al.*, 2005 ; Gabriel *et al.*, 2010).

This double dynamic in terms of landscapes and farms, provided that it is economically viable, would in fact generate significant benefits in terms of biodiversity. The maps below present the results of the regionalization of both scenarios, Dual France and Socio-territorial Recompositions, by 2050.

These differences in the evolution of farming systems and landscapes have consequences on the overall production levels, which are represented in the figure below (and which have also been taken into account in the evaluation of the employment and income impacts of the two scenarios modelled).

Figure 36. Evolution of common wheat (organic vs. conventional) and natural grassland areas in 2050 in the two scenarios



Source : MOSUT / Solagro.

Figure 37. Evolution of production volumes by main production types between 2015 and 2030 (million tonnes)

Source: authors, based on (MAA, 2018) and MOSUT/Solagro

5.4 *Sensitivity analysis of scenarios and alternative assumptions*

Table 8 puts into perspective the impacts that the Dual France and Recomposition scenarios will have on employment in the dairy sector with regard to (i) the business as usual scenario at the agricultural level proposed by the French Ministry of Agriculture in the framework of the preparation of the SNBC-A and (ii) two sets of alternative hypotheses that push the rationale of each of the two scenarios to the extreme. Thus, "Employment +" takes seriously the demands of civil society actors (voir la tribune par Girod *et al.*, 2020) in favour of a significant increase in the rate of new farm establishments and a deceleration in farm concentration,[49] while the "Danish Model" envisages a generalization of the average Danish system to the whole of the French dairy herd.[50] Additional assumptions on the agri-food component have been made

Table 8. Sensitivity of the model to alternative assumptions in terms of employment

	Average number of DC / farm	Average productivity / DC	Milk production (bn l)	Number of farms	Number of agricultural jobs (AWU)	Number of agri-food jobs (FTE)	Total jobs
2015	60	7 014	25,6	66 000	136 000	53 875	189 875
Dual France 2030	115	7 938	25,4	28 500	86 000	47 885	133 885
Recompositions 2030	75	7 313	23,4	43 000	104 000	60 223	164 223
Current trend 2030	100	8 594	27,5	35 000	98 000	57 215	155 215
Employment + 2030	45	5 969	19,1	70 000	140 000	42 820	182 820
Danish Model	173	9 500	30,4	18 500	53 000	53 950	106 950

Source: RICA & RGA (data 2015) and authors from IAACalc and SPCalc for the scenarios.

to assess the total employment impact of these two alternative scenarios.[51]

The twin objectives of maintaining agricultural employment and decarbonizing the dairy sector in the alternative Employment+ scenario is based on the massive development of very small farms (with 30 dairy cows or fewer) – which would represent 40% of farms and 27% of the herd by 2030. Such a situation would also lead to a decrease in production (18% less than the Socio-territorial Recompositions scenario, or 25% less compared to 2015), as the average productivity per dairy cow of these small systems has a much lower potential for growth than large, highly automated systems. Finally, it would require 24% of the milk produced to be processed directly on the farm to ensure sufficient value added, and to remunerate a stable workforce despite the drop in volumes – compared to less than 2% today.

These developments would have significant consequences on employment at the processing level, as the milk processed on the farm would no longer pass through the "classic" industrial tool. In total, the Employment+ scenario is the one that would generate the most jobs compared to all the scenarios tested, without however fully maintaining employment at the level of the sector (4% decrease compared to 2015). It is also based on assumptions regarding changes in production tools, consumption patterns and market balances that can easily been considered as unrealistic. In contrast, the alternative "Danish Model" scenario is based on an exacerbated rationale of concentration/intensification/specialization and economies of scale on the industry side. It would lead to an extremely high loss of farms (71% fewer than in 2015, 35% fewer than the Dual France scenario) and jobs (similar orders of magnitude) at the agricultural level. On the other hand, the high yields associated with the generalization of "Danish like" farming systems would enable the maintenance of employment at the processing level, due to the increase in milk collection, which would more than compensate for the reduction in employment intensities associated with economies of scale. In total, the set of assumptions made by the "Danish Model" would generate the greatest loss of jobs compared to 2015. While it clearly demonstrates impressive climate performance through the efficiency gains allowed by the increase in the average size of farms, its impacts in terms of food and biodiversity would certainly need to be examined very closely, as would the investment needs it implies.

49 In this model, small farms (number of dairy cows less than or equal to 50) account for 75% of the herd, and 27% of dairy cows are in production systems of 30 DCs with on-farm processing facilities.

50 In this case, the average Danish farm - 173 DCs for 3 AWU and a production of 1.6 million litres of milk - is extrapolated to the total French herd envisaged by the SNBC-A in 2030.

51 The average employment intensity of the dairy industry decreases by 19% in the "Danish Model" due to the economies of scale envisaged, while it increases by 25% in Employment+ to account for the development of on-farm processing.

6. Conclusion: ensuring the economic viability of a just transition is a political issue

The results of the Recompositions scenario for the two sectors studied ultimately make credible the hypothesis of a just transition of the food system: agricultural employment is 10% higher than in the reference scenario while agricultural incomes are maintained, agri-food employment increases by 7% while offering more varied and less processed foods, and agricultural landscapes are re-diversified. The comparison with the Dual France scenario – as well as the sensitivity analysis carried out – shows, however, that the social and political conditions for such a transition are numerous and, to put it bluntly, difficult to achieve.

This last section therefore firstly questions the type of political pathways that are likely to favour the deployment of a just transition scenario – or, in other words, that would ensure its economic viability. Finally, it puts the proposed scenario-building exercise into perspective with the identified challenges of political change, in order to point out the research questions that should be explored further to advance political action in favour of a just transition.

6.1 ***Supporting demand and organizing markets to structure a new food supply: a European project***

The comparison between the Dual France and Socio-territorial Recompositions scenarios shows that a political change aimed primarily at the supply side – as in Dual France – does not (or does so only very weakly) address the employment issues of the transition, and is particularly inequitable on the consumption side. Intervening on the demand side and on market organization thus appears to be a determining factor in achieving new market balances, bringing together a socially just and environmentally sustainable food supply with actual demand (on the domestic market as well as for export).

Supporting (domestic) demand

The current consumption dynamics in France and in Europe are giving weak but encouraging signals with regard to the challenges of the transition (reduction in the consumption of animal protein, increase in the proportion of organic products, demand for local products – see section 3.4). At first sight, deploying policies aimed at amplifying these dynamics might thus seem sufficient to accompany the transition. However, such a rationale comes up against two limitations. Firstly, the evolution of the average food basket masks a heterogeneity of dietary habits: in addition to supporting the dynamics underway, it is therefore also necessary to initiate more significant changes to practices. Secondly, this heterogeneity partly reflects the precariousness of a growing proportion of consumers, for whom an increase in their food budget (in terms of both € and time) is difficult to envisage.

More substantial interventions are therefore necessary, most of which have been under discussion or experimentation for several months/years (voir pour une revue de littérature et de la situation en France Capacci *et al.*, 2012 ; Denartigh & Descamps, 2019). While the guidelines proposed by the French National Nutrition and Health Programme are indeed consistent with the challenges of a sustainable transition, including an increase in the consumption of legumes to 20g/day, a decrease in the consumption of ultra-processed foods, and an increase in the consumption of fruit and vegetables, the plan is however struggling to have a concrete impact – and has even triggered counter-productive effects in some cases! (Inserm, 2017, p. 136).

The wider deployment of more ambitious accompanying measures, however, is currently facing significant opposition in political discussions, particularly the argument that "consumer freedom" should not be influenced by politics (Saujot et al., 2020a).[52] However, it is well known that dietary habits are themselves the product of many influences and that, in this field less than elsewhere, the idea that an act of consumption is the result of a rational decision has been undermined (voir pour une synthèse récente Olstad & Kirkpatrick, 2021). Overcoming these political reservations is therefore an important prerequisite. At least five types of measures can be drawn from the literature to change consumption on the domestic market and thus move the agricultural and agri-food supply in the direction of an agro-ecological, low-carbon and job-creating transition. The first three are no-regrets options, the next two are more exploratory in nature.

1. The development of campaigns with significant resources, going beyond the €50 million of the French National Nutrition and Health Programme, which seems trivial in comparison with the €2-3 billion spent on marketing by agri-food groups (at the French level). These campaigns should use social marketing techniques (Grier & Bryant, 2005 ; George *et al.*, 2016) to truly adapt the message to target audiences – instead of broad-based communication that fails to convince and in many cases tends to make consumers feel guilty for not being able to adapt their practices to the messages conveyed.[53]
2. Improving consumer information on the products available on the shelves in terms of environmental and even social issues through front-of-pack labelling. In addition to the Nutri-Score, the success of which in France is leading to a study of its transposability to the European scale as part of the implementation of the Farm to Fork strategy, the environmental labelling currently being developed is a key recommendation of the Citizens' Convention on Climate. Such tools are not only important for changing practices, but by helping to create a positive narrative about the existence of a sustainable demand, they also encourage changes in supply (Dubuisson-Quellier, 2013).
3. Accelerating changes in collective catering (particularly in schools) to encourage the discovery and adoption of new dietary habits, such as the consumption of more plant-based foods and less ultra-processed products, by expanding the experimentation of the Egalim Act. However, in some cases this acceleration is currently encountering difficulties related to marketing/competition regulations, on which there remains much work to be done;
4. The development of food vouchers, along the lines of the US food stamp system (which accounts for almost 50% of the public budget for agriculture in the US), has been proposed by the Citizens' Convention on Climate. While such a system can generate benefits for the poorest households (Nestle, 2019), it only becomes a lever for the just transition if it is backed up by standards that enable the specification of which products are eligible for the food voucher - but it then becomes very prescriptive and difficult to implement.
5. Finally, changes in taxation could play a role in this equation, but would require more detailed analysis to define the modalities. Several recent assessments suggest that taxes on sugar-based/processed/meat products could have very minor regressive impacts (Bíró, 2015 ; Smith *et al.*, 2018 ; Springmann *et al.*, 2018b). Conversely, a tax incentive for companies with a strong territorial base that promote low-carbon products could encourage the market penetration of these products at a reasonable cost to the consumer.

While the deployment of such measures could stimulate the emergence of new balances on the domestic market and thus limit – or even prevent – a substitution by imports, the question of the future of exports remains unresolved at this stage: are the international customers of French exporters interested

52 A campaign of exploratory interviews conducted with French parliamentarians also leads to the assumption of two other cognitive/normative barriers. For the parliamentarians interviewed, investing politically in the field of dietary habits entails two risk types: that of being seen as "anti-poor" or "pro-liberal elite", due to the growing precariousness of a part of the consumer population; and that of participating in the general "agribashing" movement by contributing, through the vocabulary of "sustainable food", to the stigmatization of conventional producers or those involved in animal production.

53 Many studies also stress the importance of going beyond an "awareness-raising" approach based on the implicit assumption that food practices are determined by conscious and rational choices. They advocate campaigns based on a positive narrative (making people want to consume in a certain way), highlighting the psycho-sensory aspects of food: rediscovering the pleasure of eating with healthier products and more sustainable food practices, identifying and listening to feelings of hunger, satiety, pleasure, etc. (voir pour une synthèse Bertin, 2020).

in the issues of a just transition? The question is all the more important because the equivalent of 40% of the French milk collection is exported each year, while almost one out of two tonnes of cereals is exported. In both cases, the European market is an important destination. In addition to demand, it is therefore necessary to intervene in the organization of markets to ensure that the development of a more environmentally sustainable and socially just supply does not come up against an absence of demand – or too little demand.

Organizing markets: the double challenge of international convergence and competitiveness

The issue of market organization is based on a simple imperative: to ensure that the search for competitiveness (price and non-price)[54] between operators from different countries is conditional on the pursuit of similar objectives and thus avoids "carbon leakage" (Antimiani et al., 2013). This assumes not only that all countries subscribe to the ambition of decarbonizing the food sector, but also that they have a shared vision of the decarbonization pathway.

The competitive dynamics in the dairy sector, especially with Denmark or Germany, provide a good illustration of the problems to be tackled in the common market – where the ambition to decarbonize the food sector can be considered, in broad terms, as shared by the majority of countries. The Danish Agriculture and Food Council's action plan to decarbonize the Danish dairy sector by 2040, thus appears to be very different from that put forward in the Socio-territorial Recomposition scenario: it relies on a continued intensification of milk production (with cows averaging 14,000l/year) to reduce the carbon footprint per tonne, on a significant reduction in the number of farms and associated jobs, while considering that biodiversity issues fall outside of the agricultural sphere through the adoption of a land sparing approach (voir Danish Agriculture & Food Council, 2019). If deployed in its current form, it would lead to an increase in the price competitiveness differential between the producers of the two countries (Perrot et al., 2018).[55] While the risk of import substitution is low given the captive nature of the dairy market, the risk of losing export market share seems very real. Exporting in non-differentiated segments could become extremely complicated, with the continuation of exports ultimately depending on the structuring of outlets for differentiated and well-identified products. It is necessary to harmonize visions on what constitutes a sustainable food system in the European context to limit such dynamics. Regarding the agricultural component, this implies the development of clear accountability mechanisms in the implementation of national strategic plans within the framework of the current reform of the Common Agricultural Policy. In relation to the agri-food component, a convergence of social and fiscal rules would appear essential to ensure a harmonization of costs and working conditions which, although such harmonization does not define the existing competitiveness differentials, it is not totally unrelated to them.[56]

Similarly, current competition dynamics between Europe and the Black Sea countries for cereals, or with the Americas for plant-based protein, are illustrative of the issues at stake regarding international trade. The price-competitiveness differential that exists today between domestic production and that of competitors is largely due to differences in

54 The notion of competitiveness refers to the fact that a country or a producer can maintain or even increase their market share in a competitive market. Price competitiveness is based on the reduction of production costs for "standard" quality products. Non-price competitiveness is based on the development of higher value-added products through innovation, differentiation, etc.

55 These are largely based on the capital intensity of the farms and the very high labour productivity associated with it, which is more than double that observed in Brittany: 513,000 L/AWU in Denmark compared to 206,000 L/AWU in Brittany and Pays de Loire according to Idele (Perrot *et al.*, 2018).

56 Competitiveness differentials are indeed largely also the result of the strategic choices made by companies to cope with market dynamics (particularly in terms of innovation and product portfolio).

57 The situation for cereals, oilseeds and protein crops is certainly very different: France is a net exporter of the former – but is facing increasing competition from Black Sea producers; and it is a net importer of the latter – and is struggling to structure domestic sectors despite several programmes for plant-based protein (apart from the specific case of rapeseed and sunflower). However, the problem in commercial terms is the same: French producers are competing on the same markets with operators who are not subject to the same production conditions.

the production conditions of producers (in social, fiscal and environmental terms).[57] It poses a risk for export outlets for cereals, but also potentially for the domestic market; above all, it has historically limited the development of protein crop areas (Magrini et al., 2016), which should nevertheless double by 2030 to limit the use of synthetic fertilisers. The challenge is therefore nothing less than to harmonize production conditions between these countries, and even, for protein crops, to protect the European market at least temporarily in order to encourage the closing of the productivity gap (Stiglitz, 2002). In the absence of a renegotiation of the entry conditions for protein crops coming into the common market, which result from the 1962 Dillon round, the implementation of a carbon adjustment mechanism at the borders, currently envisaged by the European Union, could play a decisive role in this perspective – despite its obvious complexity (Colombier et al., 2021). More generally, since the European Union is the world's largest exporter and importer of food products, it can and should be a driving force in setting ambitious standards for more sustainable production and consumption patterns, and in pushing forward these issues not only in the bilateral agreements it signs, but also at the WTO level.[58]

Structuring a sustainable supply

It will be necessary to ensure that French production is both sustainable and competitive on the international market; but at the same time, it is necessary to ensure that there is a transition of production methods towards competitive systems that exist within a renewed trade framework, both in agriculture and food processing.

In agriculture, the primary challenge for the evolution of the political framework concerns the reform of the CAP and in particular the definition of ecoschemes. These must allow for a "super greening" after the 2013 failure (Hart et al., 2016). The definition of an ambitious community framework for these ecoschemes should make it possible to establish a shared but differentiated ambition. In particular, by relying on a well-considered transposition to each Member State of the quantitative objectives set out in the "Farm to Fork" strategy (in terms of nitrogen, pesticides, agro-ecological infrastructure, the proportion of organic farming in the UAA or the reduction of emissions), this common framework will make it possible to ensure that the financed measures are adjusted to the variability of the contexts and to ensure a fair contribution by all to the achievement of the common goals. Such a framework will also make it possible to prevent countries from adopting inadequate eligibility criteria, which would limit the possibilities for progress.

On the other hand, ecoschemes will have to evolve rapidly to enable support for the transition in a rationale of progress, for example on a contractual basis – as proposed more than 4 years ago by David Baldock (Buckwell *et al.*, 2017). Indeed, these ecoschemes are currently envisaged on an annual perspective and based on unchanging specifications: only producers that meet the criteria of the specifications will be eligible. However, the transition implies a certain amount of risk-taking, it takes time and therefore requires financial support. Although it is clearly impossible to define a pathway for progression for each farm type, the experience gained during the implementation of French Territorial Farming Contracts between 2001 and 2003 provides an interesting example for analysis (Urbano & Vollet, 2005).

Another development issue in the agricultural sector concerns the possibility of remunerating farms, outside of the CAP, for their contribution to carbon capture or emission reductions. This possibility is currently regulated in France through the low-carbon label, but exists in other forms throughout Europe via voluntary standards (VCS, Gold Standard, etc.). While this has potential, greater development of low-carbon certification approaches for project financing will have to pay close attention to three aspects: (i) sufficiently demanding specifications regarding the co-benefits (or possible risks) in terms of biodiversity and natural resources, in order to promote a multi-functional transition (and not a simple continuation of the intensification/specialization rationales with only

58 This is in line with the opinion of the European Parliament's Committee on International Trade on the Farm to Fork strategy. See (INTA, 2021).

marginal increase in efficiency); (ii) the development of demanding reference scenarios, which lead to net decreases in emissions or net CO_2 capture, rather than merely "improvement"; (iii) the limitation of projects solely focused on offsetting emissions generated elsewhere by other actors.

At the processing level, the Socio-territorial Recompositions scenario requires a renewal of the industry's current approaches. Indeed, over the last 10 to 15 years, various high-level reports (e.g. Rouault, 2010) have been published, advocating for a growth in company size in order to reduce production costs. While some growth in size will undoubtedly be necessary, including in a Socio-territorial Recompositions scenario, it cannot be the only answer. The structuring of a network of high-performing SMEs, including for exports or imports, on the basis of known and recognized products (for which French agriculture has many assets) is an even greater challenge. In this perspective, two political levers can be cited. One national-level lever consists of continuing the support for quality label sectors, to increase awareness and recognition of these labels by French consumers and on export markets, by combining support tools for economic actors (fiscal and incentives) with communication tools. Another intervention type falls within the remit of local authorities, and consists of structuring territorial dynamics around production and consumption areas, by expanding and structuring the efforts currently being made by some cities (Montpellier, Dijon, Rennes), but by increasing their means to take action on the agri-food aspect.

6.2 *A pioneering modelling approach to be further developed and replicated*

The modelling work proposed in these pages is the first exercise of its kind to carry out a detailed analysis of the socio-economic effects of a transformation of the food system that is consistent with planetary boundaries. In this respect, it proposes three major methodological innovations. Firstly, it characterizes structural transformations of the production tools at stake with regard to the changes needed to bring the food system back within planetary boundaries – whereas almost all existing impact assessments are based on constant systems. Thus, instead of assessing the impact of a given change (in production or consumption patterns) on employment or income based on an economic equilibrium model – i.e. in which prices and demand are mostly endogenized – our methodology identifies the conditions in terms of prices, subsidies or wage targets, whereby changes in production and consumption envisaged in relation to environmental issues can be economically viable. While the reasoning is clearly limited by the fact that it cannot capture the interdependencies between markets from a Walrasian perspective (i.e. the fact that a change in supply or demand in the agricultural sector will necessarily have consequences for other sectors, and vice versa), it is this rationale that nevertheless allows us to move away from a constant system analysis.

This understanding of the structural changes at stake in the transition was achieved, secondly, through a cross analysis of supply and demand. Rather than endogenizing demand on the basis of an optimization function and assumptions on elasticities, which are often difficult to empirically substantiate, we felt it would be more beneficial to raise the issue of changes in food demand that would be compatible with the changes in supply envisaged to remain within planetary boundaries. This exercise is part of a context in which a growing number of foresight exercises, whether global, regional or national, are making important assumptions about consumption practices and lifestyles to keep the Earth system within the planetary boundaries (Saujot et al., 2020b).

Finally, in connection with the first two points, the proposed methodology couples the analysis of physical balances and socio-economic dynamics by understanding "production functions" from an angle that is first and foremost physical, from the perspective of the following questions: how many jobs can be generated for 1,000 tonnes of production, depending on the production methods envisaged? Given the related production costs (excluding wages), what must be the final value of this production for the associated jobs to be properly remunerated? While the objective of such reasoning is not to return to a planned economy rationale, it prevents the dissociation of the physical imperatives linked to the planetary boundaries from socio-economic issues, to identify the political conditions under which this double requirement can be met, in a rationale of strong sustainability. The proposed modelling work is also positioned at the centre of a tension between two types of foresight exercises:

- medium to long-term exercises, such as backcasting, which enable the identification of the outlines of a sustainable food system independently of its recent evolution, but as a result, offer little scope for practical actors to project themselves into the transformations at stake;
- short to medium-term exercises, which enable the establishment of 10-year transition pathways in a more precise manner, and which therefore relate more to the actors in the real economy, but which, symmetrically, are strongly constrained by current dynamics - and therefore struggle to be ambitious.

While the multiplication of the first type of exercise has made it possible to clearly identify the challenges of the transition, their appropriation by a large proportion of actors in the agri-food sector has so far proved to be much more complicated. The hope of this study is that the updating of the socio-economic challenges of the transition, and of its short and medium-term modalities, can be a major lever for bringing these actors on board for a constructive discussion and for the co-construction of solutions.

Despite the progress proposed in this report, four aspects still require major efforts to progress in structuring discussions with stakeholders.

- Only two sectors have been covered here and, although these sectors account for a significant proportion of the utilized agricultural area, the employment and the value generated in the food system, the modelling work undertaken here will only be fully conclusive when other key sectors are included, particularly meat production sectors.
- The analysis of farm income issues has been conducted in an exploratory manner, in particular concerning the question of the investments at stake in the transition. This aspect will need to be studied in greater depth and revisited to serve as a basis for discussions that are as practical as possible regarding the modalities and possible impacts of agricultural transitions.
- At the processing level, disaggregation work still needs to be carried out to better understand the diversity of possible strategies and, through this, their consequences on the evolution of production costs and, ultimately, consumer prices.
- Finally, the retail sector has not been considered in the modelling carried out here, but its inclusion seems necessary to be able to fully grasp the issues of value distribution in the sectors, which has barely been addressed here.

These four issues for further study, important as they are, do not, of course, undermine the main areas of change identified in the previous paragraph, which must be taken into account in the major political projects underway concerning food systems.

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