Towards sustainable and healthy protein consumption in the European Union

An assessment of conditions affecting protein consumption transitions in EU member states.

Thesis Research Project - MSc Industrial Ecology
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Thank you to my friends and my family for never making me doubt that you are there.

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Executive summary

Background

A protein consumption transition (PCT) in the European Union (EU) has the potential to abate the substantial negative impacts regarding environmental sustainability, health, animal welfare and food security, that are related to high meat consumption levels. Many conditions exist that influence consumption of different types and quantities of protein, which have mainly been researched in a qualitative and theoretical way. An overview of the degree to which these conditions are present in the EU could help in uncovering patterns across member states, and determining pathways towards enabling PCTs.

Methods

A framework was constructed by studying literature on conditions affecting consumption of meat and alternative proteins. Researchers were interviewed to validate and direct the literature review. Nine indicators were selected to represent conditions that influence PCTs. These spanned from conditions on an individual level (e.g. motivation for eating healthily and sustainably), to situational conditions (e.g. the affordability of meat), to conditions in the macro environment (e.g. the level of urbanisation).

EU member states' performance on the selected indicators was assessed. The member states were clustered based on their performance on the indicators through an agglomerative hierarchical cluster analysis. The clusters that emerged were then characterised based on the ways in which they were similar within their cluster, as well as dissimilar to other clusters in regards to their conditions to PCTs.

Results

The EU member states showed varying performance on all indicators. On average for the EU, 75% of citizens are motivated to pay for healthy and sustainable food, but just 35% report that that would include eating less meat. The affordability of meat is currently increasing as compared to total foods in all member states.

Three clusters emerged from the data. Cluster 1 was characterised as 'systemic constraints for consumption', as the performance for most indicators showed unfavourable conditions for PCTs. Cluster 2, labelled 'urbanised and fiscally unfavourable', showed overall more favourable conditions, though barriers for this cluster may lie in relatively higher urbanisation and affordability of meat. Cluster 3 also showed relatively more favourable conditions. Cluster 3 was characterised as 'misinformed and protein plenteous', for the relatively moderate to low performance on the knowledge indicator, and the relatively high total protein consumption.

Conclusion

The findings in this research highlight the diverse conditions that affect protein consumption in the EU. Though there are conditions that are unfavourable in all member states, it is apparent that some conditions form bigger barriers for PCTs in some member states over others. Pathways for enabling PCTs for cluster 1 could include fiscal

incentivising of alternative proteins and education campaigns. For cluster 2, fiscal incentives and interventions targeting meat consumption in urban settings could be prioritised. Member states in cluster 3 may benefit most from prioritising education campaigns on healthy and sustainable types and quantities of protein.

Further research is needed to deepen knowledge for many of these conditions, in particular for conditions in the macro environment, and for the different ways in which they affect different people. Defining effective pathways to PCTs could be assessed more extensively in policy oriented research.

Nomenclature

Meat:	In the EU, meat is generally considered to be '*skeletal muscle deriving from specified animal species, which may include edible offal and blood; the term does not include fish and seafood*.' (Lautenschlaeger & Upmann, 2017, p.1) This is the definition also assumed in this thesis, though all parts derived from these animals will be considered.
Alternative protein:	Alternative proteins in this thesis entail sources of protein that are not derived from meat. This means plant based foods are included, but also insects, cultured meat and other 'second generation' meat alternatives (Caputo et al., 2024).
Protein transition:	The protein transition in this thesis encompasses a transition away from meat. Besides substantial reductions in meat consumption and substitution of meat with alternative proteins, in many cases a reduction in overall protein consumption is desirable. (Cottrell et al., 2021; Duluins & Baret, 2024a)
PCTs:	Protein consumption transitions.
AHCA:	Agglomerative hierarchical cluster analysis, elaborated on in section 2.3.2.

Chapter 1. Introduction

This chapter explores the problem statement, after which the research question and objectives, and a brief overview of the remainder of this thesis are presented.

1.1 Introduction and problem statement

Food products in the European Union (EU) are key contributors to environmental impacts such as land use, water use, acidification, particulate matter, eutrophication, biodiversity losses and climate change (Beylot et al., 2019; Campbell et al., 2017; Crenna et al., 2019). Meat products are especially impactful within EU diets due to both their high environmental impacts during production and the large quantities consumed (Beylot et al., 2019; Notarnicola et al., 2017). The relevance and urgency for a protein transition in the EU is increasingly acknowledged (Willett et al., 2019; European Commission, 2020; van Vugt & Nadeu, 2025). Beyond environmental concerns, issues related to food security, human health and animal welfare are consistently mentioned in the discussion on changing the role of meat in our diets (European Parliament, 2017; Godfray et al., 2018; Bonnet et al., 2020; Cué Rio et al. 2022; Fumagalli, 2022; Rieger et al., 2023; European Commission, 2025). Supply-side interventions are insufficient to reduce the impacts of agrifood systems (Willett et al., 2019; Guillaume et al., 2024).

A protein consumption transition (PCT), in which meat consumption is reduced and partly replaced by alternative proteins, is increasingly recognised as essential for addressing the negative impacts associated with the current agrifood system (Springmann et al., 2018; Sun et al., 2022). NGOs such as Greenpeace have called upon the EU to set clear targets for reducing meat consumption substantially, and have even suggested a 70% reduction target by 2030 (Greenpeace European Unit, 2020). This overall reduction of meat consumption in order to reduce the associated negative impacts is generally the most central aim in PCTs. However, a one-sided approach to this challenge in which the uptake of alternative proteins is mainly stimulated may not result in the desired decrease in harmful consequences. It may not necessarily result in disadoption of meat, and total protein consumption in many EU member states already exceeds nutritional recommendations (Bayudan et al., 2025; Cottrell et al., 2021; Duluins & Baret, 2024b). As a result, even with a complete substitution of meat with alternative proteins, the consequences of excessive consumption remain (Duluins & Baret, 2024b). Taking into account these nuances, PCTs are understood not merely as a shift in protein sources, but as a move towards appropriate types and quantities of protein consumption. This generally means substantial reductions in meat consumption in the EU, alongside an increased consumption of healthy and sustainable alternative proteins.

Many studies have provided valuable and often quantifiable and comparable insights into the impacts of current food systems (Béné et al., 2019; Williams et al., 2024; Ruiz-Almeida & Rivera-Ferre, 2019). These studies highlight problematic impacts but are less insightful concerning the way in which transitions away from these problematic impacts can be achieved. The way in which food consumption is situated in broader socio-technical systems, and the way in which this influences the potential for PCTs cannot be illustrated only by indicators representing impacts (Conti et al., 2021).

Meat consumption depends on many factors which vary between countries, and are not systematically understood. An individual's choice to eat or not eat meat, goes beyond the individual and is influenced by social, cultural and political context (Godfray et al., 2018). The range of factors influencing protein consumption have been explored in various studies in a qualitative and theoretical fashion (Hoek et al., 2021; Milford et al., 2019; Srinivasan et al., 2024; Stoll-Kleemann & Schmidt, 2017). Some studies have estimated the presence and degree of influence on protein consumption of specific conditions in reality (Milford et al., 2019; Milfont et al., 2021; Mata et al., 2023). An overview of enabling and inhibiting conditions to PCTs, and the degree to which they are present in the EU has not been developed yet. This knowledge could aid in identifying patterns across national contexts, and in targeting conditions where most progress could still be achieved for effectively enabling PCTs.

To conclude, literature has a solid base in what the shape of collective protein consumption would ideally be, indicating relevance and urgency for PCTs (Willet et al., 2019). Studies have researched conditions that influence the consumption of (meat based or alternative) proteins, either experimentally or more based in theory. This thesis aimed to map the presence of these influencing conditions to PCTs in EU member states, to create insights into particularly relevant barriers per national context. A cluster analysis of these results was conducted to uncover patterns across member states. The holistic and systematic mapping that this research proposes, and the gained insights into the complex nature of PCTs line up well with the research areas and methods of Industrial Ecology, and have - to my knowledge - not previously been explored in this way. The aim is that this will aid in facilitating healthy, sustainable and just PCTs.

1.2 Research question and objectives

The research question guiding this thesis was the following: What are current conditions influencing PCTs in the EU?

The main objective was to establish a typology of conditions that enable or inhibit PCTs in EU member states. To achieve this, three subobjectives were pursued. The first subobjective was to develop a method for assessing conditions influencing PCTs in EU member states by identifying relevant indicators in existing databases. The second subobjective was to apply this developed framework in order to assess EU member states based on the expression of these conditions. The last objective was to identify patterns across national contexts by clustering the member states and creating a characterisation of their internal and external (dis)similarities.

1.3 Outline of remainder of thesis

The next chapter will present the methods, where the research approach and the framework used throughout this thesis will first be established. This is done by first discussing literature and insights from conducted interviews. The research steps will then be presented in the remainder of the methods. The results chapter first discusses the performances of EU member states on the indicators, as well as the overall EU performance. Subsequently, the results of the cluster analysis and characterisation of the clusters are presented. Lastly, the findings will be interpreted and discussed in the discussion chapter, after which a conclusion is presented.

Chapter 2. Methods

This chapter presents the methodology that was used to answer the research question and achieve the objectives. The research approach and the developed framework that are used throughout this thesis are first introduced, after which the research steps that were performed to produce the results are reported. Concluding the chapter, actions that were taken to validate the framework and results are briefly described, and the positionality of the main researcher is addressed.

2.1 Research approach

This thesis had multiple components contributing to addressing the research question and objectives (see Figure 2.1). Firstly, the framework that was used throughout this thesis was developed. This framework was synthesised by reviewing academic and grey literature, and by conducting expert interviews with researchers. EU member states were then assessed based on the indicators in the established framework. The member states were clustered based on these performances, after which they were characterised.

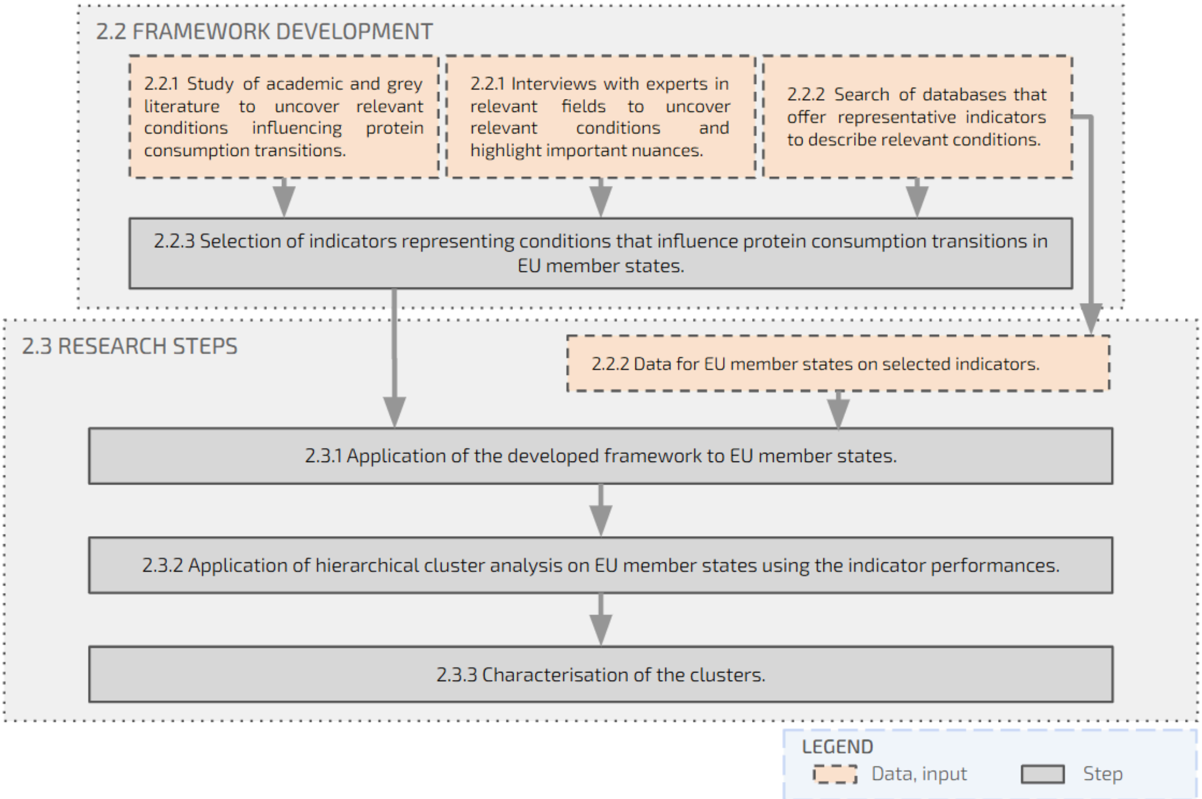

Figure 2.1. The research flow diagram, illustrating the different components of this thesis.

2.2 Framework development

The selection of indicators was done through a careful and iterative process (see Appendix A). This method for selection was based on a similar approach by Ruiz-Almeida and Rivera-Ferre (2019).

Conditions influencing PCTs in the EU were studied by consulting academic and grey literature. Literature was searched in a non-systematic way by using search terms: ('meat'

OR 'food' OR 'protein'), AND 'consumption', AND ('conditions' OR 'drivers' OR 'influenc*') on Google Scholar and Scopus. Articles that discussed factors influencing consumption of meat or more generally sustainable (food) consumption were included for review. Additional literature was included through snowballing. From this literature, conditions that influence the consumption of meat and/or alternative protein sources for PCTs in the context of the EU were considered. When literature considered different contexts, or did not make the context explicit, the transferability of the findings was carefully considered.

Concurrently to the literature search, interviews with researchers from different disciplines were conducted in order to validate, expand and direct the desk research. The goal of these interviews was to gather more insight and perspective into factors that may influence PCTs. This functioned as (1) validation to ensure that the aspects that I included were indeed relevant, (2) a way to inform and direct additional research, and also provided (3) useful insights as to the way to interpret the literature by providing context. The interviews enabled more nuanced understanding of the topic and helped uncover additional insights, academic articles and data sources. In this way, the interviews aided in grounding the research in reality (Bans-Akutey & Tiimub, 2021; Heesen et al., 2019). Five researchers were approached by sending an invitation for an interview through email. Four people responded and were interviewed in March and April of 2025. The interviews were conducted in a semi-structured way. A list of general questions was constructed and can be found in the interview guide in Appendix B. The questions were adapted to the interviewee, as different interviewees had different expertise. Additionally, interviewees were encouraged to bring topics they found relevant to the table. When interviewees reported findings that provided insight into possible conditions, they were asked to provide their reasoning or point towards the relevant literature that influenced their perspective, in order to enable triangulation.

An initial list of core conditions influencing PCTs was established based on the information from the literature and conducted interviews. The next section will present the most relevant insights on these conditions. An overview of the conditions can also be found in Appendix C.

2.2.1 Conditions based on literature and interview inputs

Factors that influence the degree of sustainability in (food) consumption have been extensively reported on. Consumption systems of one product or process are never fully comparable to consumption systems of another, and so this literature has to be carefully considered in order to extract the conditions that apply to this case (Interview G2, 2025; de Boer & Aiking, 2022).

Various classifications exist. I will report on conditions influencing PCTs by structuring them into three dimensions, similar to classifications established before (Godfray et al., 2018; Hoek et al., 2021; Poças Ribeiro et al., 2019; Stoll-Kleemann & Schmidt., 2017). The first dimension is the *individual* level. This encompasses different kinds of factors that influence meat or vegetarian consumption on a personal level. The second dimension describes *situational* conditions in people's direct environment. This means social influences as well as physical or material things that people are in direct contact with. The third and last dimension covers aspects in the *macro environment*, meaning that factors are discussed that exist on a more structural, large scale level. In literature, there is quite a heavy focus on individual consumer behaviour, and factors that influence decision-making. The more systemic aspects are less reported on (Interview G1, 2025; Hoek et al., 2021). The division of the conditions into three dimensions (individual, situational and macro environment) is not a sharply defined one (Interview G1, 2025; Interview G2, 2025). In reality, these conditions may be part of multiple of these dimensions and affect another.

2.2.1.1 Individual factors

Firstly, we will review individual factors in consumption that enable or inhibit PCTs. In a number of studies that researched individual decision making in food or particularly meat consumption, the COM-B model of behaviour change was found useful (as elaborated in Hoek et al., 2021, p. 615). COM-B is an acronym for 'capabilities', 'opportunities' and 'motivation', leading to certain 'behaviour'. Capabilities and motivation are included as individual factors in this thesis. Opportunities are included in the second and third dimensions of conditions, namely the situational level and macro environment, as they are contextual. The last part of the COM-B is about the resultant behaviour, which in this thesis entails meat or alternative protein consumption, and so is not a condition but that which is influenced by the conditions.

For an individual's capabilities, the main factors of relevance are related to their knowledge on the sustainability, healthiness, safety and preparation of meat based and vegetarian meals (Hoek et al., 2021; Guadarrama, 2023; Myers & Pettigrew, 2018; Mellor et al., 2022; Interviewee G1, 2025; Interviewee G3, 2025). Similarly, familiarity with vegetarian foods and cooking influences people's willingness to consume vegetarian foods (Eustachio Colombo et al., 2021; Mellor et al., 2022). The time people are able to spend on cooking can also influence their capability to change consumption behaviours (Milford et al., 2019). Furthermore, an individual's capabilities to consume a certain way are also influenced by the education they have obtained and the financial agency they have (Einhorn, 2021; Srinivasan et al., 2024). For both of these factors, more implies higher capability to consume in the way a person wants to consume. The link between income and meat consumption behaviour is contested. Higher income is generally associated with increased meat consumption, though this elasticity also can differ for varying national contexts and income groups (Milford et al., 2019; Špička et al., 2021; Mata et al., 2023). Higher educational attainment has been more consistently associated with lower meat consumption (Einhorn, 2021; Klink et al., 2022; Mata et al., 2023).

Besides these capabilities, the individual also possesses certain values or motivation that move them to consume food in a particular way (Hoek et al., 2017; Hoek et al., 2021; Milfont et al., 2021; Srinivasan et al., 2024). If these values particularly align with a meatless diet, this enables the disadoption of meat. In a large-scale consumer study in 9 EU member states, the top three reasons that people have given when describing why they had chosen to decrease their meat consumption related to health, animal welfare, and environment, in that order (Guadarrama, 2023).

Besides these factors that can be placed and considered in the capability and motivation categories of the COM-B model, some general demographic characteristics have also been described to influence levels of meat consumption. The described characteristics mainly are age, gender and religion (Meixner et al., 2024; Grasso et al., 2021; Guadarrama, 2023; Srinivasan et al., 2024; Milford et al., 2019).

2.2.1.2 Situational factors

Situational factors in people's direct environments influence what and how they have the opportunity to consume. These conditions can therefore be interpreted to relate to opportunities in the COM-B model of behaviour change (Hoek et al., 2021, p. 615). They will be further disaggregated into social and material factors here.

Regarding social situational factors, perceived social pressure, particularly in the household setting has been indicated to form either a barrier to or a facilitator of reducing meat consumption (House et al., 2019; Eustachio Colombo et al., 2021; Grasso et al., 2021). This can be split into social approval of meat based or vegetarian eating patterns, and social influence from these eating patterns. The former is about people tolerating particular (changes in) food consumption behaviour, whereas the latter is about the inspiring influence food consumption behaviour can have on others. Therefore, the composition of the household one lives in is of influence as well. Whether a person lives alone, with parents, children, a partner or other housemates, matters for how they are able to consume (De Boer & Aiking, 2019). Similarly, efforts to decrease meat consumption which offer built-in community support have been found to support initiation of consumption change and the maintaining of new dietary patterns (MacMillan Uribe et al., 2012; Ramsing et al., 2021).

The material situational factors shape the opportunities for meat disadoption and vegetarian consumption. The availability of meat, plant based meals, meat alternatives, etc., is directly relevant for what people are able to consume (Hoek et al., 2021; Interviewee G1, 2025; Interviewee G2, 2025; Interviewee G3, 2025). The types of meats and alternative proteins that people have access to and their general sensory appeal, as well as their affordability also influence the uptake or disadoption of these products (Srinivasan et al., 2024). Price levels have been noted as particularly influential in what people tend to purchase, more so in lower-income countries as compared to higher-income countries (Špička et al., 2021). Lastly, the point-of-purchase presentation of meat based and plant based products, such as placement and presentation, portions, and packaging are also a condition of influence (Interviewee G1, 2025; Interviewee G3, 2025; Hoek et al., 2021).

Relating to both material and social environments, the availability of plant based meals in the workplace and other institutions influences what people eat. This can be particularly relevant in schools, as youth are especially vulnerable to social influence. (Srinivasan et al., 2024; Interviewee G3, 2025)

2.2.1.3 Macro environment

Lastly, conditions that more broadly shape people's environments also determine what people (are able to) consume. To some degree, this is the context that shapes the conditions on the individual and situational level.

The cultural context in which people live shapes the conditions in which food is eaten, as well as what is on the table (Hoek et al., 2021). Cultural meals, patterns and traditions that have been built around food consumption, as well as the status that is associated with certain types of food, influence which foods are desired and which foods people are used to eating (Pieniak et al., 2009; Rosenfeld, 2023; House et al., 2024). Meat has generally been associated with ideas and realities of rising welfare in the EU, which influences the desirability of meat in diets (Chiles & Fitzgerald, 2018; Interviewee G1, 2025;

Interviewee G2, 2025; Interviewee G4, 2025). Climatology in a country has been linked to levels of meat consumption as well. More favourable conditions (e.g. in latitude and temperatures) for keeping cattle are associated with more meat consumption (Milford et al., 2019; Hoek et al., 2021).

Conditions enforced through governance have influence on what is produced and imported, and on which markets are favoured through regulations, (dietary) guidelines and public procurement (Godfray et al., 2018; Poças Ribeiro et al., 2019; Cocking et al., 2020; Hoek et al., 2021; Interview G1, 2025; Interview G2, 2025; Interview G3, 2025; Interview G4, 2025). Fiscal (dis)incentives on the side of production as well as consumption can have an influence on the types of products that are favoured over others. Regarding production, 82% of the subsidies from the EU Common Agricultural Policy support animal based products (Kortleve et al., 2024). As for consumption, the value-added tax (VAT) rate on meat and dairy products is currently higher than on fruits and vegetables (Springmann et al., 2025). Both of these examples give animal based products a market advantage.

Marketing and advertisement by different market players across various platforms, and the restrictions imposed on it are relevant factors that impact meat consumption. Similarly, mass media coverage on topics around meat and vegetarian consumption have been discussed to affect consumption as well. (Srinivasan et al., 2024, p. 8; Interviewee G1, 2025)

Education has been mentioned to form or have the potential to form knowledge and behaviour regarding food consumption. Education in primary and/or secondary schools can influence how people go on to consume later in life, and can reach people from all walks of life. (Bruckner & Kowasch, 2019; Hoek et al., 2021)

Urbanisation has been associated with increased meat consumption. This is possibly because of increased exposure to advertisement, convenience foods, food away from home, more diverse cuisines, and larger supermarkets dominated by multinational corporations (Milford et al., 2019; Interviewee G2, 2025; Interviewee G3, 2025). Increased female participation in the workforce has also been linked to increases in meat consumption, also possibly because of increased uptake of convenience foods (Milford et al., 2019). Milford et al. (2019) also found globalisation to influence meat consumption, though the ways in which it has an impact are diverse. They found a positive association of 'social' globalisation with meat consumption, whereas they found a negative association of 'economic' globalisation with meat consumption. They define social globalisation to encompass increased social and cultural global connections, whereas economic globalisation concerns mostly increased global trade.

2.2.2 Database selection

Various data sources were searched for applicable indicators that could be adopted to describe (part of) the conditions reported in section 2.2.1. The sources had to be publicly available, cover data from after 2020 that could speak to conditions influencing PCTs, and be available for all EU member states. A list of the considered databases can be found in Appendix D.

2.2.3 Selected indicators

The final selection of indicators was made based on the combined insights from section 2.2.1 and 2.2.2. Ruiz-Almeida and Rivera-Ferre (2019, p. 1324) use a structure with three tiers for developing indicators in their research: categories, subcategories and indicators. Three tiers were also used in this thesis (see Table 2.1), named dimensions (spheres of influence on people's consumption), conditions (the conditions at play within these dimensions that influence consumption) and indicators (the concrete indicators that can represent the conditions or parts of them). The dimensions align with the dimensions reported on in subsection 2.2.1: the individual level, situational level, and macro environment. The indicators and their data sources that were chosen to represent conditions within these dimensions are presented in Table 2.1.

Table 2.1. The selected indicators representing conditions categorised in three different dimensions. 'Direction' indicates whether a higher or lower value is favourable for protein consumption transitions. The 'Explanation' offers an elaboration of what the indicator entails, and the last column 'Source, time point' offers the database from which the data was sourced.

Dimension	**Condition**	**Indicator**	**Direction**	**Explanation**	**Source, time point**
Individual	Capability	Knowledge [%]	↑	Share of people that think eating meat less often is healthy and sustainable.	Eurobarometer, 2020
		Food expenditure stress [%]	~	Share of household final consumption expenditure spent on food and non-alcoholic beverages.	Eurostat, 2022
	Motivation	Motivation [%]	↑	Share of people that are ready to spend more for food which protects their health and the planet.	Eurobarometer, 2020
Situational	Social environment	Vegetarian protein uptake [%]	↑	The increase in the supply quantity of vegetarian protein divided by the increase in the supply quantity of animal protein.	FAOSTAT, 2013-2022
	Affordability	Vegetable price increase [%]	↓	The relative increase of price of vegetables as compared to total foods.	World Bank ICP, 2017-2021
		Meat price increase [%]	↑	The relative increase of price of meat as compared to total foods.	World Bank ICP, 2017-2021
		Meat price [%]	↑	The relative price of meat compared to total food.	World Bank ICP, 2017-2021
Macro Environment	Urbanisation	Level of urbanisation [%]	↓	The share of the national population residing in cities.	FAOSTAT, 2023
	Consumption culture	Total protein consumption [g/cap/day]	~	The total protein supply quantity.	FAOSTAT, 2022

Within the individual dimension, three indicators were selected. The indicator *knowledge* represents the percentage of people that answered the question 'What do you think eating a healthy and sustainable diet involves?' with 'eating less meat', possibly among other answers (Eurobarometer, 2020). The indicator *food expenditure stress* shows the percentage of the household final consumption budget that is spent on food (Eurostat, 2022). The indicator *motivation* represents the percentage of people that are ready to pay more for food that protects their health and the planet (Eurobarometer, 2020). Higher values for *knowledge* and for *motivation* are favourable for PCTs. The degree of food expenditure stress influences PCTs in different ways, as higher *food expenditure stress* will likely decrease meat consumption, though nutritional concerns in protein consumption could be more prominent with higher values here.

Regarding situational factors, four indicators were selected. As discussed in section 2.2.1.2, social environments are considered highly influential when it comes to meat consumption behaviour. For this reason, the uptake of vegetarian protein was selected. This indicator is calculated as the increase in the supply quantity of vegetarian protein [g/cap/day], relative to the increase in the supply quantity of animal based protein [g/cap/day] in the years 2013-2022 (FAOSTAT, 2024). A higher *vegetarian protein uptake* is considered favourable for social situational conditions. The other indicators in this dimension represent affordability in different ways. The first of these is the relative price increase [%] of vegetables compared to total food in the years 2017-2021 (World Bank Group, 2021). This was done to represent the affordability of healthy foods which are not meat, a lower value represents favourable material conditions. The value for price is based on price-level index (FAO, 2022). The relative price increase [%] of meat compared to total food in the years 2017-2021 was also taken as an indicator (World Bank Group, 2021). Furthermore, the relative price of meat compared to total food at the most recent time point (2021) was also included as a static indicator (World Bank Group, 2021). These last two were both included to represent the affordability of meat, a higher value represents favourable material situational conditions.

Regarding the macro environment, two indicators were included. Firstly, the percentage of the total population that resides in a city was included to represent urbanisation (FAOSTAT, 2024). A lower *level of urbanisation* is favourable for PCTs. Secondly, the total protein supply quantity [g/cap/day] was included as well (FAOSTAT, 2024). The value for this may not be directly interpretable as favourable or unfavourable, but shapes the form that a PCT should take.

2.3 Research steps

This section describes the research steps which were performed to produce the results of this thesis. The framework described in section 2.2.3 was applied, a cluster analysis was performed based on the member state performances on this framework, and the clusters which emerged were characterised.

2.3.1 Application of the framework

Data from the designated sources were retrieved to assess EU member states based on the developed framework (see Table 2.1). This was done to create an overview of the degree of progress on conditions influencing PCTs. All data were collected and accessed in March and April 2025.

2.3.2 Cluster analysis

The member states were grouped using an agglomerative hierarchical cluster analysis (AHCA), inspired by a similar analysis (Oteros-Rozas et al., 2019). This type of clustering is particularly suitable for multidimensional data that may have clusters of varying shapes and sizes (Everitt et al., 2011). The fifth edition of 'Cluster Analysis' by Everitt et al. (2011) was consulted for constructing a sound methodology for this part of the research.

AHCA entails firstly calculating the dissimilarity between the data collected of the member states. These dissimilarities are assessed and the two member states with the lowest dissimilarity between them are joined as a cluster. The dissimilarities between the member states and this newly formed cluster are then recalculated. Based on this, another cluster is formed from the member states with the smallest dissimilarity. This is repeated until all member states are contained by a single cluster. By assessing this process, one can determine the most fitting cluster formation. This process entailed five main steps:

normalising the data, testing for clustering tendency, calculating dissimilarities, creating a dendrogram, and clustering the member states. (Everitt et al., 2011)

(1) Firstly, the data was normalised using min-max scaling. Since the clustering method depends on distance calculation between data points, varying scales of indicators can distort the clustering, giving disproportionate weights to certain indicators. To mitigate this, min-max normalisation was done. This type of scaling results in every indicator holding data that is scaled to have a minimum value of 0 and a maximum value of 1. Calculating the newly scaled values is done according to [1]:

$$x_{i,j,n} = \frac{x_{i,j} - x_{min,j}}{x_{max,j} - x_{max,j}} \quad [1]$$

Where $x_{i,j,n}$ represents the normalised value for the i^{th} member states for the j^{th} indicator, $x_{i,j}$ represents the original datapoint, and $x_{min,j}$ and $x_{max,j}$ represent the minimum and maximum value in the dataset for the j^{th} indicator respectively. This method ensures that all data are scaled to the same range, and that the distributions of the data per indicator remain the same.

(2) Cluster analysis should reveal clusters based on existing patterns in the data, rather than artificially creating groups out of data. However, because the analysis will offer clusters regardless of whether meaningful patterns exist, it is important to assess whether the data is suitable for clustering (Everitt et al., 2011). The Hopkins statistic is usually employed for this purpose. It provides a statistic between 0 and 1, where the higher the statistic, the higher the clustering tendency. (Hopkins & Skellam, 1954)

(3) After the data was normalised and the clustering tendency evaluated, dissimilarities between member state could be calculated. In order to reveal meaningful clusters in the data, the extent to which some member states are similar and others are dissimilar was calculated. This level of dissimilarity was calculated for all pairs of member states with a measure of Euclidean distance using the Ward method (Ward, 1963). E.g. for member state A and B, the dissimilarity ($dis_{A,B}$) is calculated [2]:

$$dis_{A,B} = \left[\sum_{k=1}^{p} (x_{A,k} - x_{B,k})^2\right]^{1/2} \quad [2]$$

Where $x_{A,k}$ and $x_{B,k}$ are the normalised values for the k^{th} indicator of the p total indicators for member state A and B respectively. The resulting values for the dissimilarities between member states are stored in a square matrix with the member states on both axes.

(4) The dissimilarity matrix provides the information needed to visualise a dendrogram. This dendrogram provides insight into the distances between clusters. It presents a tree-like structure in which one can see the distance between clusters depending on how many clusters are defined. This structure therefore helps in choosing the number of clusters and shows the embeddedness of other smaller clusters.

(5) Based on this dendrogram, the number and composition of the clusters was defined.

To perform these steps, a python code was written which is attached in Appendix E.

2.3.3 Characterisation

To achieve the last objective, the clusters that were formed according to the developed framework were investigated. An approach inspired by research by Velthuis et al. (2024) was adopted for describing narratives for the clusters that had emerged. Profiles were made for the different clusters, based on the common characteristics in the expression of the indicators within clusters, as well as in comparison with the other clusters.

2.4 Validation

For validation of the framework, some checks were performed. The cluster analysis was performed leaving out every indicator, one at a time. This allowed a comparison of the formed clusters based on the framework, and the sensitivity of this method to the indicators in isolation. Besides min-max normalisation, z-score normalisation was also performed to see if this would result in notable differences (Kappal, 2019). Besides AHCA, k-means clustering was also used to check the sensitivity to this type of clustering. Different types of linkage besides 'Ward' in the AHCA were also tested.

In performing the AHCA, principal component analysis (PCA) was used to reduce the multidimensional data for the purpose of visualising the clusters. This allowed for visual inspection and for validation of the results of the cluster analysis (Everitt et al., 2011).

2.5 Positionality

This section concerns my perspective as the main researcher of this thesis, and as a student in Industrial Ecology. In systemic change and transitions, I think responsibility and potential never lies in just one place. I consider there to be agency in all parts of the (agrifood) system, which means I do adhere to the idea that the consumer shares in responsibility. However, so do governments and so do producers and other agents in agrifood systems, and all of these agents can influence each other. There is not one specific agent who caused these systemic and embedded issues, though all agents will have to deal with them and decide to have the agency and the urgency to do so. This is why I think it is worthwhile to look at consumption and the factors that influence consumption, but to also do this in a holistic way. Considering not only that which focuses on individuals, but also those things which are more socially and systemically constructed.

Furthermore, my thesis discusses consumption within a large geographical and social context, namely that of the EU. I myself do not have experience in the multitude of contexts and the many people that this thesis in theory covers and includes. I have gone through this thesis reminding myself regularly of this fact, and have aimed to include ways in which the findings and analysis could be questioned and enriched. I aimed to approach this research in an open-minded manner, while maintaining some voice, direction and perspective of my own.

Chapter 3. Results

This chapter reports on the findings of this thesis. Firstly, the expression of the developed indicators in EU member states are presented. Following this, the clusters that were made based on the indicator performances are reported and characterised.

3.1 Applied framework

The performance of all EU member states on the nine indicators is displayed in Figure 3.1. The data can also be viewed in the table in Appendix F. The red dotted lines in the figures show the average values in the EU. This EU average was calculated per indicator by weighing all the member state performances for that indicator with their corresponding populations. The population in the year 2023 was used, corresponding to the most recent data point in the indicators (Eurostat, 2023). Performances will be discussed per dimension.

The indicator for *knowledge* on the sustainability and healthiness of meat consumption yields an average value of 35% for the EU. The majority of EU member states (16 out of 27) show a lower value, the lowest of which is 16% for Croatia, Estonia and Latvia. The highest value for *knowledge* is 54% for Denmark and Germany. The indicator *food expenditure stress* showed 14% on average for EU citizens, ranging from 9% for Ireland to 25% for Romania. Most of the newer member states (who joined after 2004) have a higher than average value for *food expenditure stress* (except Cyprus, Malta, and Slovenia). *Motivation* revealed an average percentage of 75% of EU citizens to be ready to spend more for food that protects them and the planet. Member states ranged from 60% (Bulgaria) to 90% (the Netherlands), except for Portugal which had a performance of 50% for this indicator.

For *vegetarian protein uptake*, only seven member states showed a positive value. The average *vegetarian protein uptake* was -10% for the EU, indicating the increase in supply quantities of vegetarian protein to be 10% less than that of animal based protein. The lowest value for this indicator was -51% in Estonia, and the highest value was 19% in Sweden. *Vegetable price increase* yielded an average of 9%, indicating that vegetable price has increased 9% more than total food price. Only two member states had a negative value (Ireland and Malta). The lowest value was -1% for Ireland and the highest value was 24% for Luxembourg. For *meat price increase*, the EU average was -5%, ranging from -19% for Denmark to 0% for Germany. For these two price increase indicators it is important to stress that for all member states the vegetable price has increased more than other foods (with the exception of Ireland and Malta), whereas the meat price has increased less than other foods (with no exceptions). For most member states, relative *meat price* compared to the price of all food was negative. The EU average for the *meat price* was 3%. The lowest value was -19% for Denmark, and the highest was 18% for France.

The *level of urbanisation* in the EU showed that 40% of EU citizens reside in cities, with the majority of member states being less urbanised. Luxembourg is the least urbanised at 18%, and Cyprus is most urbanised at 62%. *Total protein consumption* in the EU was on average 113 g/cap/day, with a minimal value of 79 g/cap/day in Slovakia, and 139 g/cap/day in Ireland. The six original EU member states all had higher than average *total protein consumption* except for Germany, whereas most of the newer member states have lower *total protein consumption*.

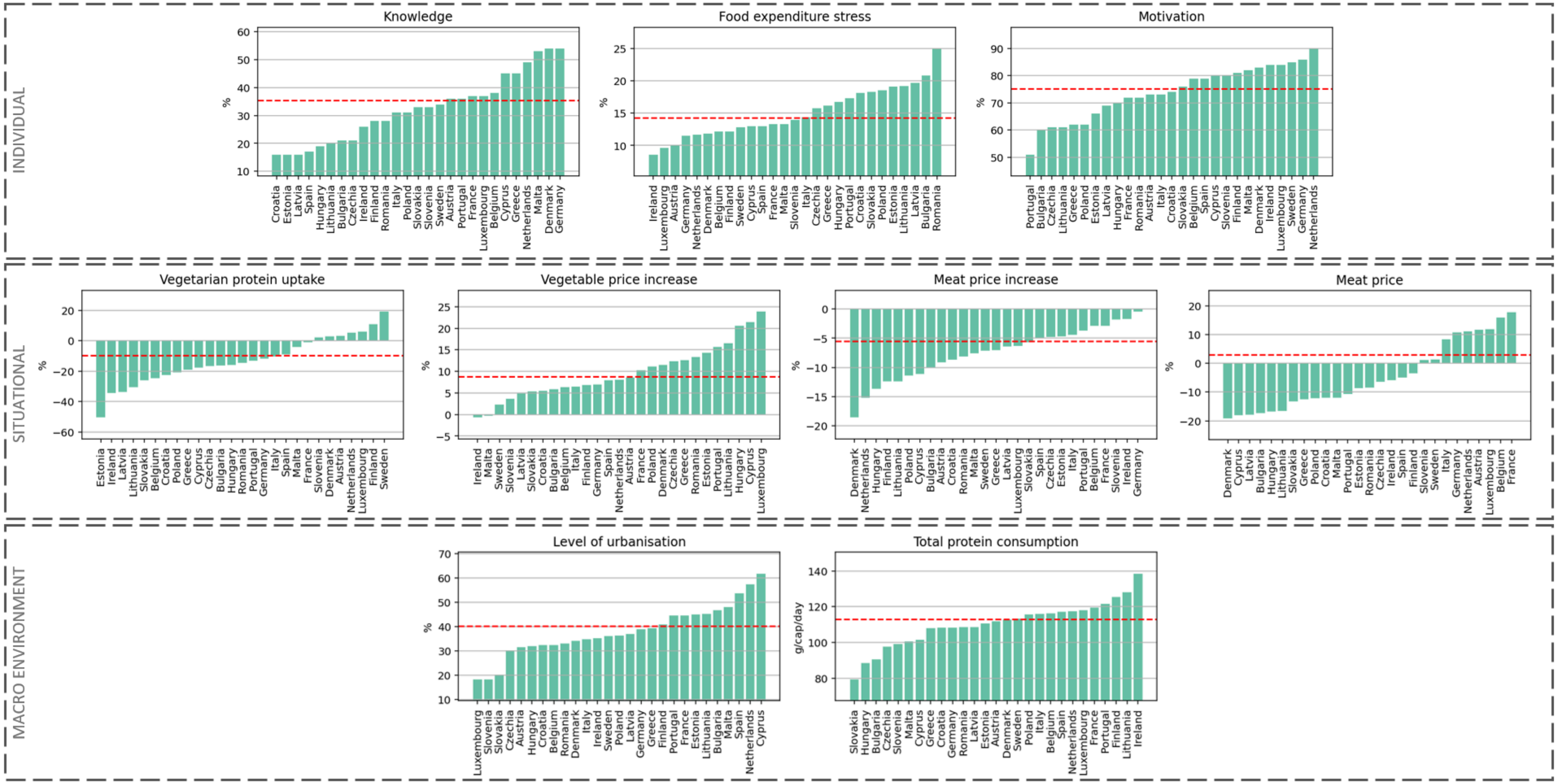

Figure 3.1. Performances on the nine indicators per EU member state. The indicators are ordered according to the dimension as defined in section 2.2.3. The data for the member states within each subfigure are sorted from the lowest value to the highest value. The red dotted line shows the EU average for each indicator, calculated using the 2023 (national) populations as reported by Eurostat (Eurostat, 2023).

3.2 Cluster analysis

The clustering tendency of the EU member states based on the indicators was tested with the Hopkins statistic. The statistic yielded a value of 0.575.

The dendrogram that was produced in order to perform the AHCA can be viewed in Figure 3.2. Based on visual inspection of this dendrogram, a categorisation into three clusters was deemed most suitable. The dendrogram shows which member states are then clustered together, and also which embedded cluster distributions could be revealed within the three identified ones. The three formed clusters are displayed on the map in Figure 3.3. Two of the three clusters are geographically coherent, where most Eastern European member states have emerged to be part of cluster 1, and most Western/Northern European member states part of cluster 3. All member states in cluster 1 except for Greece are EU member states which joined the EU relatively recently, in 2004 or after. Cluster 2 consists of four member states that are more geographically dispersed.

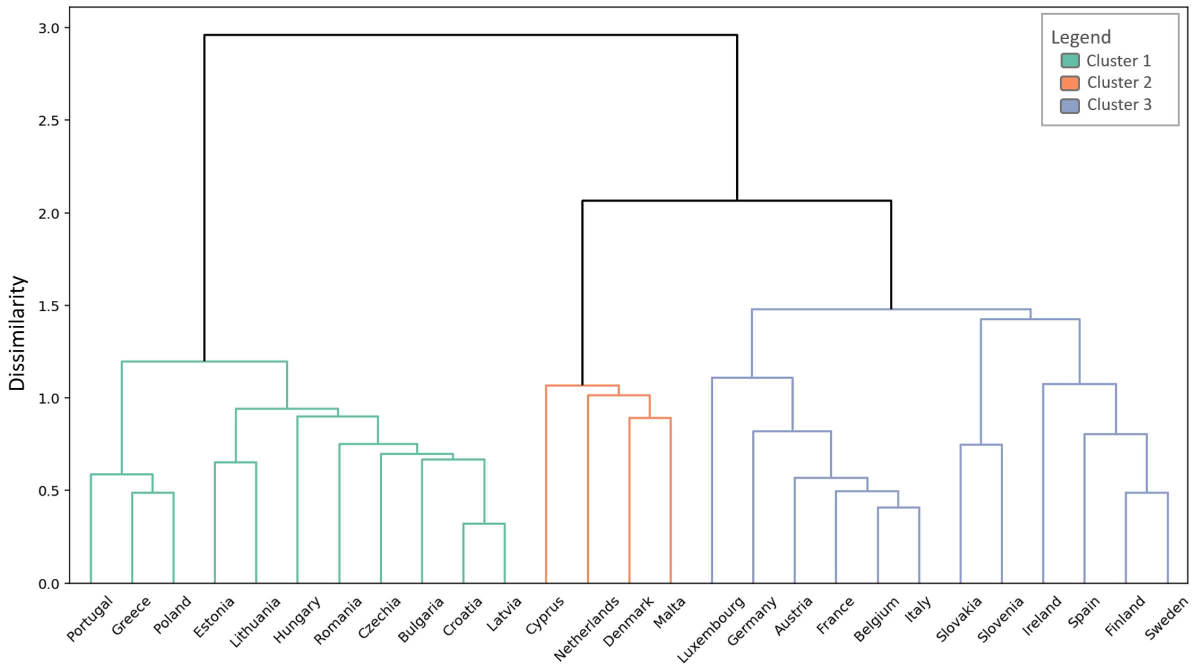

Figure 3.2. Dendrogram visualising the degree of dissimilarity between the member states on different levels of clustering.

3.3 Characterisation

The performances of the emerged clusters were analysed, and based on the common features of the clusters regarding the indicators, a characterisation was made (see Table 3.2). The distribution of indicator performances per cluster is visualised in the boxplots in Figure 3.4. The performance per member state, sorted by cluster can also be seen in Appendix G, as well as average values and standard deviations per cluster, weighted with their corresponding population sizes.

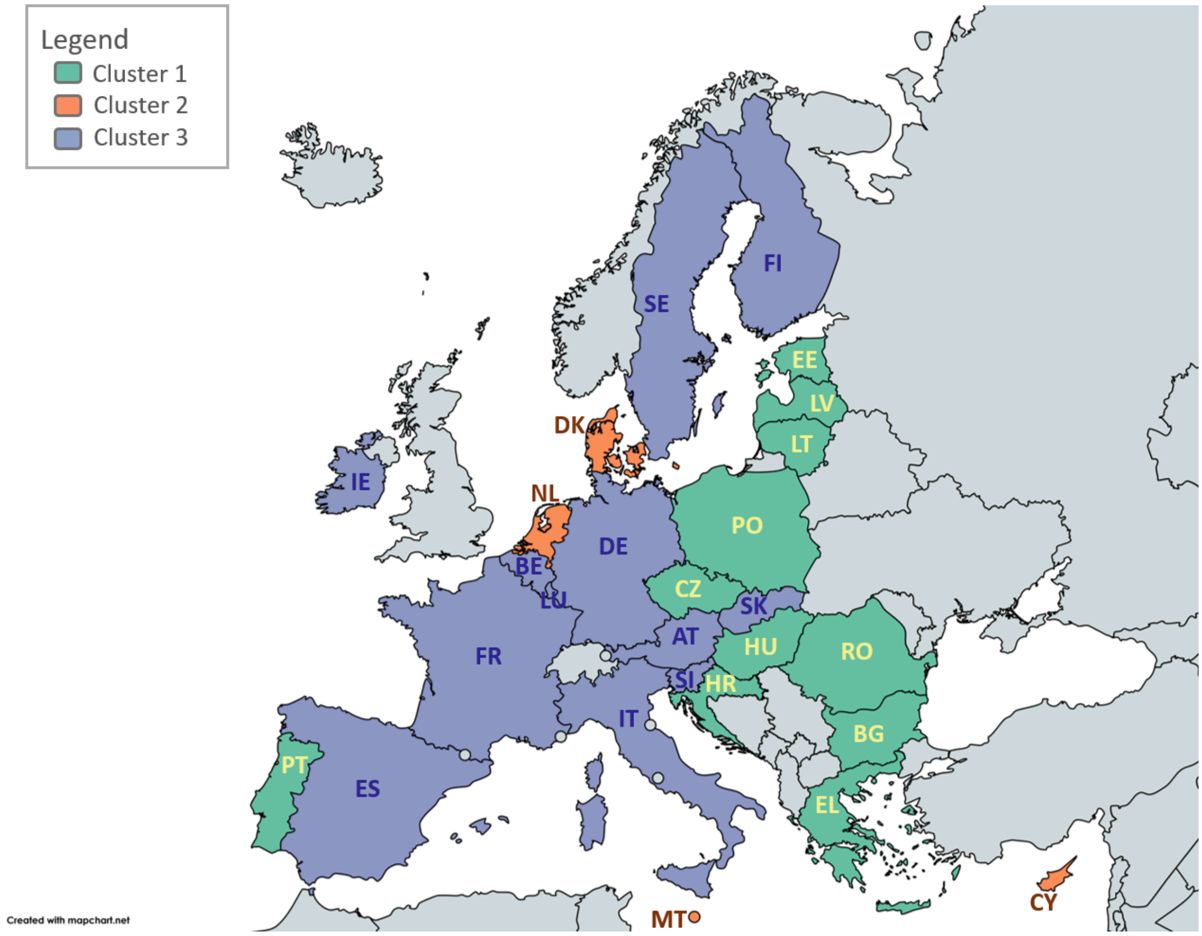

Figure 3.3. The EU member states coloured according to cluster.

Table 3.2. The three clusters and their main characteristics.

Cluster	Description
1. Systemic constraints for consumption (11 countries, 25.4% of EU population)	On an individual level, people generally face higher financial constraints to their consumption, and *knowledge* and *motivation* are lower in comparison with the other clusters. Meat is relatively affordable compared to total foods, whereas vegetables are relatively expensive. The *vegetarian protein uptake* is also unfavourable compared to the other clusters, representing a social barrier.
2. Urban and fiscally unfavourable (4 countries, 5.6% of EU population)	There are barriers rooted in all indicators representing affordability (though the ranges are big). This cluster also has a relatively high *level of urbanisation*, making challenges associated with urban consumption environments more prominent.
3. Misinformed and protein plenteous (12 countries, 69.0% of EU population)	Though *motivation* is relatively high, its values for *knowledge* lag behind as compared to cluster 2. *Total protein consumption* is slightly higher for most countries in this cluster.

3.3.1 Cluster 1: Systemic constraints for consumption

The first cluster consists of Bulgaria, Croatia, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Portugal, and Romania. This is eleven member states in total, representing 25.4% of the total population in the EU as of 2023 (Eurostat, 2023). As illustrated in the boxplot in Figure 3.4, this cluster has high internal similarity for some indicators, and low internal similarity for others. The indicators this cluster has high internal similarity for, are *food expenditure stress*, *vegetarian protein uptake*, *meat price* and *level of urbanisation*, whereas the internal similarity is relatively low on *knowledge*, *motivation*, and *total protein consumption*. The cluster will be described here through the expression of the indicators according to the three dimensions of the framework: individual, situational, and macro environment, as described in section 2.2.3.

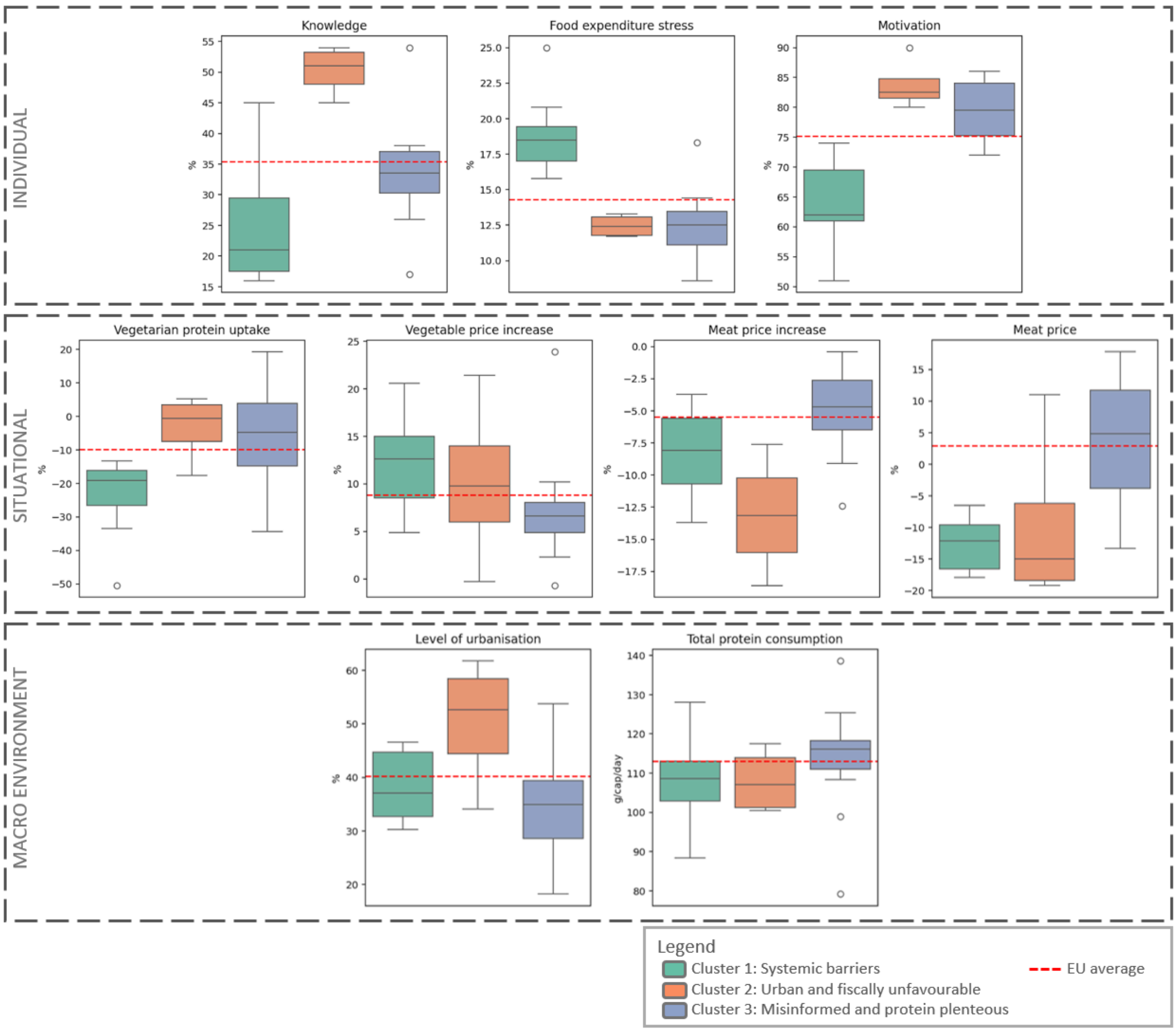

Figure 3.4. Distribution of the indicator performances per cluster. The indicators are ordered according to the dimensions as defined in section 2.2.3. The circles represent outliers within a cluster. The red dotted line shows the EU average for each indicator, calculated using the 2023 (national) populations as reported by Eurostat (Eurostat, 2023).

The performance of the indicator *knowledge* was in general low for cluster 1, with a median value of 21%. The range within this cluster is still relatively large, as the highest percentage in the cluster is 45% (Greece). Almost all member states which have a higher performance for *food expenditure stress* than the EU average are in cluster 1 (see Figure 3.1). The *food expenditure stress* ranges from 16% to 25%. Cluster 1 has relatively low percentages for *motivation*, with the nine lowest scoring member states being part of this cluster. The values within this cluster do span from 51% to 74%. This entire range is still lower than the EU average of 75%.

Cluster 1 has a relatively low score for *vegetarian protein uptake* (median of -19%). The range within the cluster for the price increase indicators is rather large. The *vegetable price increase* is slightly higher than the other clusters, though the *meat price increase* is relatively low. The static *meat price* in comparison to other foods is more uniform than the price increase indicators, and is relatively low for this cluster (median value of -12%).

Lastly, regarding the macro environment, the *level of urbanisation* in cluster 1 is generally moderate. Most member states in this cluster are less urbanised than the EU average. The majority of the member states in cluster 1 also have a lower than (EU) average *total protein consumption*, with a range of values from 88.4 (Hungary) to 128.1 (Lithuania) g/cap/day.

This cluster was named 'systemic constraints for consumption' as the relative barriers to PCTs that were identified cover different aspects of the framework. The dissimilarities between cluster 1 and the other two clusters are most apparent in the individual dimension. People generally face higher financial constraints to their consumption, and *knowledge* and *motivation* are lower in comparison with the other clusters. Meat price increases less, and vegetable price increases more than other foods. The static *meat price* is also low, and so affordability of meat is relatively high. The *vegetarian protein uptake* is also unfavourable compared to the other clusters, representing a social barrier.

3.3.2 Cluster 2: Urbanised and fiscally unfavourable

Cluster 2 consists of Cyprus, Denmark, Malta, and the Netherlands. For these four member states that represent 5.6% of the EU population, the expression of especially the individual indicators is internally similar (Eurostat, 2023). The situational indicators are less internally similar, particularly those relating to price levels. Regarding the macro environment, the *total protein consumption* is relatively internally similar, the *level of urbanisation* less so (see Figure 3.4).

Starting with the individual dimension, both *knowledge* and *motivation* are generally high in cluster 2 compared to the other clusters, with a median value of 51% for *knowledge* and 82% for *motivation*. All member states included in cluster 2 have higher performances on both of these indicators than the EU averages. On the contrary, they all have lower performances on *food expenditure stress* than the EU average.

Regarding situational factors, the performance for *vegetarian protein uptake* is relatively high for cluster 2, though the values span from -18% (Cyprus) to 5% (the Netherlands). Cluster 2 also has a large range for *vegetable price increase* (the second highest and second lowest value for this indicator are found in this cluster, belonging to Cyprus and Malta respectively). The *meat price increase* as well as the static *meat price* also show a large range, but with values that are generally more uniformly low.

As for the macro environment, cluster 2 generally shows a higher *level of urbanisation* with a median value of 53%. Three out of the four highest performing member states on this indicator belong to this cluster (see Figure 3.1). The *total protein consumption* is relatively moderate in relation to the EU average and the other clusters.

The title of this cluster is 'urbanised and fiscally unfavourable', which refers to the particular barriers it faces. It is characterised by relatively favourable conditions relative to the other clusters. However, there are barriers rooted in the affordability of vegetables and of meat in comparison to other foods (though the ranges are big). Furthermore, this cluster has a relatively high *level of urbanisation*, making challenges associated with urban consumption environments more prominent.

3.3.3 Cluster 3: Misinformed and protein plenteous

The last cluster consists of Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Slovakia, Slovenia, Spain, and Sweden. These twelve member states, representing a large majority of the EU population (69.0%), showed high internal similarity regarding the individual indicators and the indicators relating to price increases (Eurostat, 2023). Generally though, the ranges are rather large and there are outliers in this cluster for five out of the nine indicators (*knowledge, food expenditure stress, vegetable price increase, meat price increase,* and *total protein consumption*).

As for the individual dimension, performance on the *knowledge* indicator for cluster 3 was moderate as compared to the other clusters and the EU average. The *food expenditure stress* was relatively low, with almost all member states in this cluster having lower values than the EU average (see Figure 3.1). *Motivation* was relatively high, with the median value being 80%.

Regarding the situational indicators, most member states in cluster 3 showed relatively higher values for *vegetarian protein uptake* than the EU average, though three member states showed particularly low values (see Figure 3.1). This caused the moderate overall performance and large range visible in Figure 3.4. The *vegetable price increase* was relatively low as compared to the EU average, though still positive (median value 7%). *Meat price increase* was relatively high for this cluster compared to other clusters, but the value was still negative (median value -5%). Static *meat price* is also relatively slightly high in cluster 3 compared to the other clusters.

Lastly, *the level of urbanisation* is generally lower in cluster 3 than in the other clusters, though with a large range. *Total protein consumption* is relatively higher, with most member states in cluster 3 having higher values than the EU average.

This cluster was named 'misinformed and protein plenteous', for its performance on the indicators of *knowledge* and *total protein consumption*. Though *motivation* is relatively high in this cluster, its values for *knowledge* lag behind. Moreover, *total protein consumption* is slightly higher for most member states in this cluster. Lastly, it has relatively favourable conditions in affordability, as the relative *vegetable price increase* is lower than in other clusters, the *meat price increase* is slightly higher than in other clusters, and the static *meat price* is also relatively high.

Chapter 4. Discussion

This discussion firstly provides an interpretation of the results, followed by reflections on the framework and clustering approach.

4.1 Discussion of results

The findings of this thesis offer some interesting starting points for discussion. The performances of the EU member states on the indicators have yielded an overview of conditions influencing PCTs in the EU. Notably, the willingness to pay more for food that protects one's health and the planet is quite high, on average 75% in the EU. Only 35% of EU citizens consider eating sustainably and healthily to encompass eating less meat. Research has quite consistently pointed out that the main reason for people to eat less meat, is for reasons relating to health (Guadarrama, 2023; Hoek et al., 2017). These two indicators do not cover the same ground exactly, but it would seem that an increased association between healthiness/sustainability and decreased meat consumption has high potential for enabling PCTs. The situational factors assessed in this thesis do not yet provide favourable conditions to reducing meat consumption. Overall, the uptake of vegetarian protein as compared to animal based protein in the EU is negative. Regarding affordability, the average *meat price* is slightly higher than total foods, but the price level is increasing less than total food prices, meaning that meat is becoming relatively cheaper. Meanwhile, vegetable price values increase relatively more than total food price in almost all member states. The general *level of urbanisation* of around 40% shows a significant part of the EU population lives in cities. Interventions targeting convenience foods, urban food culture and marketing may be particularly relevant in these urban contexts. The *total protein consumption* shows a culture of high protein intake. A daily intake of 0.83 g per kg body weight per day is estimated to cover virtually all the requirements of the population, which would mean that the average European would have to weigh 136 kg if they would heed this advice and arrive at 113 g/day of protein consumption (Mariotti, 2016, p. 14). This also has implications for how to intervene, as targeting overconsumption and absolute meat reduction could be prioritised over development of additional alternatives in some contexts.

Three clusters emerged from the data, leading to the identification of three narratives; 'systemic constraints for consumption', 'urban and fiscally unfavourable', and 'misinformed and protein plenteous'. There is a geographically coherent distribution to the clusters that emerged, to which cluster 2 seems to be an exception. This implies there is some spatial pattern in which the selected conditions influencing PCTs tend to be expressed in the EU currently.

Member states in cluster 1 generally have higher financial constraints to their consumption. In combination with those individual constraints, affordability of meat is relatively high, and the willingness to pay for healthy and sustainable food is lower than in the other clusters. Additionally, the share of people that think that eating meat less often is healthy and sustainable is relatively low in cluster 1.

Cluster 2 showed more favourable conditions than the other clusters regarding individual factors, but faces relatively high barriers to PCTs in their level of urbanisation and in the affordability of meat.

Member states in cluster 3 have relatively more favourable conditions for PCTs when it comes to affordability, but total protein consumption is relatively high in this cluster, and the share of people that associate healthy and sustainable food consumption with eating meat less often is rather low.

The clustering tendency is relatively weak. This does not mean that the clusters discussed here are fictional, as the clusters that have emerged do share similar characteristics. Rather, for some indicators the clusters are very internally similar and dissimilar to the other clusters, whereas for other indicators this pattern is less strong or not really observable at all. Within clusters, salient differences are sometimes present because of this. For example, Luxembourg and Ireland both are categorised under cluster 3, but have values on the far ends of the *vegetable price increase* indicator.

4.2 Framework

The framework this thesis was built on and the limitations associated with it will be discussed in this section. Spiegelhalter and Riesch (2016) describe five levels of uncertainty in modelling. These five levels cover uncertainty about (1) events that may (not) occur, (2) parameters within models, (3) model structures, (4) model inadequacy from recognised sources, (5) model inadequacy from unspecified sources. The first three levels cover aspects within model structures, whereas the last two discuss inadequacies of the modelling process itself. These levels of uncertainty are considered relevant to the developed framework in this thesis, and will be used to discuss the framework.

4.2.1 Level 1

The first level of uncertainty as discussed by Spiegelhalter and Riesch (2016) relates to uncertainty about things that may occur that could change the degree of applicability of models to a real world system. Regarding the developed framework, this relates to unpredictability about events that may occur that may change the conditions that influence PCTs, or the way in which these conditions influence PCTs. The framework is limited to the current body of knowledge on conditions influencing PCTs. Additional research on the effects of the indicators on consumption, on determining the most appropriate indicators for relevant conditions, and on validation of the findings of this thesis, can help in reducing this level of uncertainty.

4.2.2 Level 2

The second level of uncertainty relates to parameters in a model and the degree to which they represent that which they are meant to represent. All indicators chosen in this thesis are imperfect representations of reality. This is more so the case for some indicators over others. For example, the indicator relating to social situational factors is meant to proxy the degree of social acceptability and influence of eating vegetarian foods. The indicator is calculated as the uptake of vegetarian protein supply as compared to the uptake of animal based protein supply. If vegetarian protein supply quantities were already high, this is not clear from this indicator. The indicator was selected as I did consider it to provide insight into the condition, but there are apparent limitations to how much can be deduced from this about social conditions for protein consumption. Most indicators have limitations of some sort in representing the actual conditions. Further research could focus specifically on uncovering or developing more accurate indicators, and on defining the expected limitations of individual indicators in how they influence PCTs.

4.2.3 Level 3

The third level that Spiegelhalter and Riesch (2016) describe relates in this thesis to uncertainty about the knowledge on the conditions influencing PCTs for people in the EU. A general concern on this level is that food consumption behaviour is highly complex, and contingent on all types of factors. The aim for this thesis was of course to shed light on these factors, but the degree to which we have knowledge on that which shapes protein consumption in different cultural contexts should be questioned. The following three paragraphs present three discussion points that relate to this level of uncertainty.

The framework that this thesis is based on is grounded in existing knowledge on conditions that affect PCTs, but the indicators in this framework have not been validated. The limitations of the underlying work equally are limitations of this thesis. Future research could investigate the correlation between the conditions that are represented in this thesis (and perhaps more or others), and the actual state of meat consumption and PCTs in EU member states. It could dive deeper into strategies that are already being employed by different governments and other entities, which conditions these strategies aim to target, and if these strategies are effective in influencing the conditions as well as actual meat consumption. It would be particularly interesting to combine this with the insights on the various clusters that this thesis presents. Member states within clusters have similar conditions, and may benefit from similar strategies.

The conditions included in this research are considered and reported as separate conditions. In reality, they are not completely independent. They may have factors in common that shape them, and they may shape one another. For example, price and affordability affect people in different ways. People with low income generally are more conscious of value and price than people with higher income (Einhorn, 2021; Špička et al., 2021). Price also generally has a larger impact on consumption behaviour in low-income countries as compared to high-income countries (Green et al., 2013; Špička et al., 2021). This could indicate that less favourable conditions when it comes to the indicators relating to affordability, are exacerbated by less favourable individual financial conditions. This is the case for cluster 1 where meat price is decreasing in comparison to total foods, and the food expenditure stress is relatively high. This does not pose a problem in this thesis, as the exact results of the indicators on PCTs are not determined. Further research could aim to estimate the degree of influence of the indicators on PCTs, and the way in which they may influence each other. This would help in defining which conditions are most salient and in which ways the conditions may strengthen or weaken this influence in combination with each other. An interesting study on the effect of educational attainment and income illustrates how this could be done (Mata et al., 2023).

Generally, the way in which conditions affect people in different socio-economic groups is understudied (Einhorn, 2021; Mata et al., 2023). People with relatively low income and educational attainment are generally underrepresented in current literature and literature included in this thesis also has a stronger base in Western European countries (Srinivasan et al., 2024). Other subpopulations may also be underrepresented in studies.

Conditions that are particularly relevant for underrepresented people may have been given less attention in this thesis because of this. As emphasised before, food consumption cultures can differ greatly for subpopulations, regions, etc. This could mean that relevant conditions for people with higher stakes in healthy PCTs are not included, or perhaps nuances on conditions are not sufficiently understood. Future research directions to abate this lack in knowledge, may be to research conditions affecting PCTs, specifically for previously underresearched subpopulations, regions, and countries. Studying the relationship between the indicators in this thesis and actual protein consumption behaviour in different subgroups may also yield insightful results. Evaluating PCTs on subnational levels will remain important as well, as all specifics and nuances about populations and individuals cannot be captured on the scale of this research.

Lastly, there are conditions that are very salient in their potential for enabling or inhibiting PCTs which I could not include as indicators. This concerns conditions such as governmental dietary guidelines (regarding meat and overall protein consumption), lobbying from meat industries, fiscal (dis)incentives for production and consumption, cultural status of meat, perceived social pressure, and food education. These conditions (mostly in the macro environment, but also touching on situational and individual aspects) are reported in section 2.2.1 but could not be included in the framework. As this was done in most cases due to a lack of appropriate data, additional extensive research in finding or creating fitting indicators for conditions could be helpful.

4.2.4 Level 4 and 5

The fourth and fifth level of uncertainty put forward by Spiegelhalter and Riesch (2016) covers uncertainties about the known and unknown inadequacies of modelling. This covers tensions about how this issue should be framed and factors I am aware of but do not have sufficient information on (indeterminancy), and also aspects to this issue of which I am not aware that I do not know about (ignorance). The various indicators draw on data from different sources and different time points. The most recent time point was always taken to most accurately represent the current status of the EU member states for the indicator at hand, which means that the data have been used that were captured at different time points (from 2013-2023). In general, the difference in sources and time points introduces uncertainty on contextual factors that may have influenced the indicators. An obvious contextual factor is the COVID pandemic that was at different stages throughout these time points, which could have affected the indicator performances in expected and unexpected ways. Extensive validation was not part of this thesis, but could be a valuable future research avenue to pursue, as also mentioned in previous sections. Three types of validation that could be valuable were proposed by Bocktaller and Girardin (2003) for validating indicators: (1) design validation, evaluating the scientific foundation of indicators, (2) output validation, assessing the quality of indicator outputs, and (3) end-use validation, assessing if the indicators are useful for decision-making.

4.3 Cluster analysis

The cluster analysis performed in this thesis also has its limitations. A necessary step for the clustering of the used data was normalisation. This had to be done in order to compare dissimilarities on the different indicators. Min-max scaling was used for this, which scales all of the data to the minimum and maximum value in the dataset for the relevant indicator. The distribution of the data stays the same with this method. However, an indicator may yield values with relatively small differences which are stretched out using this method. For another indicator that may hold data with relatively larger differences between member states, the data are scaled in the same way. Through this method, the differences between member states for different indicators become more comparable as they are on the same scale, but relatively small differences for one indicator may be given disproportionate weight in comparison to relatively large differences for other indicators. Min-max scaling is also more sensitive to outliers as compared to z-score scaling for example, but no extreme outliers were identified in the dataset. Overall, min-max scaling was estimated as the most suitable method.

The AHCA with 'Ward' linkage allowed for insight into the cluster structure of the data, and for clusters to emerge with varying shapes and sizes (Ward, 1963; Everitt et al., 2011). A limitation of this type of 'agglomerative' clustering, is that clusters are formed and joined step by step, meaning that once a cluster is formed it cannot be split up later on in the process (Everitt et al., 2011, p. 71). To test for sensitivity of the clustering method, K-means clustering, and clustering with different linkage methods were also performed, which yielded different results. These results were reviewed but made less methodological sense and provided less convincing clusters, confirming AHCA as the more suitable clustering method.

Chapter 5. Conclusion

The research question guiding this thesis was the following: What are current conditions influencing protein consumption transitions in the EU? A framework with nine indicators representing relevant conditions was developed in order to assess EU member states' performance on these conditions. After assessing EU member states' performance on the indicators, a cluster analysis was performed to find commonalities across national contexts in the EU. Three clusters were found in the data. Each cluster was characterised and described based on the internal and external (dis)similarities.

This research intended to add to the current literature base by proposing a method for mapping the conditions that influence PCTs in the EU, and by applying this method and constructing an overview of the degree to which these conditions are present. Beyond this, the cluster analysis provided insight into three different patterns in which these conditions are currently expressed in the EU. The member states in these three clusters could use these insights to focus on areas of intervention where most progress may be achieved in facilitating healthy and sustainable protein consumption. Increasing the enabling capacity of the conditions presented in this thesis could be done in many ways, and further policy oriented research could focus on this. Some initial suggestions for improving conditions will be given in the following section.

5.1 Recommendations for practice

The type and nature of any intervention should be carefully considered in order to move to meaningful change. For example, when stimulating the uptake of specific types of alternative proteins, this may lead to short term meat consumption reduction. However, as no or little behavioural change is achieved, dominant food system structures can stay in place (Interviewee G4, 2025; Hoek et al., 2021, p. 617).

Member states in cluster 1, 'systemic constraints to consumption', may generally benefit from a focus on making alternative protein a more well-known and financially attractive option. Interventions enabling PCTs for this cluster may therefore target increasing affordability of alternative proteins and education and dietary guidelines on healthy and sustainable protein consumption.

For cluster 2, 'urbanised and fiscally unfavourable', interventions could be targeted to tackle issues related to urban consumption, such as convenience foods and high exposure to advertisement (Milford et al., 2019). Fiscal incentives for decreasing meat consumption could also be considered for enabling PCTs.

Member states in cluster 3, 'misinformed and protein plenteous', could opt for interventions rooted in education and dietary guidelines on healthy and sustainable protein consumption. This could be directed to encompass knowledge and recommendations on types as well as quantities of protein.

Overall, it could be useful to track the developed indicators, as well as meat consumption over time. As member states within the established clusters have different views and strategies in approaching PCTs, effective strategies could potentially be identified. Some member states have implemented interventions in recent years, such as reform of governmental dietary guidelines in multiple member states, and even the planned introduction of a tax on livestock emissions in Denmark (Sanchez Manzanaro &

Simon Arboleas, 2024; Searchinger & Waite, 2024). Keeping track of the indicators and the state of PCTs in these member states, especially in relation to the others in their corresponding clusters, could provide insights into possible pathways forward.

In the pursuit of PCTs, current nutritional situations and the disproportionate effects on different people cannot be neglected. This thesis assumes the importance of PCTs. Total protein consumption in the EU is relatively high as shown in the results, and many studies have illustrated the need to substantially reduce meat consumption (Willett et al., 2019). However, substantial differences undoubtedly exist on subnational levels. For example, reduced meat consumption in adults with lower educational attainment levels is associated with higher health risks and higher intake of ultra-processed foods, while reduced meat consumption for people with higher educational attainment is associated with a healthier nutritional status (Levasseur et al., 2024). PCTs may in reality have starkly different consequences to individual lives, which should be thoroughly considered when designing interventions.

The high potential for health benefits of low levels of meat consumption should be stressed and used in strategies for PCTs. This consistently seems to be the main reason people choose to reduce meat consumption, but the knowledge on this among consumers is quite low (Eurobarometer, 2020; Guadarrama, 2023; Hoek et al., 2017). These health benefits should be front and centre in strategies for PCTs to unfold in a healthy, sustainable, and just way. The exacerbation of the gap in nutritional status as mentioned before, should be prevented, and health benefits should instead be a collective win.

Lastly, in transforming agrifood systems, consumption cannot be the only domain that is targeted. As Guillaume et al. (2024) concluded: '.. *strong supply-side policies are needed to complement the power on consumers' plates*' (p. 570). Clearly, meat consumption is not a phenomenon existing in a void, and critical examination of production and distribution schemes is crucial as well (Bruckner & Kowas, 2019; Guillaume et al., 2024; Duluins & Baret, 2024b).

Sources

Conducted interviews

Interview #	Type of Organisation/Role	Date
General 1 (G1)	University, researcher	26/02/2025
General 2 (G2)	University, researcher	06/03/2025
General 3 (G3)	Think tank, researcher	21/03/2025
General 4 (G4)	University, researcher	03/04/2025

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Appendix

A. Indicator selection flow diagram

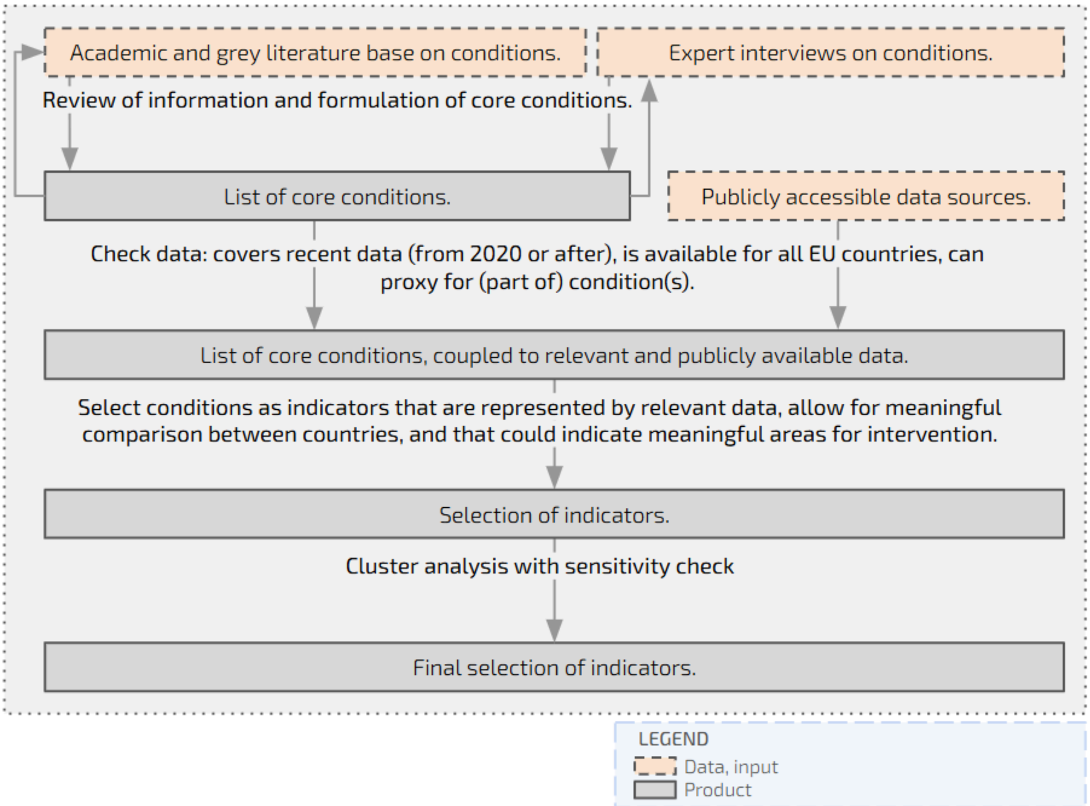

Figure A.1. Indicator selection flow diagram.

B. Interview guide

- Can you tell me about your background and the research that you are working on?
- Can you tell me about what you see as relevant factors that influence sustainable food consumption?
- To what degree do you think this applies to the consumption of meat versus meat alternatives?
- What would you consider the most relevant conditions to the consumption of meat and meat alternatives, what weighs most and why?
- Do you feel particular relevance lies with individual, direct physical or social environment, or macro environment conditions?
- Do you feel there are sides to this research area that are under researched or under represented and can you elaborate on how so?
    - Like for example certain domains or factors influencing consumption?
    - Populations?
- Are there databases/projects/papers that you would recommend to look into?
- Are there other people that you would recommend to speak to?

C. Full list of core conditions

Table C.1 The core conditions influencing protein consumption transitions as found through the literature and interviews reported in section 2.2.1.

DIMENSION	CONDITION	INDICATOR	JUSTIFICATION
Individual	Capability	Knowledge on sustainability	Whether consumers know about the impacts of different kinds of protein consumption on environmental and social sustainability can affect their choices in consumption of meat or vegetarian proteins. In cases consumers have underestimated the environmental impact of animal based products relative to product packaging and food waste. (Srinivasan et al., 2024, p.6)
		Knowledge on healthiness	Knowledge on the healthiness of vegetarian diets is a main reason people opt to eat less meat (Smart protein project, 2023).
		Knowledge on safety	Knowledge that a product is safe for consumption increases their adoption, which is mostly relevant for novel foods and insect proteins. (Myers and Pettigrew, 2018 as cited in Srinivasan et al., 2024, p. 7)
		Knowledge on cooking	Knowledge on how to cook nutritious meals without meat is essential to following a healthy vegetarian diet in societies where people prepare their own meals. (Srinivasan et al., 2024)
		Familiarity	The more familiar people are with alternative proteins, the more willing to purchase and consume they have been, and the other way around. This relates to knowledge on cooking as well. (Srinivasan et al., 2024, p. 9)
		Time for cooking	When more time is spent on cooking, there is more space to cook healthily and sustainably, and consider a variety of options in this. It also implies less convenience foods, which often include animal based products. (Milford et al., 2019)
		Education level	Higher educational attainment is associated with lower the consumption of mainly processed and red meat. (Klink et al., 2022; Mata et al., 2023)
		Food expenditure stress	Higher income levels also provide more agency in consumption and can expand capabilities for food consumption. Increased income is also sometimes related to increased meat consumption, and in general, the link between the two is contested. It is also important to note that vegetarian diets for people with lower income are associated with lower nutritional status, whereas this is the opposite for people with higher income. Though income and expenditure stress are likely a conditions impacting food consumption, this should be interpreted in a holistic way. (Einhorn, 2021; Levassaur et al., 2024; Mata et al., 2023)
	Motivation	Motivation	The degree to which people have certain motivations or values that particularly align with choosing to eat less or no meat influence whether they will choose to do this. (Hoek et al., 2019)
	Demographic factors	Age, gender, religion	Some demographic factors have been found to correlate with different degrees of meat consumption, such as age, gender and religion. These factors are culturally contingent. (Meixner et al., 2024; Grasso et al., 2021; Guadarrama, 2023; Milford et al., 2019)
Situational	Social	Vegetarian uptake	Perceived social pressure, particularly in the household setting has been indicated to form either a barrier to or a facilitator of meat intake reduction (Eustachio Colombo et al., 2021; Grasso et al., 2021). This can be split into social approval of meat based or vegetarian eating patterns, and social influence from these eating patterns. (Hoek et al., 2019; Srinivasan et al., 2024)
		Household composition	Whether a person lives alone, with parents, children, a partner or other housemates, matters for how they are able to consume (De Boer & Aiking, 2019).
		Community based efforts	Community based efforts can provide a base of support for people to shift their diets. This can be through communal initiatives such as a 'meatless monday' or a national meatless week/month, or through get-togethers (MacMillan Uribe et al., 2012; Ramsing et al., 2021).
	Material	Availability of vegetarian meals	Availability and normality of vegetarian options in schools, hospitals, the workplace, etc. makes vegetarian meals more physically accessible, more socially accepted, and can increase familiarity with vegetarian meals. (Hoek et al., 2021)
		Access to vegetarian groceries	The availability of alternative proteins in supermarkets and relevant points of purchase important for facilitating uptake of vegetarian diets, as it directly influences what people can purchase and consume. (Hoek et al., 2021)

		Placement and presentation	Placement of products in supermarkets and relevant points of purchase can influence what people are inclined to purchase, and currently there is a highly unequal playing field here between meat and alternative proteins. (Interview G3, 2025; Hoek et al., 2021)
		Alternatives quality	Alternative proteins with enjoyable taste, texture and smell increase the uptake of these products. A variety in options heps tendering to diverse tastes, and can allow for more similarity to animal based foods . (Srinivasan et al., 2024)
		Price of vegetarian meals	In order for people to have the opportunity to eat vegetarian foods and meals, this has to be affordable to them. People are more likely to try more sustainable foods if they are priced at a lower cost (Hoek et al., 2017; Srinivasan et al., 2024)
		Price of meat	Higher pricing of meat has been associated with lower consumption as less people are able and/or willing to purchase it. (Milford et al., 2019)
Macro Environment	Governance	VAT rates	VAT rates send can cause price premiums for consumers and can signal implicit messaging about which kinds of products are stimulated by governments and which are not. (Springmann et al., 2024; Godfray et al., 2018)
		Subsidies	What is produced and imported and which markets are favoured is influenced through regulations, guidelines and fiscal (dis)incentives (Godfray et al., 2018; Hoek et al., 2021; Korteleve et al., 2024; Poças Ribeiro et al., 2019; Interviews).
		Governmental dietary advice/ guidelines	Formalised guidelines and advice on healthy and sustainable diets set a standard for food consumption. The inclusion of meat in these and the degree to which they are recommended or discouraged sets the stage for healthy/sustainable reference diets. (Cocking et al., 2020 ; Interviews)
		Meat lobby	The livestock sector has political influence and allocates budget for this. Civil society organisations have claimed that this has influenced e.g. dietary recommendations. (Godfray et al., 2018)
		Marketing regulations	The limits to marketing of meat and alternative proteins impacts whether they are able to reach their target audience. Consistent information provision about meat based and vegetarian products and diets is important so people can confidently decide on consumption in a well informed way. (Godfray et al., 2018; Poças Ribeiro et al., 2019; Srinivasan et al., 2024)
	Marketing	Media coverage	Coverage on social media, as well as traditional mass media platforms influences type of protein consumption. (Srinivasan et al., 2024)
		Investment in marketing	Marketing enables the distribution of knowledge on a product as also illustrated by the two previous conditions, and so it enables uptake.
	Urbanisation	Level/rate of urbanisation	More urbanisation has been associated with increased meat consumption. This is theorised to be because of increased uptake of convenience foods, which often include animal based foods. (Milford et al., 2019)
	Globalisation	Economic and social globalisation	Globalisation has been reported to influence meat consumption, though it does so in different ways. Economic globalisation is associated with less meat consumption, whereas social globalisation is associated with more meat consumption. (Milford et al., 2019)
	Education	School programmes	Programmes in lower schools on what healthy and sustainable eating entails can set the tone for what children know to eat later on in their lives. Lessons in some basic cooking skills and recipes that are tasty, nutritious and vegetarian can be very helpful for people to take up healthy vegetarian consumption patterns. (Bruckner & Kowasch, 2019; Hoek et al., 2021)
		Other programmes	Programmes that provide education and training on healthy and sustainable foods, particularly for disadvantaged populations. (Hoek et al., 2021)
		Recipe provision	Recipes for vegetarian cooking provided by governmental organisations/ngo's/other parties. (Mellor et al.,2022)
	Meat consumption culture	Cultural meals	The natural presence of meat in cultural meals, and traditions that include eating meat, make it more difficult to shift away from eating meat. (Hoek et al., 2017; House et al., 2024; Pieniak et al., 2009)
		Total protein consumption	Currently, many countries have consumption patterns that include excessive levels of total protein intake. In these countries, more focus on protein reduction besides substitution could be desirable. (Duluins & Baret, 2024b)
		Natural conditions	Climatology and some natural conditions that are favourable for meat production systems have been associated with higher meat consumption. (Milford et al., 2019)

D. Searched databases

Food and Agriculture Organization of the United Nations (FAOSTAT, n.d.)
- Food balance sheets
- Annual population
- Food based dietary guidelines
- Annual population: share of population urbanised

International Labour Organisation (ILOSTAT, n.d.)

World Bank International Comparison Programme (World Bank Group, n.d.)

Eurostat (Eurostat, n.d.)
- HETUS survey results for time spent
- Population data

Eurobarometer (Eurobarometer, 2020)

Taxes in Europe (Springmann et al., 2024)

Association of Religion Data Archives (ARDA, n.d.)

Smart Protein Project (Guaderrama et al., 2023)

World Population Review (World Population Review, n.d.)

E. Clustering code

```
"""
Author: Liesje Mijnders
Thesis Research Project - Towards sustainable and healthy protein consumption in the European Union
Clustering code
"""
#%% import libs
import pandas as pd
import numpy as np
from sklearn.neighbors import NearestNeighbors
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.cluster import KMeans
from sklearn.decomposition import PCA
import scipy.cluster.hierarchy as sch
from scipy.cluster.hierarchy import fcluster
from scipy.spatial.distance import pdist, squareform

#%% opening the data file
fin = pd.read_excel(r'Data.xlsx')

#%% data selecting
fin = fin.iloc[0:14, 3:32].T
X = fin.iloc[2:29, 1:10]
X.columns = fin.iloc[0, 1:10]
X.columns = X.columns.astype(str)
X.index = fin.iloc[2:29, 0]
X.index = X.index.astype(str)

# min-max normalising
Xnorm = (X - X.min()) / (X.max() - X.min())
Xnorm = Xnorm.astype(float)

# population sizes
population = fin.iloc[2:29, 10].tolist()

#%% determining clustering tendency of the data with hopkins statistic
def hopkins(Xnorm, sampling_size=100):
  Xnorm = np.array(Xnorm)
  n, d = Xnorm.shape
  m = min(sampling_size, n)

  # random sample from actual data
```

```
    np.random.seed(38)
    sample_indices = np.random.choice(n, m, replace=False)
    X_sample = Xnorm[sample_indices]

    # uniform random points in the same range as X
    X_min, X_max = np.min(Xnorm, axis=0), np.max(Xnorm, axis=0)
    X_random = np.random.uniform(X_min, X_max, (m, d))

    # nearest neighbor distances
    nbrs = NearestNeighbors(n_neighbors=2).fit(Xnorm)
    u_distances, _ = nbrs.kneighbors(X_random, n_neighbors=1)
    w_distances, _ = nbrs.kneighbors(X_sample, n_neighbors=2)

    u_sum = np.sum(u_distances)
    w_sum = np.sum(w_distances[:, 1])  # second neighbor (to exclude the point itself)

    hopkins_stat = u_sum / (u_sum + w_sum)
    return hopkins_stat

Hstat = hopkins(Xnorm, sampling_size=100)
print(f"Hopkins statistic: {Hstat:.3f}")

#%% hierarchical clustering using dissimilarity
dissimilarity = squareform(pdist(Xnorm, metric='euclidean'))   # other option is
manhattan/cityblock
dissimilarity_df = pd.DataFrame(dissimilarity, index=X.index, columns=X.index)

dissimilarity_df.columns = fin.iloc[2:29, 0]
dissimilarity_df.index = fin.iloc[2:29, 0]

# condensed version
condensed_diss = squareform(dissimilarity_df)

# agglomerative hierarchical clustering using ward (I also tested single, complete,
weighted, average, but these made less methodological sense and gave less sensical
results as well)
Z = sch.linkage(condensed_diss, method='ward')

# define number of clusters based on dendrogram below
n_clusters = 3
hiclusters = fcluster(Z, n_clusters, criterion='maxclust')
X['Cluster'] = hiclusters
Xnorm['Cluster'] = hiclusters

# dendrogram
plt.figure(figsize=(12, 7))
```

```
sch.dendrogram(Z, labels=dissimilarity_df.index.tolist(), color_threshold=0.68 * max(Z[:,
2]))

plt.xlabel("Country", fontsize=12)
plt.ylabel("Distance", fontsize=12)
plt.tight_layout()
plt.show()

#%% k-means clustering, done to check if the results would be similar
kmeans = KMeans(n_clusters, random_state=42)

# fit the model to the data
kmeans.fit(Xnorm)
kmclusters = kmeans.labels_

# add the cluster labels to the original dataframe (not done because this clustering was not
used)
# X['K-means Cluster'] = kmclusters
# Xnorm['K-means Cluster'] = kmclusters

#%% 2D visualisation, to visually check if the clusters make sense
# principal component analysis, reduce to 2D
pca = PCA(n_components=2)
X_pca = pca.fit_transform(Xnorm)

# 2D visualisation of kmeans clusters
plt.scatter(X_pca[:, 0], X_pca[:, 1], c=kmclusters, cmap='plasma')
plt.xlabel('PCA reduced axis 1')
plt.ylabel('PCA reduced axis 2')
plt.title('Clusters (through K-means clustering)')
plt.show()

#2D visualisation of hierarchical clusters
plt.scatter(X_pca[:, 0], X_pca[:, 1], c=hiclusters, cmap='plasma')
plt.xlabel('PCA reduced axis 1')
plt.ylabel('PCA reduced axis 2')
plt.title('Clusters (through hierarchical clustering)')
plt.show()

#%% 3D visualisation, also to check if the clusters make sense
# reduce to 3D
pca = PCA(n_components=3)
X_pca = pca.fit_transform(Xnorm)

# 3D visualization of kmeans clusters
fig = plt.figure(figsize=(8, 6))
```

```
ax = fig.add_subplot(111, projection='3d')

sc = ax.scatter(X_pca[:, 0], X_pca[:, 1], X_pca[:, 2], c=kmclusters, cmap='plasma')
ax.set_xlabel('PCA reduced axis 1')
ax.set_ylabel('PCA reduced axis 2')
ax.set_zlabel('PCA reduced axis 3')
ax.set_title('Clusters (through K-means clustering)')

plt.colorbar(sc)
plt.show()

# 3D visualization of hierarchical clusters
fig = plt.figure(figsize=(8, 6))
ax = fig.add_subplot(111, projection='3d')

sc = ax.scatter(X_pca[:, 0], X_pca[:, 1], X_pca[:, 2], c=hiclusters, cmap='plasma')
ax.set_xlabel('PCA reduced axis 1')
ax.set_ylabel('PCA reduced axis 2')
ax.set_zlabel('PCA reduced axis 3')
ax.set_title('Clusters (through hierarchical clustering)')

plt.colorbar(sc)
plt.show()

#%% save cluster distribution
X.to_excel("Clusters.xlsx")
Xnorm.to_excel("Norm + Clusters.xlsx")

#%% visualising the clustered data with averages
variables = X.columns[:-1]  # only the indicator data
cluster_col = X.columns[-1]  # last column = clusters
ylabels = fin.iloc[1,1:10].tolist()

# create a figure with 3x3 subplots
fig, axes = plt.subplots(3, 3, figsize=(12, 12))
axes = axes.flatten()

for i, var in enumerate(variables):
    sns.boxplot(x=cluster_col, y=var, data=X, ax=axes[i], palette='Set2')
    axes[i].set_title(f'{var}')
    axes[i].set_ylabel(ylabels[i])
    axes[i].get_xaxis().set_visible(False)

    # population-weighted average
    weighted_avg = np.average(X[var].values, weights=population)
    axes[i].axhline(weighted_avg, color='red', linestyle='--', linewidth=1.5)
```

```
plt.tight_layout()
plt.show()

#%% means and standard deviations
population_series = pd.Series(population, index=X.index)
X_with_pop = X.copy()
X_with_pop['Population'] = population_series
X_with_pop = X_with_pop.astype(float)

weighted_means = {}
weighted_stds = {}

for cluster in sorted(X[cluster_col].unique()):
    cluster_data = X_with_pop[X_with_pop[cluster_col] == cluster]
    weights = cluster_data['Population'].values

    # weighted mean
    mean = np.average(cluster_data[variables], axis=0, weights=weights)

    # weighted std
    avg = cluster_data[variables].values
    variance = np.average((avg - mean) ** 2, axis=0, weights=weights)
    std = np.sqrt(variance)

    weighted_means[f'Cluster {cluster} mean'] = mean
    weighted_stds[f'Cluster {cluster} std'] = std

w_means = pd.DataFrame(weighted_means, index=variables)
w_stds = pd.DataFrame(weighted_stds, index=variables)
stats = pd.concat([w_means.iloc[:,0], w_stds.iloc[:,0], w_means.iloc[:,1], w_stds.iloc[:,1],
w_means.iloc[:,2], w_stds.iloc[:,2]], axis=1)
```

F. Indicator performances table

Table F.1. The indicator performance per member state, indicated as their EU country codes.

Dimension	Condition	Indicator	unit	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE
Individual	Capability	Knowledge	%	36	38	21	16	45	21	54	16	28	37	54	45	19	26	31	16	20	37	53	49	31	36	28	33	33	17	34
		Food expenditure stress	%	10	12.2	20.8	18.1	13	15.8	11.8	19.1	12.2	13.3	11.5	16.2	16.7	8.6	14.4	19.7	19.2	9.3	13.3	11.7	18.5	17.3	25	18.3	14	13	12.8
	Motivation	Motivation	%	73	79	60	74	80	61	83	66	81	72	86	62	70	84	73	69	61	84	82	90	62	51	72	76	80	79	85
Situational	Social environment	Vegetarian protein uptake	%	3.1	-24.5	-16.2	-22.5	-17.6	-16.7	2.8	-50.5	10.8	-0.8	-11.6	-19.1	-16	-34.3	-10.2	-33.5	-30.7	6	-4	5.2	-20.9	-13.3	-14.6	-26.1	2.3	-8.9	19.3
	Affordability	Vegetable price increase	%	8.5	6.3	5.9	5.5	21.4	12.4	11.5	14.3	6.8	10.2	6.9	12.6	20.6	-0.7	6.4	4.9	16.5	23.9	-0.3	8.1	11.1	15.7	13.3	5.3	3.7	7.9	2.3
		Meat price increase	%	-9.1	-2.9	-10	-8.7	-11.1	-4.8	-18.6	-4.7	-12.4	-2.9	-0.4	-7	-13.7	-1.7	-4.4	-6.4	-12.4	-6.3	-7.6	-15.2	-11.4	-3.7	-8.1	-5.7	-1.8	-5	-7.1
		Meat price	%	11.7	15.8	-17.3	-12	-18.1	-6.5	-19.2	-8.6	-3.4	17.8	10.8	-12.5	-16.7	-5.8	8.4	-17.9	-16.5	11.9	-11.9	11	-12.1	-10.6	-8.5	-13.3	1.1	-5	1.3
Macro environment	Urbanisation	Level of urbanisation	%	31.5	32.5	46.6	32.5	61.8	30.3	34.1	45.0	40.9	44.5	39.0	39.2	31.9	35.1	34.8	37.0	45.2	18.2	47.9	57.3	36.2	44.4	33.0	20.1	18.4	53.7	36.2
	Consumption culture	Total protein consumption	g/cap/d	111.9	116.3	90.5	108.3	101.4	97.7	112.8	110.6	125.4	119.4	108.3	108.1	88.4	138.6	117.7	108.7	128.1	117.9	100.5	117.5	115.6	121.7	108.6	79.2	99	117.1	113.2

G. Indicator performances, formatted differently

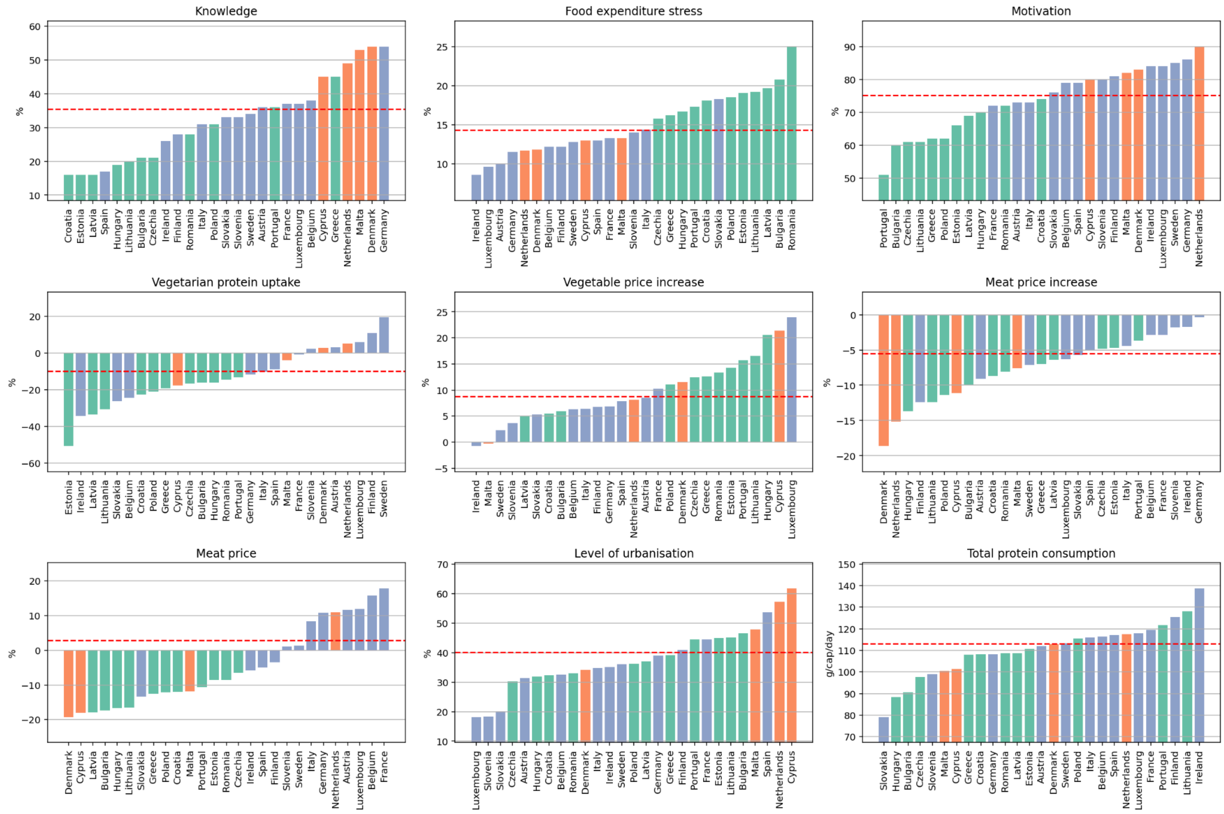

Figure G.1. Performances on the nine indicators per EU member state. The data for the member states within each subfigure are sorted from the lowest value to the highest value and coloured per cluster. The red dotted line shows the EU average for each indicator, calculated using the 2023 (national) populations as reported by Eurostat (Eurostat, 2023).

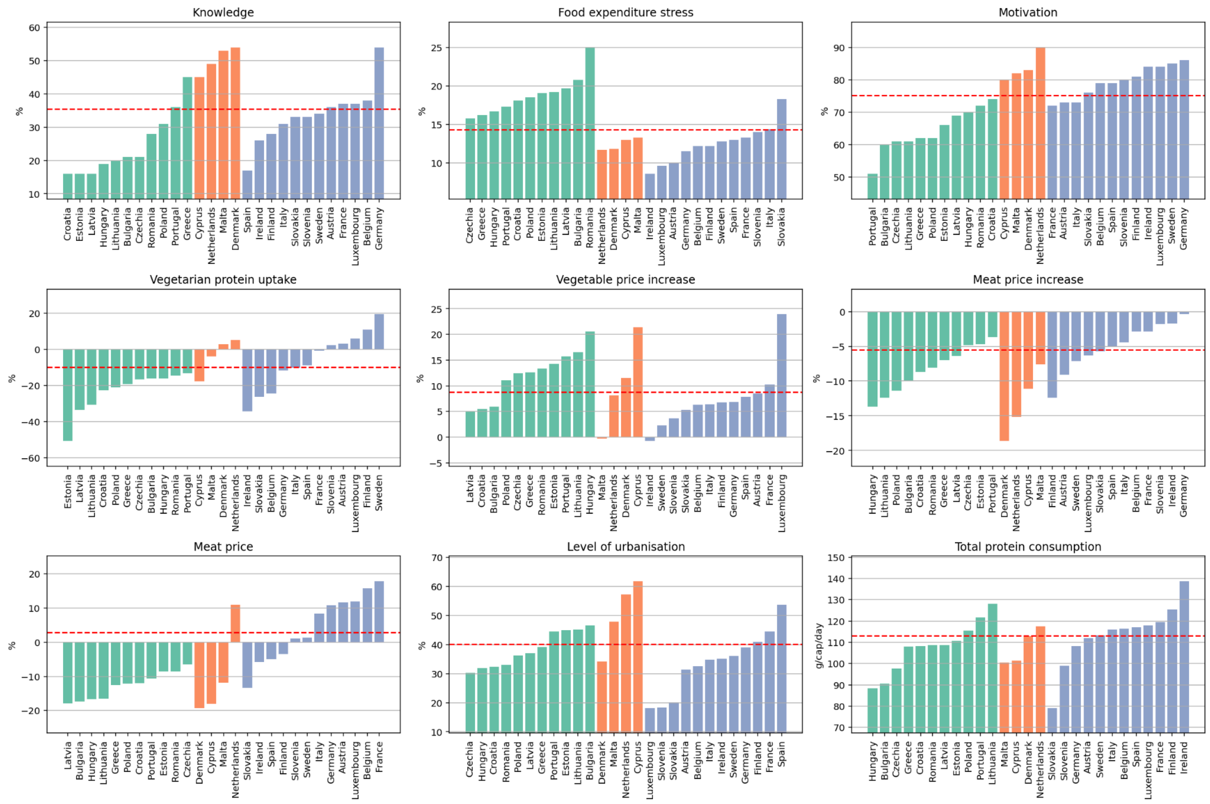

Figure G.2. Performances on the nine indicators per EU member state. The data for the member states within each subfigure are coloured and sorted per cluster from the lowest value to the highest value. The red dotted line shows the EU average for each indicator, calculated using the 2023 (national) populations as reported by Eurostat (Eurostat, 2023).

Table G.1. The weighted averages and standard deviations of indicator performances for the three clusters. The values were weighted with the populations of the corresponding member states, so that the averages and standard deviations given here represent the percentages and per capita values that represent the populations of these clusters.

	Average value ± standard deviation			
Indicator	**Total European Union**	**Cluster 1: Systemic barriers**	**Cluster 2: Urbanised and fiscally unfavourable**	**Cluster 3: Misinformed and protein plenteous**
Knowledge [%]	35.43 ± 12.06	28.49 ± 7.75	50.11 ± 2.36	36.76 ± 12.31
Food expenditure stress [%]	14.33 ± 3.35	19.02 ± 2.96	11.81 ± 0.33	12.80 ± 1.46
Motivation [%]	75.13 ± 9.08	63.66 ± 6.08	87.80 ± 3.45	78.31 ± 5.78
Vegetarian protein uptake [%]	-9.82 ± 9.87	-18.75 ± 5.33	3.57 ± 4.51	-7.64 ± 8.97
Vegetable price increase [%]	8.82 ± 3.47	12.55 ± 3.57	9.22 ±3.12	7.41 ± 2.12
Meat price increase [%]	-5.49 ± 4.35	-8.97 ± 3.04	-15.67 ± 2.10	-3.37 ± 2.48
Meat price [%]	2.88 ± 11.56	-11.70 ± 3.12	2.31 ± 13.49	8.28 ± 8.24
Level of urbanisation [%]	40.20 ± 7.79	36.60 ± 4.83	51.85 ± 9.93	40.60 ± 7.45
Total protein consumption [g/cap/day]	113.04 ± 8.41	108.77 ± 10.29	115.41 ± 4.13	114.43 ± 7.29