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Drivers and Barriers to Accelerating the Plant-Based Dairy Alternatives Innovation System – The Case of the Netherlands

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ABSTRACT

Increasing pressures on current practices related to dairy production and consumption have urged societies to explore more sustainable alternatives. In this respect, plant-based alternatives to dairy (PBD) products have emerged as a more environmentally responsible option. In the Netherlands, the market for plant-based dairy alternatives has developed as an upcoming niche over the past decades. With a dairy industry that is embedded in its economy and institutions, this country makes for an interesting case to study the dynamics between the upcoming niche and the established regime. The framework of technological innovation systems (TIS) has been applied as the theoretical fundament to analyze this PBD transition. With incorporating developments of both niche and regime processes, this study aims to investigate the diffusion of PBD in the Netherlands, as well as the interactions of established incumbents and their involvements in the PBD innovation system. In doing so, this research has identified several barriers that may hamper the acceleration of this innovation system, which have been linked to the theory of systemic problems. Accordingly, this study has conducted a qualitative event-history analysis from 2006-2022, alongside qualitative interviews with stakeholders of the PBD innovation system. Findings indicate several systemic barriers to PBD acceleration. First, this study identified hard institutional failures that result in misalignment in governmental strategies and visions versus existing policies and instruments for PBD development. Second, capacity and network failures were recognized in disparities of knowledge and information flows between industry actors and knowledge institutes. Finally, technological aspects of nutritional parity of PBD products were identified as the most hampering factor in larger consumer uptake, combining system problems of capacity, presence, and quality failures.

TABLE OF CONTENTS

INTRODUCTION

With the current world population reaching 7.9 billion people (UNFPA, 2021), pressures on global food provision are becoming increasingly critical. Agricultural systems, covering 38% of the global land surface, are extremely resource intensive. More specifically, approximately two-thirds of agricultural land area is dedicated to grazing livestock, causing depleted water resources, degraded aquatic and terrestrial ecosystems, and drivers of climate change (FAO, 2020; Poore & Nemecek, 2018). Alongside an expected further increase of the future world population, global food demand is estimated to continually increase and even double by 2050 (FAO & GDP, 2019).

As a response to the negative externalities of animal agriculture, plant-based alternatives for meat and dairy products have been on the rise over the last decades (Rödl, 2021; Choudhury et al., 2020; Tziva et al., 2020; Lonkila & Kaljonen, 2021). Even a country with a dominant traditional dairy industry as the Netherlands (ZuivelNL, 2021), is no exception to the increased uptake of plant-based alternatives (ING, 2020; Rabobank, 2021; ZuivelNL, 2021). However, plant-based dairy alternative (PBD) products seem to experience more difficulties penetrating the Dutch market compared to the meat alternatives. PBD products are products similar to traditional cow-based milk, yoghurt, cheese, and ice cream, but only with plant-based ingredients. With a total sales value of €118 million, they cover the lesser part of the Dutch plant-based market, as meat alternatives take the lead covering 60% of the total supermarket sales (Smart Protein Project, 2021). While these numbers are not unimpressive, the Dutch PBD consumption is still very small in comparison with consumption share of traditional dairy products in Dutch households, which amounted to €5,9 billion in 2019 (ZuivelNL, 2021). Meanwhile, various projects from business as well as governmental actors have been initiated to stimulate the development of PBD products. For example, in December 2020, the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) even presented a National Protein Strategy (NPS) with the intention to improve the country's developments regarding plant-based proteins over the next five to ten years (LNV, 2020). Furthermore, the Netherlands is home to large research institutes and facilities such as the Wageningen University and Research (WUR), Danone Nutricia Research, and Unilever, that are increasingly making progress in both alternatives for meat products and PBD products (Danone Nutricia Research, 2021; Unilever, 2021). Finally, not only are plant-based startups such as the Those Vegan Cowboys emerging, even the Dutch dairy-giant FrieslandCampina has started to dip its toes in the vegan territory (FrieslandCampina, 2020; Food Navigator USA, 2021). Efforts into the uptake of PBD thus seem not to be lacking, which brings up the question as to why the alternative dairy sector, despite its potential, is underdeveloped compared to the alternative meat sector in the Netherlands, and what causes this slow diffusion. Therefore, researching the interplay between the upcoming PBD niche and the established

large dairy industry in the Netherlands make for an interesting case to study the transition from traditional dairy to PBD and possible corresponding barriers to these developments in this country.

The transition to PBD regards one of a sociotechnical nature, as it involves a shift with changes along several dimensions, such as cultural, business, and policy dimensions, in a multi-actor network (Geels, 2002; Markard et al., 2012). Studies regarding sociotechnical transitions have provided valuable insights into processes and dynamics of system changes, allowing for more sustainable pathways in society. However, most research has been focused on transitions in the sectors of water, energy, and mobility (Sutherland et al., 2014; Bergek, et al., 2015; Markard et al., 2012). Existing analytical frameworks and transition typologies may therefore need to be adjusted for them to apply to sustainability transitions in food systems (Mylan et al., 2019). Studies into sustainable transitions regarding the food processing industry are emerging, but most are focused on the reduction of meat consumption and the protein transition of meat substitutes (Dagevos, 2016; Tziva et al., 2020; Vinnari & Vinnari, 2014). Transitions regarding PBD are thus largely understudied.

The diffusion of PBD can be studied through the concept of the TIS framework, which conceptualizes how such novel technologies find their way in established technological regimes, that have deep roots in the existing system or landscape (Hekkert et al., 2011; Hekkert et al., 2007; Tziva et al., 2020). More details on theoretical concepts will be elaborated on in the theory chapter, however it should be noted that in the case of the PBD transition, the evolution is bigger than one technological trajectory. It is not only focused on the technological innovations, but on various processes that lead to a fundamental system shift (Markard et al., 2012). Studying the PBD transition using solely the TIS framework thus does not suffice since implications of the existing regime structures and dynamics are also determinant for the development of that upcoming niche. Therefore, this study aims to further investigate the developments regarding the diffusion of PBD, as well as the interactions and involvements of incumbent actors of the established dairy sector regarding PBD developments, that may create systemic barriers to the acceleration of PBD products in the Netherlands. The Netherlands has been used as an empirical case study, which will be elaborated on in the methodology chapter. The following research question was studied:

What factors are either hampering or stimulating the acceleration of the transition towards the plant-based dairy alternatives innovation system in the Netherlands?

This study can provide an understanding into how these developments evolve and what barriers prevent PBD to accelerate on a larger scale. This can help in closing existing literature gaps, as previous research

has acknowledged the need for understanding of the protein transition in order to make sense of how disruptive firms can interact with the established actors in the system (Lonkila & Kaljonen, 2021). Furthermore, it can bring additional insights to the ongoing transition to sustainable food related innovations, as well as add to or strengthen the sustainability transitions literature by adding the understudied concept of PBD. Additionally, this study is of societal relevance, as the PBD transition is part of larger shift to more sustainable processes and consumption within the food processing industry.

2. THEORY

This chapter will elaborate on the theoretical fundaments of this study. It does so by first explaining the concepts of sociotechnical transitions and sociotechnical systems, after which relevant strands of literature for innovations and transitions in sustainability will be highlighted. Afterwards, the core theoretical concepts of this study, being the TIS framework and the concepts of systemic barriers will be explained and related to the aim of this study.

2.1 Sociotechnical transitions in sustainability

As mentioned in the introduction, the PBD transition is not only of a technological nature. It entails a mutual unfolding and a co-evolution of wider societal aspects in a multi-actor network, or a *sociotechnical system* (Markard et al., 2012; Geels, 2002, 2005). One can thus speak of a *sociotechnical transition*, which is defined as "*a set of processes that lead to a fundamental shift in sociotechnical systems*" (Markard et al., 2012, p956). It involves changes along various dimensions such as economic, socio-cultural, political, institutional, organizational, and technological dimensions.

Literature on innovations and transitions in sustainability has increasingly provided theoretical concepts to comprehend the complex dynamics of such transitions that may lead to systemic change (Tziva, Negro, Kalfagianni, & Hekkert, 2020). Two prominent strands of literature are those of the multi-level perspective (MLP) and the innovation systems approach. The MLP conceptualizes the dynamic patterns of sociotechnical transitions, where interactive developments on the niche (micro-level) and regime (meso-level) levels lead to changes in factors that are embedded in the larger landscape (macro-level) (Geels, 2011; Geels, 2002; Rip & Kemp, 1998). Literature on the innovation systems approach, on the other hand, defines innovation systems as "*networks composed of actors and institutions that develop, diffuse, and use innovations*" (Markard & Truffer, 2008, p. 597). Such innovation systems can be evaluated based on how various interactions or relations between those actors and institutions are performing (Markard & Truffer, 2008; Hekkert et al., 2007). While both strands of literature have developed as separate theoretical concepts, both are used for explaining similar phenomena, are rooted

in economic evolutionary theories, and share commonalities such as the acknowledgement of lock-in, path dependency, interdependence, ad non-linearity (Markard & Truffer, 2008). Markard and Truffer (2008) have integrated these two theoretical concepts by proposing technological innovation systems (TIS), which can be defined as "*a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion, and utilization of variants of a new technology and/or a new product*" (Markard & Truffer, 2008). Further explanations, including structural and functional elements of the TIS framework will be provided in chapter 2.2.

One of the main criticisms for the TIS framework, is that it does not shed light on how dominant practices of the sociotechnical regime are destabilized and phased out. This would require explicit attention to and insights in regime players and their strategies (Elzinga et al., 2021). The most recent notion of the mission-oriented innovation (MIS) takes this critique into account. However, the MIS framework revolves around the presence of a clear mission and corresponding objectives and shared goals, and plant-based alternatives are only a fraction of the Dutch NPS (Elzinga et al., 2021; Wanzenböck et al., 2020). Therefore, the TIS framework was deemed a better fit for this study. More specifically, the NPS focuses on the increase of plant-based products, the Netherlands becoming less dependent on certain crops as soy, and around improving the rate of self sufficiency of the Nehterlands with regards to plant-based protein consumption and production (LNV, 2020). Thus, PBD is one of the possible solution pathways to reach that mission. Considering the PBD pathway remains understudied, this study will focus on understanding and analyzing the drivers and barriers for PBD. However, as mentioned, it remains important to consider the established and difficult to change regime of the Dutch dairy industry.

2.2 The TIS framework

The technological innovation systems framework is focused on how the innovation system surrounding a specific technology is functioning and has become a prominent framework in the literature on sustainability transitions (Bergek, et al., 2015; Markard et al., 2012). It allows for an evaluation of developments in a specific technological field or niche, in this case PBD products, regarding dynamics of actors, institutions, networks, and interactions that either stimulate or hamper it (Hekkert et al., 2011; Wieczorek & Hekkert, 2012). Such niches provide a temporary protective space for the development and generation of those innovations, so that actors can nurture the innovation and allow it to become more robust. Gradually, those innovations can enter more diverse and broader markets, making them more influential and competitive, which in turn contributes to a shift in the existing regime (Smith & Raven, 2021). Within the literature of transitions, the TIS framework has proven to be valuable in exploring the dynamics of system changes and of conditions for the success of sustainable innovations (Hekkert et al., 2007; Markard & Truffer, 2008; Tziva et al., 2020). Analyzing TIS allows for a systemic

understanding and evaluation of developments in terms of processes and structures in a specific technological field that can support or hamper acceleration. A TIS analysis provide insights into the circumstances needed for the technology to become successful and part of the existing regime. Taking on a systemic perspective on innovation provides explanations as to why technological change often happens gradually and to the fact that TIS are often subject to inertia (Hekkert et al., 2007; Geels, 2002).

2.2.1 Structural elements of the TIS

The TIS framework includes both structural and functional elements of the innovation system. There are four structural dimensions or elements, which are identified during the structural analysis of the innovation system (Wieczorek & Hekkert, 2012). The first element refers to the system's *actors*, which are categorized into knowledge institutes, educational organizations industry and market actors, and government bodies and supportive organizations. The second structural dimension of a TIS includes institutions, both hard (laws, regulations, and rules) and soft (norms, expectations, routines, habits, etc.). Third, the interactions or *networks* of a TIS relate to the notion that innovation system actors operate in networks. The fourth structural element includes physical, intellectual, and financial *infrastructures* (Wieczorek & Hekkert, 2012; Hekkert et al., 2011). Conducting a structural analysis, thus identifying the structural elements of a TIS, is a critical step of the overall TIS analysis, as it allows for an overview of the system's current presence or absence of structural elements (Wieczorek & Hekkert, 2012; Hekkert et al., 2011). The next step is then to analyze how this system functions, which can be done along the seven system functions.

2.2.2 The seven system functions of a TIS

The TIS framework studies the key processes and activities in a system according to its *system functions*. Where the system structure provides a depiction of the established system, functions of innovation systems allow for assessment and evaluation of their performance in the system (Hekkert et al., 2007; Hekkert et al., 2011). Table 1 provides the definitions and explanations of these seven system functions, as proposed by Hekkert et al. (2007). Interactions between the functions and establishing the state of development of the innovation are also both essential elements, as they precede on identifying barriers or drivers for a well-functioning innovation system (Hekkert et al., 2011).

Table 1: definitions of the technological innovation system functions, as adapted by Hekkert et al. (2007)

System Function	Definition
F1. Entrepreneurial Activity	The extent of presence and diversity of active entrepreneurs. They are essential for well functioning innovation systems, considering their experimentation with business opportunities, ability to cope with uncertainties, and willingness to take risks.
F2. Knowledge Development	This function encompasses mechanisms of learning through research & development and knowledge development regarding patents, investments, and overall markets, technologies and networks.
F3. Knowledge Diffusion	The essence of this function lies in the exchange of information. It regards not only 'learning by interacting', but also 'learning by using'.
F4. Guidance of the Search	This function referst to "those activities within the innovation system that can postively affect the visibiltiy and clarity of specific wants among technology users" (Hekkert et al., 2007, p 423). It regards a cumulative and interactive process of exchanging ideas between system actors.
F5. Market Formation	Market formation regards the processes involved in creating temporary niche markets for the innovation, to provide a protected space and to create (temporary) competitive advantage.
F6. Resources Mobilization	This pertains to all resources, both financial and human capital, that need to be allocated to fullfill other system functions.
F7. Creation of legitimacy / counteract resistance to change	This function regards all efforts to reach social acceptance and compliance of the innovation with relevant institutions.

Barriers associated with TIS that may hamper it from further development, can be related to larger structural or systemic problems that may hinder the acceleration of diffusion of these innovations. This is an important aspect in the case of the PBD innovation system, as the established dairy regime in the Netherlands needs to be considered while researching the upcoming of the PBD niche. In this respect, Wieczorek and Hekkert (2012) identified such problems of the associated structural-functional analysis as systemic problems, which are defined as those aspects that hamper the evolution of these innovation systems. The TIS framework was used as the theoretical fundament of this research in order to evaluate the PBD innovation system on the one hand, with the concept of systemic barriers as a rationale for

accounting for the established dairy regime on the other. Therefore, the next section elaborates on those systemic barriers.

2.3 Systemic barriers to innovation system development

Systemic failures are defined as "*problems that hinder the development of innovations systems*" (Wieczorek & Hekkert, 2012, p. 78). In their analysis on systemic instruments for systemic innovation, Wieczorek and Hekkert (2012) acknowledged that explanations as to why certain system functions are weak or even absent, can be related to the overall structure of the innovation system. Even more so, literature shows the TIS framework can be strengthened by adding a broader conceptualization of structures from the broader context the TIS-context, or niche-regime interactions (Bergek, et al., 2015). As became evident in previous sections, the TIS framework elaborates on processes and structures of the studied TIS, but events and relations outside of that scope remain neglected (Bergek, et al., 2015; Weber & Rohracher, 2012). In this respect, Wieczorek and Hekkert (2012) proposed a framework where structural elements of innovations systems are linked to various types of systemic problems. In doing so, they conceptualized systemic problems as related to the four structural elements described in section 2.2.1. Those problems are related to (i) the presence or capabilities of system actors, (ii) the presence or quality of institutions, (iii) the presence or quality of networks or interactions, or (iv) the presence or quality of the system's infrastructure. Table 2 provides a more detailed explanation of each systemic problem. By linking the structural and functional elements of the TIS, including hampering factors or barriers that became evident during the analysis, to corresponding systemic problems, this study aims to identify systemic barriers that may prevent the PBD innovation system from accelerating. Taking on this systemic perspective allows for including both niche and regime players, as well as interactions between them, which can provide valuable insights as this incorporates the role of both the Dutch PBD sector as the dairy industry.

Table 2. Structural elements and their systemic problems, adapted from (Wieczorek & Hekkert, 2012)

Structural element	**Type of systemic problem**	**Description**
Actor	Presence related	Relevant system actors are not present
	Capacity related	Present actors in system lack competence or the capacity to learn, or have difficulties in developing strategies and visions
Institutions (hard and soft)	Presence related	Specific institutions are absent
	Capacity related	Established institutions have issues with their quality or capacity. *Rigorous institutional issues* can lead to problems with appropriability or favoritism of incumbents. *Weak institutional problems*, on the other hand, can hamper innovation by providing insufficient support for new developments or technologies.
Networks or interactions	Presence related	The lack of interactions caused by different objectives, assumptions or cognitive distance between system actors, or by a lack of trust
	Quality related	*Strong network problems* occur when certain actors are misguided by larger system actors, leaving them unable to supply each other with necessary knowledge. *Weak network problems* arise by a weak or low connectivity between system actors, hampering interactive innovation and learning.
Infrastructure	Presence related	When a specific sort of infrastructure is not present in the system
	Quality related	When the existing infrastructure is malfunctioning or incompetent

3. METHODOLOGY

3.1. Case selection: the Netherlands

As mentioned in the introduction, the case of PBD in the Netherlands was used as a case study. With a contribution €7.8 billion to the Dutch economy, the traditional cow dairy industry of the Netherlands belongs to the top five of the world's largest dairy exporters (ZuivelNL, 2021). Even this country, with a leading dairy industry, has recognized the need to increase its uptake in plant-based products, regarding both meat and dairy substitutes (LNV, 2020). The PBL Netherlands Environmental Assessment Agency (PBL) recognized the switch to a more plant-based diet as an important way to significantly contribute to lessening the pressures individuals put on their environment (PBL, 2020). The upcoming plant-based trend has become evident in the expanding plant-based assortments in large supermarkets (Albert Heijn, 2021; Albert Heijn, 2020), increased supermarket sales of plant-based products (ING, 2020;

Rabobank, 2021), but mostly in the recognition by the Dutch government of the importance of this protein transition. As mentioned, the LNV launched their National Protein Strategy (NPS) in 2020, part of which is aimed at improving research, development, and self-sufficiency in the production plant-based proteins (LNV, 2020). The strategy acknowledged the Netherlands' strong position in protein innovation and technology developments, as it is internationally known for its agricultural innovation and biotechnology (LNV, 2020). The NPS allowed for various public-private partnerships to arise, such as the Knowledge and Innovation Agenda Netherlands, the Sustainable Food Initiative, and Regiodeal Foodvalley, which are working on the development and improvement of plant-based proteins, novel protein sources and sustainable processing technologies. Furthermore, the NPS recognized that the overall value chain of plant-based is not yet accelerating. There is a need for simultaneous and integrative innovations regarding technological, social, cultural, and environmental aspects. Therefore, the LNV stimulated research and development for innovations by investing in multiple national and regional projects and asking for a joint approach of public-private collaborations. These projects involved actors such as the WUR, the Dutch Research Council (NWO), and the Netherlands Enterprise Agency (RVO), among others (LNV, 2020).

Besides the NPS and its involved projects, other business and research actors started to pick up on the PBD trend. Research institutes have increasingly made progress in research and development regarding plant-based alternatives, startups started to emerge, and even larger companies announced participation in the uptake of PBD products (Danone Nutricia Research, 2021; FrieslandCampina, 2020; Those Vegan Cowboys, 2020; Unilever, 2021).

Thus, multiple actors in the system are involved in the acceleration of PBD in the Netherlands. However, the PBD niche is still battling to find its way in a dairy-entrenched regime. The Netherlands makes for an interesting case study, as it is home to large agricultural cooperatives such as FrieslandCampina. This allows for researching not only the upcoming of the plant-based niche, but also how this relates to dynamics and institutions of involved actors of the incumbent dairy regime. The fact that dairy substitutes seem to experience more difficulties penetrating the Dutch market than the sector of plant-based meats, is another reason for this case study to research the drivers and barriers for the PBD uptake in the Netherlands. To maintain a feasible scope, and because this study took on an innovation systems perspective, this research had not explicitly looked at the technological details of the origin and species of the plant-based crops. This could, however, be valuable for future research.

3.2. Data collection and analysis

The data necessary to conduct the structural-functional analysis of the TIS framework, after which systemic problems were identified, were gathered through several rounds of research. A deductive approach was deployed, considering the case study used and tested existing theories, rather than developing new theories. Using notions of both the TIS framework and the systemic problems, this case study consisted of a structural analysis of the PBD niche and the cow dairy regime of the Netherlands. This is followed by an evaluation of the system functioning of the Dutch PBD innovation system and ends with the identification of the most prominent systemic problems or blocking mechanisms for the PBD innovation system to further develop.

The first round of data collection consisted of desktop research, where secondary data was be collected from websites and reports of PBD or dairy industry associated companies and governmental organizations, NGOs, newspapers, and public campaigns, in addition to scientific papers. The following search were used, both in Dutch and English: “National Protein Strategy”, “plant-based dairy alternatives”, and “protein transition”. Through the snowballing method, additional literature or documents relevant to the subject were found. This desktop research was done to establish a level of background information for the researcher, on which pre-defined search terms could be determined to use for the second round of data collection. During this second round, data was gathered through a qualitative event-history between the years 2006-2022 analysis using the LexisNexis database, to study the early diffusion of PBD and regime developments of the dairy regime in the Netherlands. The LexisNexis database contains data on news, business, and legal information from international and national sources. It has been utilized for similar purposes in previous studies on sustainability transitions and has proven itself to be a useful tool for providing information as a digital newspaper archive, contributing longitudinal data from sources such as news articles, patent data, and press releases (Hekkert et al., 2007; Negro & Hekkert, 2008; Tziva et al., 2020). Collecting this data provided information on key events and developments, and reasons for those developments, that have occurred regarding PBD in de past 16 years. In addition to the document analysis, the LexisNexis data allowed for insights on how the established regime and upcoming PBD niche have embedded themselves in the current Dutch society. The period of 2006-2022 was chosen because studies have indicated that around the mid-2000s, PBD products have started to break out of the small ethical and medical niches and entered more mainstream markets. More specifically, in 2006, “Livestock’s Long Shadow” was published (Steinfeld, et al., 2006) which indicated a starting point where sustainability and animal welfare became increasingly more important subjects, enlarging the issue of the negative impact of the livestock production (Mylan et al., 2019; Tziva et al., 2020). Events were studied through four advanced search terms in the LexisNexis database, all between the dates of January 1st, 2006 up until May 2022. As this

research analyzed the case of the Netherlands, the following search terms were translated in Dutch: (i) “plant-based dairy”, (ii) “plant-based proteins” AND “dairy”, (iii) “dairy” AND “plant-bassed”, and (iv) “protein strategy”. These search queries resulted in a total of 2040 events. Each event was carefully read, but items regarding meat substitutes or items that did not relate to the subject were filtered out, as these were not relevant for this study’s research question. After filtering, 274 events were left, which were structured into an Excel database. Each event was assigned an event type and categorized according to the seven TIS functions, to identify the function fulfillment. For example, in the case an event indicated the establishment of a PBD start-up, this event was coded under the function of entrepreneurial activity (F1) and assigned the event-type “PBD start-up”. In order to provide a clear perspective of the niche-regime relations, a distinguishment was to be made between events related to niche actors and those related to regime actors. Therefore, events relating to regime actors were additionally labeled with *regime event*. Furthermore, the Excel database allowed for the events to be categorized to a function having either a postive (+) or negative (-), thus hampering, influence the development and diffusion of PBD.

Including other or broader search terms during this event-history analysis could have influenced the composition of this database and thus the results. However, this database was substantiated with the final round of data collection through semi-structured interviews with a range of Dutch stakeholders in the PBD innovation system. These interviews served two purposes. First, to validate the results of the structural analysis and possibly provide additional insights on the system structure or niche-regime relationships. Second, to create insights on the system functioning of the PBD innovation system in the Netherlands and to identify barriers to the acceleration of the innovation system. The questions of the interview guide were based on the diagnostic questions and indicators as proposed by Hekkert et al. (2011), and on additional questions that arose during the structural analysis, to fill potential knowledge gaps. The diagnostic questions and indicators can be found in Appendix A. The complete interview guide is provdided in Appendix B. Before conducting the interviews, the interview guide was evauated by the researcher’s supervisor and a PhD student that is also conducting research in the area of the protein transition. Ideally, at least one actor per category that was identified in the structural analysis would have been interviewed. This includes market actors, knowledge institutes, industry actors, government bodies and supportive organizations, and educational organizations (Hekkert et al., 2011). The structural analysis allowed for identifying the most important niche and regime players within the PBD innovation system, and served as indication for the actors that needed to be interviewd. Furthermore, the ability to interview actors was dependent on the accessibility of interviewees. The sampling strategy was therefore a combination of both purposeful and convenience sampling.

After reaching out to 34 possible interviewees, nine were available and willing to participate. Table 3 shows the types of respondents that were interviewed. While these interviews covered industry and market actors, knowledge institutes, educational organizations, and governmental bodies or supportive organizations, no interviews were conducted with a representative of a dairy cooperative or with farmers. Insights of these actors could have increased the validity of this research as the results showed they are both key players in the PBD transition. However, representatives of the agricultural cooperatives offered important insights in the interests of farmers. Furthermore, several interviewees were aware of strategies or involvement regarding PBD of dairy incumbents through various collaborations or consortia projects where these incumbents were also active. These insights, combined with newspaper articles from the database, provided relevant insights into the current involvement and dynamics of incumbent dairy actors. Before conducting each interview, research subjects were asked for informed consent for participation. These informed consent related questions can be found in the interview guide of Appendix C. The interviews were conducted via Microsoft Teams and lasted between 50 to 65 minutes. The first interview was joined by the mentioned PhD student, to evaluate the process and to provide necessary tips for improvement. The interviews were recorded to allow for transcription. Furthermore, the interviews were made anominous to protect the research subjects' privacy. Afterwards, the interviews were coded. First, the interview as broken down and assigned codes along the system functions as describe in the theory chapter. When the researcher recognized a new barrier during the coding of the interviews, this barrier was added as a code under the corresponding system function, leading to a total of 18 observed barriers.

Accumulating all the collected data allowed for the researcher to conduct the structural-functional analysis, where the developments of the PBD innovation system from 2006 to 2022 and corresponding barriers were described. Afterwards, each barrier was assigned a level of priority with the use of a three-point Likert scale (Vagias, 2006). This seperated each identified barriers into eather low priority (-) if less than 33% of the interviewees acknowledged that barrier, medium priority (+) if 34% to 66% identified that barrier, and high priority if over 67% of the respondents acknowledged that barrier. Sequentially, barriers that were evaluated of high priority were linked to systemic problems to understand how barriers were linked and were hampering further development of the PBD innovation system.

Table 3. Overview respondents that were interviewed

Name actor	Category of innovation system actor
AG 1	Agricultural Cooperative
AG2	Agricultural Cooperative
RMP 1	Raw Material Provider
INT1	Intermediary/PBD Supportive Organization
KI1	Knowledge Institute
INV1	Investment Service Provider
INNO1	Innovation Service Provider
SU1	PBD Alternative Startup
GB1	Governmental Agency

3.3. Data quality

These interviews allowed for insights and alternative perspectives on barriers for the PBD innovation system, and for additional sources of information that had not yet been identified during the document analysis and event-history analysis. This triangulation of research methods allowed for internal validity in this research. The steps taken in this research were documented, as described in the previous section, meaning the reliability of this research was maintained. As this research focuses on a single case, the generalizability of this study is limited. However, the construct of this study could be applied to other cases in the future.

4. RESULTS

4.1 Structural analysis

The evolution of the PBD innovation system is embedded in the context of the established dairy regime in the Netherlands. Technological, institutional, economic, and other developments related to PBD alternatives cannot be evaluated separately from the developments of the existing dairy industry, as involvement and change of practices by incumbent regime actors is a prerequisite for the acceleration of the PBD innovation system. This section will elaborate on the structural analysis of the PBD innovations system, while considering the overall context of the regime by identifying key actors and institutions from the embedded dairy regime.

4.1.1. Actors

With the Dutch dairy industry being valued over €8 billion (ZuivelNL, 2022), the Netherlands is home to large incumbent dairy actors such as FrieslandCampina, Royal A-ware, Westland Cheese, among others.

Furthermore, many market and industry actors of the dairy regime are present with over 15.000 livestock dairy farms and 51 dairy factories (ZuivelNL, 2022) and large agricultural cooperatives such as FrieslandCampina and DOC Cheese. While the Netherlands is not unique in having a sizeable cooperative dairy sector in Europe, it has one of the largest, with Dutch cooperatives accounting for 86% of all milk handling in the Netherlands in 2015 (Bijman, 2018). With various ways of market protection, which will be elaborated on in section 4.3.1, the Dutch cooperative dairy sector has been able to evolve into its current size over the past decades. The cooperative structure differs from supply chain structures of those in for example the energy or mobility sector. The largest Dutch dairy cooperative FrieslandCampina, for example, has a horizontally organized structure with its farmers, thus integrating its processors and distributors. Here, farmers that are part of FrieslandCampina's cooperative have ownership in the form of assets of the company (Letizia & Hendrikse, 2016). In this system, smaller businesses and farmers are subject to being price takers, leaving them with little bargaining power compared to the larger dairy organizations. This cooperative dairy regime makes for a unique environment for the PBD innovation system to develop in. When comparing it to transitions in energy, water, or mobility sector, for example, these sectors are more decentralized in the sense that they do not comprise of a cooperative structure where cooperative organizations represent aggregates of producers as members of those organizations.

However, not only established dairy actors, but also PBD related organizations are present in the ecosystem, with producers of PBD products, raw material suppliers, start-ups, and service providers for financial or technological support. Besides industry and market actors, various knowledge institutes, educational and governmental organizations are present in the playing field, which led to various niche-regime interactions for the development of the PBD innovation system that became evident during the structural-functional analysis. Table 4 shows the types of market actors including examples of this innovation system.

Table 4. System structure of actors in the PBD innovation system and relevant actors in the dairy regime of the Netherlands.

Actors		**Examples**
Industry and market actors		
	Dairy regime	
	Agricultural/ dairy cooperatives or dairy processors	FrieslandCampina, Royal A-ware, Agrifirm, Royal Cosun, Westland Cheese
	Dairy livestock farms	
	Supermarkets with private label dairy and PBD products	Albert Heijn, Jumbo, Lidl
	PBD actors	
	PBD producers and raw material suppliers	DSM, Danone, Avebe, Upfield
	PBD start-ups	Abbot Kinney's, De Nieuwe Melkboer, Willicroft, Those Vegan Cowboys
	Service providers for financial or technological innovation support	Invest NL, TOP BV
Knowledge institutes		
	Universities	Utercht University, Wageningen University and Research, TU Delft
	Research centers	NIZO, Danone Nutricia Research, Unilever Research Center
Educational organizations & programs		Proveg, Dutch Nutrition Center
Governmental bodies and supportive organizations		
	Governmental bodies	Rijksoverheid, NWO, LNV
	Dairy supportive organizations	NZO, EDA, LTO
	PBD supportive organizations/collaborations	Green Protein Alliance, Food Valley

4.1.2 Institutions, infrastructures, and networks

Besides the Dutch 'dairy culture' developing through its large industry, it has also been enforced by various supportive networks and lobby groups that value the traditional dairy consumption as standard practice, on national as well as European level. Since the 1960s, (inter)national policies such as the Common Agricultural Policy have supported the dairy industry and its cooperatives, and created an advantageous institutional environment, which will be elaborated on in section 4.3.1. Furthermore, the Dutch Dairy Association (NZO) has been committed to maintain the consumption of dairy products as

part of the national dietary advice of the Dutch Nutrition Center by various lobbying activities and marketing (Van Nierop, 2015). Even more so, organizations such as the NZO or the European Dairy Association (EDA) have actively lobbied for the restriction of dairy-related terms for PBD organizations (Coyne, 2021), which will be further explained in section 4.3.2 on lawsuits and lobbying. On the other hand, various networks have arisen in favor of research and development for PBD innovations. One example of such a collaboration is the program Fascinating, where large incumbents Royal Cosun, Avebe, Agrifirm and even the largest dairy cooperative FrieslandCampina are involved in research into cultivation of new protein-rich crops in the Netherlands (Nieuwe Oogst, 2020). Another example entails the innovation platform The Protein Cluster, where companies can collaborate and innovate to provide plant-based alternatives for protein sources (Leeflang, 2017).

4.2 Main characteristics of each time period of the PBD innovation system

The data analysis showed three categories of time periods, as shown in Figure 1:

1. 2006-2015: Dairy dominance, but increasing environmental and animal-welfare awareness with the first signs of plant-based competition
2. 2016-2019: The rise of the protein transition and the "dairy censorship"
3. 2020-present: The plant-based takeover

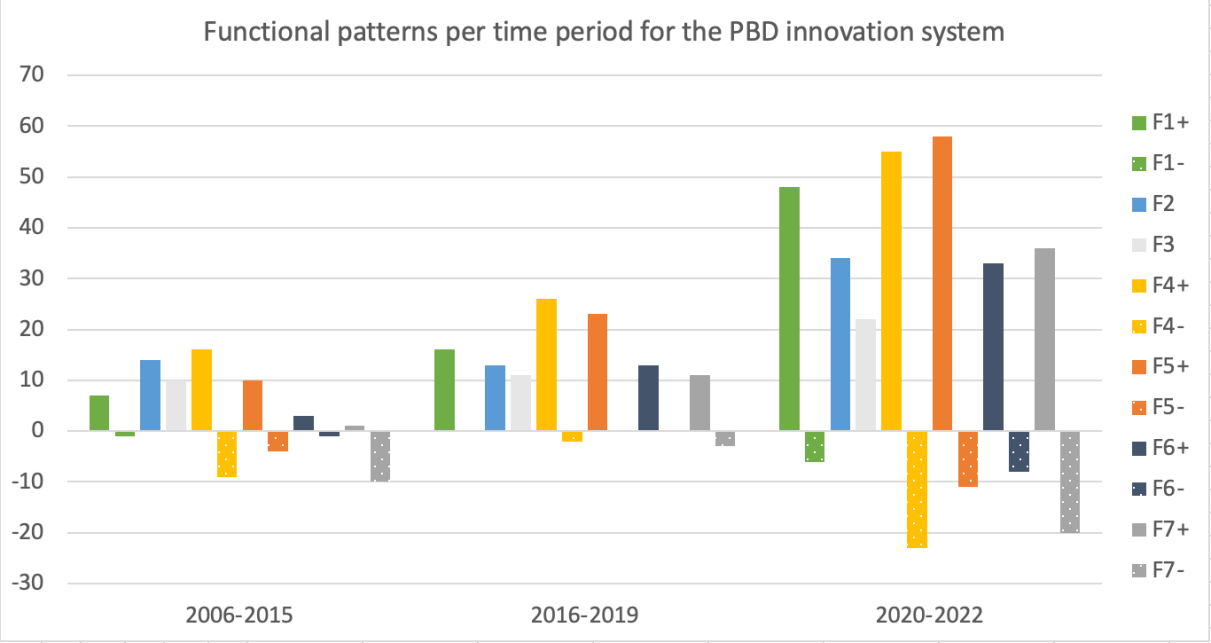

Figure 1. Overview of functional patters per time period for the PBD innovation system. The X-axis shows the years of the periods, the Y-axis shows the number of events from the event-history analysis.

The following section will provide a brief overview of the overall characteristics of each period, alongside explanations for these specific periods. Afterwards, those periods will be further explained by highlighting key developments that led to the coming about of the PBD innovation system of today. This

will be done by providing a structural-functional analysis that elaborates first on the events that triggered developments in the first two periods, and second on developments in the period of 2020 – present. Finally, the observed barriers from the structural-functional analysis will be linked to systemic problems and blocking mechanisms for the PBD innovation system in the Netherlands.

4.2.1 2006-2015: Increasing environmental and animal-welfare awareness with the first signs of plant-based competition

The publication of "Livestock's Long Shadow" (Steinfeld, et al., 2006) by the FAO indicates the starting point of this period, as it recognized relations between environmental impact, livestock industries, and climate change (Tziva et al., 2020). Throughout this period a low number of events are visible. Entrepreneurial activities (F1) were low, as the data showed no start-ups of PBD alternatives present yet. Knowledge development (F2) and knowledge diffusion (F3) were present, but despite increasing awareness of unsustainable practices in the livestock industry, there were no visions or policies on either Dutch or European level to incentivize a protein transition for businesses, which also indicates a weak guidance of the search (F4). While the EU dairy market did not remain unaffected by the global recession and fluctuating prices during the years of 2008 and 2009, various EU policy instruments, which will be elaborated on in chapter 4.3.1, supported this sector and allowed it to grow further (Jongeneel, et al., 2010). Even more so, despite increasing concerns for the de-intensification of the livestock industry, the dairy sector only became more intensive. However, during the second half of this period, the first signs of competition from the plant-based industry were coming from the large brand Alpro, which was part of incumbent WhiteWave Foods before it was purchased by Danone in 2017 (Tuenter, 2020). Furthermore, there seemed to be more involvement on a policy level, showing the first signs of improvements of the guidance of the search (F4) and market formation (F5). In 2008, Project Protein Transition was published, a public political document that identified the need for more sustainable ways of protein provision. When speaking of a protein transition during this period, the emphasis was on decreasing the meat consumption, rather than a holistic approach that looked at the complete livestock industry. While there seemed to be more policy involvement, actionable interventions were still mostly absent. Finally, the system functions of resource mobilization (F6) and creation of legitimacy (F7) were still weak.

4.1.2 2016-2019: The rise of the protein transition and the "dairy censorship"

The year 2016 makes for the cut-ff year between the first two periods, as it was characterized by the increased number of PBD start-ups and the start of the institutional battle of the "dairy censorship", which will be defined in chapter 4.3.2. During this period, the analysis showed an increase in events

regarding plant-based alternatives on various system functions. Where entrepreneurial activity (F1) in the latter half of the previous period was mostly present through existing companies introducing a first plant-based product or ingredient, this period showed improvements of this function with for example the establishment of the first start-ups for PBD products, among others, as shown in Table 5. An example of this is the founding of start-up Abbot Kinney's (Van Unen, 2016). Knowledge development and diffusion (F2 and F3) showed improvements through increased collaborations, consortia projects and networks that stimulate innovation, for example the knowledge symposium for the protein transition in 2017 (Van Leeuwen, 2017), or the opening of innovation center for plant-based proteins CHIEF (Boluijt, 2018). Furthermore, new technological innovations for products or ingredients were introduced. A few examples of these are knowledge institute NIZO introducing a plant-based ice cream ("NIZO presenteert vetvrij ijsje", 2014), PBD incumbent Danone introducing an oat-based yoghurt and an oat-based drink in Dutch supermarkets with Alpro ("Alpro introduceert zuivel", 2017), or Dutch multinational DSM introducing a method for protein extraction from rapeseed oil ("Duurzaam eiwit uit raapzaadolie", 2017). With increased European and national policy involvement, and the protein transition becoming a more prominent subject on the policy agenda, which will be explained in section 4.3.1, guidance of the search (F4) is also improving during this period. This also showed in changing visions on sustainable protein consumption that eventually lead to the Dutch National Protein Strategy, which will also be elaborated on in section 4.3.1. Besides, changes in the national dietary advice to consume less animal proteins also strengthened the vision on how the market should develop. This in turn also has its effects on the function of market formation (F5), considering more (incumbent) companies are getting involved in the plant-based trend. While the upcoming PBD niche was developing, this created several tensions on market and institutional developments, which will be explained in section 4.3. The upcoming of the plant-based niche also became evident in the allocation and mobilization of resources (F6), for example with Wageningen University and Research investing €5 million in research into the protein transition in 2019 (Smid, 2019), or the opening of a factory to extract proteins from duckweed (Van Mersbergen, 2018). The resistance to change (F7) among consumers seemed to decrease concurrent with the upcoming "flexitarian" diet, which entails eating both plant-based and animal products, where plant-based diets became increasingly accepted among consumers (Van Ditmars, 2016).. This changed in the sense that plant-based diets used to have a "dull" image with products of lesser quality, but with increasing environmental and health concerns and products improvements, this view has started to change among consumers. However, resistance to change is present from the dairy regime through active lobbying of the so-called "dairy censorship" which will be explained in the section 4.3.2 on lawsuits and lobbying.

Table 5. Establishment of PBD start-ups

Year	PBD Start-up
2016	Abbot Kinney's: plant-based yoghurts (Van Unen, 2016)
2018	Plant Based Cheese (later becomes Willicroft): plant-based cheeses (Van der Horst, Roep om bundeling tegen zuivelalternatief, 2018)
2020	Willicroft: plant-based cheeses (Salhany, 2020)
2020	Those Vegan Cowboys: plant-based cheese (ANP, 2020)
2020	De Nieuwe Melkboer: soy-based drinks (Van Cooten, 2020)

4.2.3 2020-present: the plant-based takeover

The publication of the National Protein Strategy (NPS) makes for a tipping point between periods. During this period, the subjects of the protein transition and plant-based alternatives became increasingly present in the media, news publications and policy discussions, as will be explained in section 4.4. While the most prevalent characteristics of this periods are briefly described here, more elaborate explanations will be given in section 4.4. Increased entrepreneurial activity was shown by start-ups, supermarkets, restaurants, etc. and large incumbents as Danone, DSM, Unilever, and Westland Cheese, amongst others, started stepping into the plant-based territory. In 2022, even the largest dairy cooperative FrieslandCampina announced to start getting involved in PBD ingredients. More and more plant-based companies located themselves around Foodvalley as well as more research projects, innovation centers, and collaborations for knowledge development and diffusion. The goals and visions on European and Dutch policy level were becoming better aligned on how the market and industry should develop. However, there seemed to be a lack of political guidance as the protein transition is led more by the business community than governmental institutes.

4.3 Structural-functional analysis: 2006-2020. From dairy-dominance to the rise of the protein transition

As mentioned, to understand the dynamics of today's functioning of the PBD innovation system, several aspects of the developments leading up to the current situation must be highlighted. The event-history analysis, combined with insights from the interviews, showed two evolving concepts that led to the situation as is: (1) the events leading up to the NPS and (2) lawsuits and lobbying activities regarding the "dairy censorship". As these developments are all integrated and have simultaneously resulted in today's PBD innovation system, this section will elaborate on the unfolding of these events.

4.3.1 Interactions between the dairy regime and the upcoming plant-based niche: events leading to the National Protein Strategy

> *"Look at how the Dutch dairy industry got to the place it is. It's because there was a merge between the government and the farming community, it was heavily supported and there was a lot of interaction. That model worked and it's created something that is very successful and recognized around the world, but I think they didn't understand the implications of it. We should take a lot of lessons on how it was set up and be aware that we now need to have a different way of producing food"* - SU1.

As institutional developments for dairy support and the protein transition over the years can provide explanations as to why certain differences or conflicts of interests between the dairy and PBD industry occur today, this section highlights the most important developments. A key policy that has supported the Dutch dairy industry over the years, is the Common Agricultural Policy (CAP), which was introduced in 1957 to secure dairy supply, among others, with guaranteed price minimums for European producers. During the 90s, this system of price supports developed into a subsidy system, and after a reevaluation in 2003 this CAP transformed into a system where Dutch farmers received payments that were based on historical levels of production. Over the years, this support system evolved and reformed in various ways, but it has always remained a pillar for European agricultural support and economic growth (GLB, 2022). Furthermore, such institutions have played an important role in the price setting of dairy products, which relates to the barrier of the function market formation (F5); *price differences between dairy products and PBD substitutes*. This barrier was identified by 78% of the interviewees. While these price differences are caused by several other factors, the governmental support of dairy products is embedded in the lower dairy consumer prices and is still evident in today's prices. To provide an example, Table 6 depicts examples of supermarket prices for PBD products compared to its dairy variant. This shows that even today, regular dairy milk products are, in this specific example 37%, cheaper than PBD products on average. Respondents indicated this to be a possible barrier to market acceleration of PBD products, as consumers often opt for the cheaper choice.

> *"You've still got massive subsidies and price reduction on dairy. We're not a company that advocates for the removal of dairy, but we are a company that argue for a level playing field and I think a reduction in dairy. At this moment, the only reason you can buy cheese and milk cheaply, is because it is protected, heavily, by subsidies"* – SU1.

Table 6. Price comparisons of PBD alternatives to milk and regular dairy milk products. Products do not include chocolate or other flavored types of milk, coconut milk, or baby milk. Prices are based on supermarket prices of supermarket Albert Heijn on May 18th, 2022 (Albert Heijn, 2022).

PBD alternative to milk	Price per liter	Milk product dairy	Price per liter2
Albert Heijn private label Almond drink	€ 1.57	Albert Heijn organic semi-skimmed milk fresh	€ 1.19
Albert Heijn private label Oat drink unsweetened	€ 1.79	Albert Heijn organic whole milk fresh	€ 1.29
Albert Heijn private label Soy drink naturel	€ 0.88	Albert Heijn private label semi-skimmed milk fresh	€ 1.19
Albert Heijn private label Soy drink unsweetened	€ 0.88	Albert Heijn private label semi-skimmed milk unref	€ 0.99
Albert Heijn private label Soy drink unsweetened refrigerated	€ 1.59	Albert Heijn private label skimmed milk fresh	€ 1.15
Alpro Barista Oat	€ 2.39	Albert Heijn private label skimmed milk unrefrigera	€ 0.95
Alpro Barista Oat refrigerated	€ 2.92	Albert Heijn private label whole milk fresh	€ 1.29
Alpro Barista Soy	€ 2.15	Albert Heijn private label whole milk unrefrigerated	€ 1.04
Alpro Hazelnut drink	€ 2.49	Arla organic semi-skimmed milk fresh	€ 1.69
Alpro Oat and Almond drink	€ 2.79	Arla organic whole milk fresh	€ 1.85
Alpro Oat drink no sugar	€ 2.25	Campina organic semi-skimmed milk fresh	€ 1.59
Alpro Oat drink no suger refrigerated	€ 2.29	Campina organic semi-skimmed milk unrefrigerate	€ 1.25
Alpro Soy drink light	€ 2.09	Campina organic whole milk fresh	€ 1.55
Alpro Soy drink no sugars	€ 1.69	Campina semi-skimmed milk fresh	€ 1.45
Alpro Soy drink original	€ 1.75	Campina semi-skimmed milk unrefrigerated	€ 1.39
Alpro Soy drink original fresh (refrigerated)	€ 2.09	Campina skimmed milk unrefrigerated)% fat	€ 1.39
Alpro This is not m*lk semi-skimmed	€ 1.99	Campina whole milk unrefrigerated	€ 1.49
Alpro This is not m*lk whole	€ 2.09	Zaanse Hoeve semi-skimmed milk fresh	€ 0.99
Oatly! Fresh Oatdrink (refrigerated)	€ 1.99	Zaanse Hoeve skimmed milk fresh	€ 0.79
Oatly! Fresh Oatdrink organic	€ 2.09	Zaanse Hoeve whole milk fresh	€ 1.05
Oatly! Fresh Oatdrink semi-skimmed (refrigerated)	€ 2.05		
Oatly! Oatdrink barista edition	€ 2.05		
Oatly! Oatdrink organic	€ 1.99		
Wunda plant-based drink original	€ 2.62		
Wunda plant-based drink unsweetened	€ 2.57		
Average price per liter	**€ 2.04**	**Average price per liter**	**€ 1.28**

While in 2001 the ministry of Dutch Agriculture already advocated for a change in livestock production, the sector only seemed to intensify further during the next decade (Ankersmit, 2010). Even more so, despite unstable milk prices caused by the global economic recession of 2007, the dairy industry in the Netherlands remains strong in the 2000s, and consumers remained skeptical regarding the use of soy products as dairy substitutes ("Meer met melk", 2007; "Ongekend optimisme", 2007; "Ministers en boeren voor vorm bijeen", 2009; "De wonderboon bestormt Nederland", 2007; Van Zuilen, 2009). However, during the second half of this decade, the dairy industry started to notice the first signs of competition of PBD substitutes, mainly established regime actors such as WhiteWave (which was owner of Alpro before it was purchased by Danone in 2017), but also from other incumbent Avebe, who was also an early adaptor with activities in protein extraction ("De wonderboon bestormt Nederland", 2007; Engwerda, 2007). This also showed the start of large incumbents operating in both the regime and the upcoming PBD niche, thus getting involved in the PBD industry. However, no entrepreneurial activity (F1) was coming from start-ups yet.

While the environmental challenges around the global livestock production were already recognized in academic literature (Elferink, Nonhebel, & Moll, 2008) (Voorburg, 1991) (Olesen & Bindi, 2002), (Stoate, et al., 2001) (Tilman, 1999), the concerns of environmental impact and animal welfare for the dairy

industry became increasingly present in the media in the period 2006-2015 (Severt, 2006; "Zuivelsector kan in 2020 energieneutraal", 2008; Van Keken, 2008; Veldman, 2009; "Vooral geen beelden", 2009; Ankersmit, 2010; Van der Horst, 2010; Ter Horst, 2011). As mentioned, with publishing "Livestock's Long Shadow" (Steinfeld, et al., 2006), the FAO created more awareness on the relations between environmental impact, livestock industries, and climate change (Tziva et al., 2020). This created a starting point for the function guidance of the search (F4) to show first signs of improvement. However, governmental intervention so far was absent ("EU moet consumptie vis en vlees terugdringen", 2011; "Partij voor de Dieren pleit voor vleestaks", 2011; Thieme, 2013; Van Dinther, 2014). In response to these increasing concerns and pressures on the livestock industry to reduce its negative impacts, the discussion of sustainability in meat production increased among societal organizations and political parties (Tziva et al., 2020). In 2008, the publication of the public document "Project Protein Transition" (PPT) emphasized the need for efforts into responsible ways of protein provision (Hoogland et al., 2008). While the PPT report acknowledged nuances of the environmental impacts of meat, dairy, beans and other protein sources, the document mainly revolved around the concept of decreasing meat consumption. This also became evident in news and other publications, where the concept of the protein transition revolved mostly around proteins from meat products ("Twee ton voor studie naar vleesconsumptie", 2008; Severt, 2009a; Severt, 2009b). The publication of the PPT initiated a period where the need for a protein transition was acknowledged more on both national and European policy levels. For example, in October 2008, the Dutch government invested €200.000 in the research for decreasing the meat consumption. Furthermore, in 2009, the Dutch Arable Farming Union (NAV) pleaded for a plan regarding the cultivation of plant-based proteins, as the EU had no stimulating policies for such activities (Veldman, 2009). Additionally, in 2011, the Netherlands Environmental Assessment Agency (PBL) called for a European collaboration to reduce the production and consumption of animal-based proteins, after which the CAP was announced to be revised in the upcoming years ("EU moet consumptie vis en vlees terugdringen", 2011). However, despite policy intentions to enhance the sustainable performance of the Dutch protein provision and consumption, actions were contradictory as none of the mentioned advocacies led to actionable interventions. This is in line with the barrier *misalignments between long-term policy goals and national or EU policies or interventions* of the function guidance of the search (F4), which was identified by four out of the nine interviewees. While this barrier already was evident during the first period, respondents still deemed it relevant in the present, as today's ecosystem still lacks clear policy interventions that stimulate the uptake of PBD products on the one hand, but also the embedded price protection in the dairy industry on the other. Even in 2017, the then new Dutch coalition agreement did not explicitly acknowledge any vision for changes to a sustainable food system with more plant-based foods (Laugs, 2017).

Nevertheless, the first signs of the protein transition as we understand it today were showing during the end of the 2000s and the topic became more relevant over the years.

Meanwhile, the region of Food Valley, that already existed in the late 90s, was attracting more business and knowledge organizations, and more collaborations regarding sustainable food provision were established (Visser, 2006; Otma & Fortuin, 2013; "Ambities in FoodValley regio", 2015; Huibers, 2020), which were positive developments in terms of market formation (F5), but also of knowledge development and diffusion (F2 and F3). In 2017, The Protein Cluster was established, an innovation platform where companies can collaborate and innovate to provide plant-based alternatives for protein sources (Leeflang, 2017). From this year onwards, the term "dairy alternatives" was increasingly incorporated in the discussion of the protein transition (Koonstra, 2018). More importantly, the European Parliament started advocating for policy programs regarding the European protein cultivation, as to become less dependent on protein sources coming outside of the EU (Braakman, 2018). Such events showed further positive developments of the guidance of the search (F4). Increasing relevance of the subject also became evident with Wageningen University investing €5 million into research for the protein transition in October 2019 (Smid, 2019), and with pilots starting in the province of Flevoland for cultivation of Dutch soy ("Telers doen proef met verse soja", 2019), thus showing stronger resource allocation (F6). In May 2020, their European Commission presented her Farm to Fork Strategy (FFS), as part of the Green Deal, which aimed to address the challenges of sustainable food provision in Europe and, as part of that goal, acknowledged alternative protein sources as a key area of research (European Commission, 2020; Van Gruisen, 2020). In September 2020, in response to the European FFS, Dutch minister Carola Schouten announced the ambition to focus on sustainable production of alternative proteins, for livestock feed as well as human consumption (Van der Aa, 2020), which led to the National Protein Strategy being published in December 2020 (LNV, 2020; Braakman , 2020). The NPS made for a pivotal point between two periods, as the data after this date showed developments for all system functions, which will be elaborated later in section 4.4.

4.3.2 Lawsuits and lobbying: increasing pressures on the dairy industry and the upcoming of the plant-based niche

Since the rise of the plant-based niche, an ongoing "battle" with the larger dairy sector seemed to be portrayed in the media, affecting both the guidance of the search (F4) and on the creation of legitimacy (F7). Already in 2006, the first case started when WhiteWave promoted their plant-based "milks" of their brand Alpro as healthier by containing no cholesterol, after which the Dutch Dairy Association (NZO) responded with a lawsuit (Reijnders, 2006). Starting in period 2016-2019 however, the conflicts

of interests became more evident, mainly through two themes. The first theme relates to the national dietary advice of the Dutch Nutrition Center (Voedingscentrum) which is provided through the Wheel of Five (Schijf van Vijf), an information model that provides recommendations for healthy food consumption (Boer et al., 2016). In 2016, the recommendations for this model were adapted for the first time in twelve years, with the most noticeable insight of "less meat and more plant-based" ("Nieuwe Schijf van Vijf", 2016). As with the protein transition, the focus remained on decreasing meat consumption at this point. In this case, the NZO represented the interests of the dairy sector by being involved in the discussion through lobbying, which lead to refraining the Nutrition Center from advising against dairy consumption (Van Nierop, 2015; "Nieuwe Schijf van Vijf", 2016). The second, more elaborate conflict of interests, regards to the so-called "dairy censorship", which relates to the use of dairy-related terms for plant-based substitutes. The first signs of this dispute showed in the US in 2010, when the American National Milk Producers Federations filed a request at the Federal Drugs Administration (FDA), to prohibit the use of the term "milk" for plant-based alternatives ("Amerikaanse zuivelaars: sojadrank is geen melk", 2010). However, the discussion in Europe was ignited in 2017, when the Court of Justice of the EU ruled that dairy-related terms such as "cheese" or "milk" cannot be used for plant-based products, with exception of several products such as "peanut butter" or "coconut milk", among others (Tuenter, 2017). In 2019, the European Parliament went even further by proposing additional restrains with Amendment 171, as to prohibit the imitation or imagery of dairy products, which potentially could have gone as far as to ban the packaging of plant-based substitutes for looking similar to those of dairy products (European Parliament, 2019). An ongoing conflict of interests unfolds, with organizations as the NZO and the European Dairy Association (EDA) on one side and plant-based producers and NGOs on the other (Van der Horst, 2020; Van der Boon, 2020). In 2020, the European Parliament decided for stricter rules regarding PBD products but allowed for meat substitutes to use meat-related terms, such as "veggieburger" (Daamen, 2020; Obdeijn, 2020). In 2021, after joint efforts of plant-based organizations such as Proveg, Oatly and other parties, the European Parliament withdrew their proposal of Amendment 171 (Van Dinther, 2021; Brandsma, 2021; Vermaas, 2021). While the conflicts between the dairy regime and the upcoming PBD niche were thus published in the media as the big "dairy censorship", only one of the interviewees indicated the barrier *resistance of the dairy industry*, which relates to the function resistance to change (F7), to be a barrier to current developments of the PBD niche. Other interviewees did not acknowledge that the dairy industry could hamper developments of the PBD industry. Even more so, interviewees indicated that while these dairy incumbents may have been a hampering factor in PBD development through this dairy censorship, current involvements of those actors are a stimulating factor to the PBD innovation system. These involvements will be explained in the section 4.4.

4.4 Structural-functional analysis: 2020-present. The plant-based takeover

As mentioned, the publication of the National Protein Strategy (NPS) created a starting point for the present period. The data showed three prevalent subjects in which the PBD innovation system was developing during this time: PBD market developments with increased involvement by incumbent dairy actors, developments and diffusion of knowledge and resources, and increased alignment of visions, goals, and resource allocation for the PBD acceleration. This section will explain how the system structure and functioning progressed in these three subjects, alongside the accompanied system barriers that became evident during the data analysis.

4.4.1 PBD market developments and increasing involvement by incumbent dairy actors

One of the motivations for the NPS was Europe's weak global market position in the production of protein-rich crops (LNV, 2020). This also relates to the barrier of *missing business models for the transition of farmers,* of the function entrepreneurial activity (F1), which was identified by seven out of nine respondents. This regards the transition for farmers from their current business, whether this is livestock or other production, to the cultivation of protein-rich crops, for example leguminous plants such as field beans, peas, and lupine, among others. While the NPS provided strategies and examples for the commitment to producing local plant-based protein sources (LNV, 2020), a profitable business model for farmers thus far is absent. The NPS acknowledged the competition of cheap imports of proteins, as livestock feed as well as for human consumption, as an important barrier in developing a profitable revenue model for farmers. This applies to a large extent to imports from outside the EU, as well as (to a lesser extent) to imports from within the EU (LNV, 2020). The largest reason for the EU's dependence on imports of raw materials such as soy, was the introduction of the Blair House Agreement, the free trade agreement between the EU and the US, in 1992, which made it cheaper to get soy and grains for livestock feed from the US (LNV, 2020). As a result, many farmers in the EU are concerned about their competitive position when it comes to producing plant-based proteins, because of such international trade agreements.

> "*There is a reason that farmers are not changing what they put on their land now, because they are simply paid too little for it. In other countries, there are subsidies allocated to farmers. You could say we should subsidize our farmers to ensure they will grow other crops from which we can extract proteins. So, making sure the whole process is considered and factories are changed to process all of this. In that case, there is a responsibility for the government"* – KI1

The NPS responded to these concerns with proposing several possible solutions. First, it proposes to install stricter requirements for imported raw materials so that they become comparable with the minimum requirements for raw materials produced in the EU and the Netherlands, creating a global level playing field for the cultivation of protein-rich crops. After the introduction of the Farm2Fork Strategy (European Commission, 2020), the European Commission followed up on this by introducing a proposal that aimed at putting a halt to the import of raw materials, such as soy, that is related to deforestation (European Parliament, 2022). Second, the NPS proposed that when cultivating crops for protein production, in addition to proteins, other parts can also be harvested that can be brought to market value, such as oil, seeds, fibers, or chemical components for the processing industry. By doing so, the combined market value could be increased (LNV, 2020). Third, the NPS proposed increased research into improving the production levels, or yield security, of leguminous plants. Fourth, improvements of cooperation along the complete value chain were encouraged. Finally, the NPS acknowledged that farmers' business models could be improved if their produces were brought to the attention of consumers, thus proposing regular associated market research (LNV, 2020). While these recommendations represent intentions for improving farmers' business models, 44% of the interviewees identified the lack of interventions to support these plans.

While this European market position remains relatively weak due to import against low prices (Wolters, 2021), the European consumption of PBD products has increased compared to previous years. From 2019 to 2021, sales values of meat and dairy substitutes have increased with 50 percent (Kloosterman, 2021c). Supermarkets seemed to have noticed an increase in demand for plant-based products (Kloosterman, 2021d; "verdubbeld vega aanbod", 2021; Grimm, 2022). In the Netherlands, there was overall increase of demand for PBD products (Braaksma, 2021; "Gezond bakkie?", 2022), and themes such as animal welfare, environmental responsibility and good governance, and local and natural production became increasingly important for consumers (Hillhorst, 2021; Kloosterman, 2021f), strengthening the market development (F5) of PBD products. However, despite increases in consumptions, data from the interviews showed several barriers related to consumer demand. The first barrier is *the consumer demand and intention gap* of the function market formation (F5), which was acknowledged by five out of nine interviewees. This intention gap refers to the difference in consumers' intention of buying more sustainable food options and less animal products, and their behavior of actual purchase and consumption (Vermeir, et al., 2020). Furthermore, it refers to the PBD demand that is still relatively low compared to dairy products. In turn, this is related to the next barrier*, information provision to consumers* of knowledge diffusion (F3), as 33% of the interviewees acknowledged that part of the reason for this intention gap, is a lack of sufficient general knowledge regarding environmental and animal welfare impact and nutritional values. The final, and most important, barrier related to

consumer demand is *nutritional parity*, which causes resistance to change (F7) for consumers. This barrier was identified by all the interviewees. The concept of nutritional parity revolves around the challenge for PBD alternatives to mimic the looks, taste, feel, and nutritional values of regular dairy products. Nutritional parity complies of two aspects. On the one hand, it regards the nutritional values of PBD alternatives. Interviewees acknowledged alternatives to traditional dairy products have a nutritional content that is of significant lesser quality compared to cow dairy products. They either contain too much sugar, starch, salt, or fats, and almost always too little or no protein. To improve these aspects, the second part of nutritional parity becomes a challenge. Here, the obstacle of organoleptic properties arises, which entails the taste, texture, mouthfeel, sight, and smell. When increasing the protein content, the plant-based products are subject to a dryer mouthfeel and a lesser taste.

> *"The consumer decides. In the end, the consumer decides what he does or does not choose, but that is stimulated by retail, which products are incorporated in their assortments, and in terms of price. They* [supermarkets] *can take that into account. It is the case that plant-based drinks are relatively expensive, and one could increase consumption fastest through the price. The production costs are quite low, so there are huge margins on that part*" – AG2

> *"What you see is that you can't just cram more proteins into a product without affecting organoleptic properties: taste, mouthfeel, etc. That's a challenge, to understand how to still make a nice drinkable, creamy milk product. I say milk, but I mean substitute. That is particularly important for milky products, that mouthfeel. That you don't have a dry mouthfeel or that you can actually taste bits and pieces. And of course, the general taste, meaning it doesn't taste like dirty pea soup if you made something on a pea basis."* KI1

> *"With plant-based products, if the consumer still sees a dairy alternative as a white, dairy-tasting, creamy product, then they will be disappointed with plant-based proteins. So, you also must adapt a lot in terms of color, smell, taste, and texture in order to eventually be able to meet those properties."* RMP1

As for the market development through activity of business actors, the years leading up to 2020 already showed signs of entrepreneurial activity (F1), for example through the establishment of various Dutch PBD start-ups, as shown in Table 5. However, the barrier *transition from start-up to scale-up* the function entrepreneurial activity (F1), was identified by 78% interviewees as a barrier that is still relevant today. While respondents indicated the Netherlands to have a good entrepreneurial ecosystem, the process for start-ups to upscale their business was evaluated rather slow. This was blamed partially on new

businesses prioritizing certain aspects too soon in their business development, leading to them skipping important steps and focusing on commercializing and expanding too soon. Because of this inconsistent growth, these businesses are at risk for not being well-equipped to successfully apply for financing at the right time or for lacking knowledge and support to make progress in the valorization of their business. Other explanation given by interviewees are related to the formalities that come with setting up or scaling up businesses in the Dutch business ecosystem, which is a slow process, and with a lack of governmental support in the scale-up phase.

> *"There are many interesting companies in the Netherlands, and many start-ups. But the step from start-up to scale-up takes a very long time. If you compare it with England, Germany, or the UK, it sometimes takes six times as long before start-ups take the step to scale-up"* – INV1

> *"There is a lot there for companies to use, I think it's more just the actual mechanics of stepping up and running a company. That's the bit that is so formal. We've taken nine months to do our latest round and four to five months was just paperwork. I would say that of the €2 million we've raised, €150k was on legal fees"* – SU1.

Another barrier to the market formation (F5) that 44% of the interviewees identified, relates to the *conservative investment culture in the Netherlands.* Respondents pointed out the difference in the investing culture of the risk-averse Netherlands, versus more risk-taking countries such as the US or the UK. A result of this, can be that Dutch startups move their business outside of the Netherlands if those countries are willing to invest in their propositions. An example of this happening is Dutch startup Plantible Foods, that moved their innovative business around the protein RuBisCo to the US in 2017, because "innovation in Europe just goes very slow" (Meyer, 2021).

> *"In terms of private financing, it is quite conservative. If you look at the propositions available in the Netherlands regarding development and the investments that are eventually made, and compare them to other countries such as Germany, the UK, or the US, we are very conservative. I believe we should certainly take more risk in that regard. However, this also has to do with the culture that prevails in Europe itself. Europe itself is quite risk averse. If you compare it with the US, for example, failure is not seen as something negative. It is perceived more as a learning moment, meaning that the moment you fail, it's fine. Better next time. It has no effect on raising funding. While here in the Netherlands, the investments entail smaller amounts, because larger amounts are considered*

dangerous. People would like a company to be at TLR [technological readiness level] *level six or higher, so it is quite successful. Only then do they want to invest"* – INV1

Nevertheless, the period of December 2020 – present showed more entrepreneurial activity through increased technological innovations and advancements by the introduction of new types of PBD products and ingredients ("Dr. Oetker bakt nieuwe taarten", 2021; Verhaest, 2021; Violife ontwikkelt plantaardig alternatief", 2021; "FrieslandCampina: in tweede helft", 2022), the opening of more vegan restaurants (Rothoff, 2021; Kuijpers, 2022; Obdeijn, 2021; Hofman, 2021; Veldman, 2021) and the expanded assortments of existing supermarkets with a larger variety of PBD products (Mons, 2021; Olthuis, 2020; Voois, 2020; "Consument kan met Flora Plant", 2020; Violife ontwikkelt plantaardig alternatief voor roomboter, 2021). Furthermore, this period showed an increasing number of soy cultivators in the Netherlands and dozens of plant-based companies and institutes that moved to the Foodvalley NL business network (Van der Velden & Smit, 2021; Kuijpers, 2022). Above all, the most noticeable shift in market developments during this time, was the increased involvement in PBD products of large regime incumbents such as Danone, DSM, Arla, and Westland Cheese, among others (Schelfaut, 2020; Van Velzen, 2020; Kloosterman, 2021e).

"The fact that they [FrieslandCampina]*, as a cooperative, have decided to put plant-based proteins on the market, is a very big step. It seems cautious, but of course it is gigantic. That is THE dairy company of the Netherlands, and that they have somehow become willing to go plant-based, really says something"* - KI1.

Examples of increased market involvement by incumbents are Danone taking over WhiteWave, which includes Alpro (Tuenter, 2020), DSM opening factory for producing plant-based protein CanolaPRO, which can be used as raw material or ingredient for PBD products ("Fabriek DSM voor plantaardig eiwit", 2020), and Unilever introducing vegan ice creams from Magnum and Ben & Jerry's (Van Velzen, 2020). Table 7 provides more examples of incumbents' activities PBD developments. Even the largest dairy cooperative of the Netherlands, FrieslandCampina, became increasingly involved in PBD products. While in 2018 the company's CEO claimed to monitor plant-based alternatives with the goal of offering better alternatives (Van der Horst, 2018), this attitude changed when in August 2021, when the organization stated to be looking at the developments for vegan variants of their brands such as Chocomel and Campina (Schelfaut S. , 2021). Not much later, in February of 2022 they announced the introduction of a plant-based whipped cream for the B2B market and the plan to produce a plant-based chocolate milk to be available in supermarkets by the second half of 2022 (Van Der Meulen, 2022; Melkvee.nl, 2022). In May 2022, FrieslandCampina quickly followed up on this promise by launching an

oat-based coffee creamer in Dutch supermarkets (Van der Meulen, 2022). Six out of nine interviewees also named these developments as an important indicator of change. Increased activity for the functions of entrepreneurial activity and market formation in this period also is visible in Figure 2, where performances of both functions over the years is shown. However, two respondents were concerned of the barrier *risk of greenwashing instead of a shared responsibility by involved large incumbents*, relating to the guidance of the search (F4). One respondent elaborated on this by stating the following:

> "*I welcome them, I don't necessarily mind what the motive is. It has to be encouraged in this transition. I just hope that we don't go from one industrial monoculture of farming to another. If they are going to go into these things, let's make them regenerative, nutritious, and low in emissions. The problem with big food, is that it usually just copy-pastes whatever it does. It doesn't really learn its lesson. I'm encouraged by it, but they need to change their entire mindset if they want to do it, and actually have a positive impact. If they make a non-nutritious, soy-based milk that is coming from the other side of the world, that's not solving the problem. It requires some depth of thought, and it requires a different approach."* – SU1

Table 7. Examples of incumbent actors' activities regarding PBD developments

Month	Year	Involvement incumbent actors
December	2020	Dairy incumbent Westland Cheese and start-up Those Vegan Cowboys are collaborating to produce plant-based cream cheese
May	2021	Dr. Oetker introduces vegan cheesecake
July	2021	Alpro introduces new product NOT MLK, a plant-based milk alternative
July	2021	Restaurant chain the Yoghurt Barn aims at becoming completely plant-based
August	2021	Supermarket Albert Heijn doubles vegetarian and vegan assortment
October	2021	Violife introduces plant-based butter Vioblock
November	2021	Oatly opens factory in Netherlands
November	2021	Dutch retail chain Zuivelhoeve collaborates with vegan cheese brand Max&Bien
November	2021	DSM acquires Norwegian Vestkom Milling, which produces proteins from peas and beans
December	2021	Dairy incumbent DMK, owner of DOC Cheese, acknowledges need for production of plant-based products
February	2022	FrieslandCampina introduces plant-based whipped cream for B2B market
February	2022	FrieslandCampina announces production vegan chocolate milk

February	2022	DSM announces to start production CanolaPro by the end of 2022
February	2022	Agrifirm announces collaboration with start-up De Nieuwe Melkboer for developing soy crops that are appropriate for Dutch climate

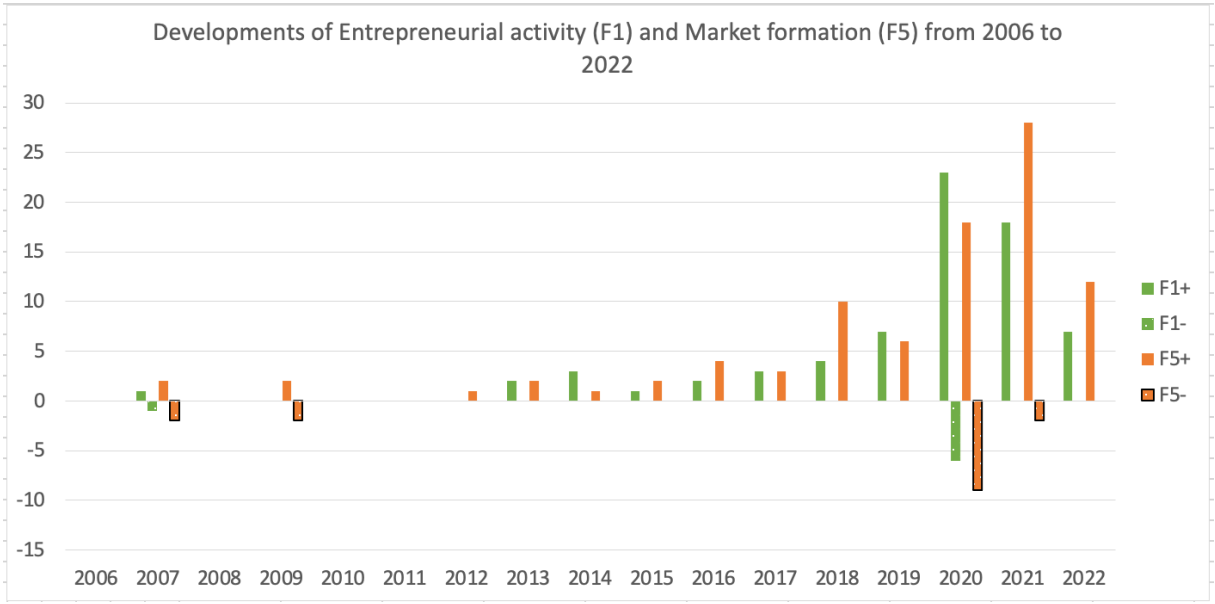

Figure 2. Developments of Entrepreneurial activity (F1) and Market formation (F5) for the PBD innovation system from 2006 to 2022. The X-as shows each year, the Y-axis shows the number of events from the event-history analysis per function.

4.4.2 Developments and diffusion of knowledge and resources for the PBD acceleration

The data analysis showed that the Netherlands, largely because of Wageningen University, is seen as one of the frontrunners when it comes to developments in plant-based nutrition. (Van der Velden & Smit, 2021). Six out of nine Interviewees indicated that the level of knowledge development and diffusion (F2 and F3) for PBD products is evaluated as strong in the Netherlands. As mentioned, from 2017 onwards, the concept of dairy substitutes became increasingly present in discussions on plant-based proteins, as was shown in the data. Furthermore, the publication of the NPS in 2020 has led to more research projects and collaborations for knowledge development and diffusion regarding the protein transition, for both meat and dairy substitutes (Goudsmit, 2020; Brinks, 2020; Schelfaut, 2019; Traverse, 2020; Braakman, 2020). One example of such collaborations is the regional innovation program “Fascinating”, which stands for Food Agro Sustainable Circular Nature Technology in Groningen (“Boost voor eiwittransitie Groningen”, 2020). In this program, large incumbents Cosun, Avebe, Agrifirm and even the largest dairy cooperative FrieslandCampina are involved in research into cultivation of new protein-rich crops, with a budget of €10 million for the first three years (“Boost voor eiwittransitie Groningen”, 2020).

"It [the amount and quality of knowledge development in the Netherlands for the plant based dairy industry and flows of knowledge exchange] *is very high. Compared to other countries, we are at the top of protein transition research … We are a highly educated country. People around Wageningen University and Food Valley, are highly educated and there are many companies there that move there, meaning that knowledge remains within the Netherlands. You can see that this is attracting internationally. It is true that if you look at food technology at a global level, Wageningen is at the top, or in the top three"* – KI1

Despite strong knowledge development in the Netherlands, 67% of the interviewees indicated *information flows or knowledge gap between business and knowledge institutes, and conflicts of interests among system actors* to be a barrier for knowledge development and diffusion (F2 and F3). This knowledge gap refers to disparities between fundamental and applied research and entrepreneurial developments, meaning that the valorization or the entrepreneurship that should follow from research is often missing or not stimulated. Additionally, one respondent indicated that conflicts of interests can arise because of intellectual property (IP) rights, as the IP system in the Netherlands is very complicated, resulting in competition.

"I think it mainly comes down to communication and the willingness to work together in that regard. I think there is still a knowledge gap between the universities and the application of that knowledge. Large companies often have access to university, but it quickly becomes more difficult for SMEs. So, how do you valorize those insights? Much more could be done with that. The dialogue between scientists and those who will commercialize it should be much improved" – INT1

Furthermore, one interviewee indicated that while there is sufficient knowledge development amongst stakeholders of the PBD innovation system, actors that are not yet part of that network (farmers, small businesses, consumers, etc.) can have a hard time gaining access. One interviewee was even critical on innovation platforms such as the Protein Cluster, by stating the following:

"They are [the Protein Cluster] *not that important. That's well-intentioned marketing, that's making sure that small businesses know where to find us and that they can help us, especially start-ups. But a cluster stems from 1990-1995, or at least long ago. The same goes for Food Valley and all those others ... All that clustering happening is old thinking … People who want to do something together will find each other; you don't have to organize clusters for that*" INNO1

However, overall, most interviewees did not identify knowledge development and diffusion (F2 and F3) to contain the largest barriers. Even more so, 7 out of 9 interviewees expressed optimism regarding current innovation projects and future technological developments regarding PBD alternatives. Figure 3 also shows these increased performances of both functions over the years.

The function of resource mobilization (F6) has also improved this period, as the data analysis showed increased events related to the allocation of physical, human and financial resources. This improved function performance also shows in Figure 3. Examples of such events are investments into technological PBD developments, opening of plant-based ingredient factories, collaborations between organizations to further develop PBD alternatives, or governmental investments for research and development of the protein strategy. To stimulate research & development into the protein transition, Dutch governmental bodies have allocated various subsidies, as elaborated on in Table 8. However, while the Dutch government has allocated significant investments towards innovation programs for plant-based alternatives, within the function resource allocation (F6) 44% of the interviewees still indicated *lack of governmental support through subsidies* as a barrier, and 33% named the *lack of financial resources and high costs of technological innovations*. Respondents noted that this is partly due to misallocations or inefficient use of those funds. One respondent provides the following explanation:

> *"That* [€25 billion to agricultural transition] *is an incredible fund. I think that is worth noticing as a starting point. But it's misdirected. All it's been used for is just to buy up farms. We've had the chance to speak to a lot of farmers … There's a lot of them that want to continue farming and would love to use that budget to transition … I think it's a good initiative but it's not being used in an intelligent way, or not in enough different ways. We, for example, are now using* [crop-type] *as our main base ingredients. The reason we've selected those, is that we can grow them in the Netherlands …That is the kind of thing that the government should be encouraging for farmers to do … So, the government talks about all these things, but when it comes down to it and you give them a part of the solution, they don't act upon it"* – SU1

Besides inefficient use of available funds, these barriers also relate to the barrier of entrepreneurial, *transition from start-up to scale-up,* as interviewees identified a role for the government to overcome this barrier in providing the right resources for upscaling. Furthermore, because of the high-tech innovations regarding PBD alternatives, interviewees acknowledged the high costs of technological innovation also as a barrier, as larger scale production is needed to lower these costs. This in turn is also reflected in the *price differences between BPD products and dairy products.* Finally, two out of nine

interviewees identified the resource mobilization barrier of human capital, being *lack of talents* as a barrier, relating to there not being enough employees with the necessary knowledge for PBD acceleration.

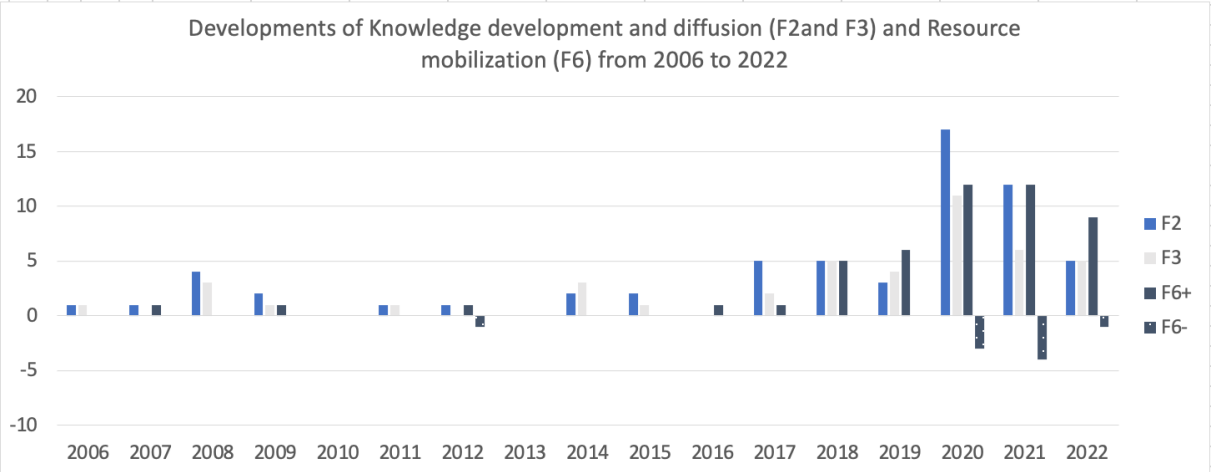

Figure 3. Developments of Knowledge exchange and diffusion (F2 and F3) and Resource mobilization (F6) for the PBD innovation system from 2006 to 2022. The X-axis shows each year, the Y-axis shows the number of events from the event-history analysis per function.

Table 8. Subsidies for R&D into protein transition Netherlands that became evident from EHA analysis

Month	Year	Reference	Description
April	2021	(Vos, 2021)	Province of Groningen provides subsidy of €800.000 to innovation project Fascinating
April	2021	(Van Dijk, 2021)	€13,6 million subsidy of Dutch government to Foodvalley, to start their program Food Valley 2030 on the protein transition
October	2021	(NIZO, 2021; European Union, 2021)	As part of the REACT-EU program, a subsidy of €5.000.000 is granted to research center NIZO for project SPRINT. This project aims at improving the sustainable food production and a main pillar of this project regards the transition to plant-based materials in food production.
December	2021	(Nieuwe Oogst, 2021)	Provincial government of Groningen invests €265.000 in protein transition. €240.000 is dedicated for experimental cultivation research of program Fascinating and €25.000 to Food Valley for The Protein Cluster
December	2021	(Wolters, 2021)	Dutch cabinet allocates €25 billion fund to the transition of Dutch agriculture, incorporating five themes: nitrogen reduction, climate policies, business models, food policies, and circular agriculture.

4.4.3 Visions on PBD market development and counteracting resistance to change

As discussed, the Farm2Fork Strategy of the European Commission and NPS made 2020 a pivotal year for ambitions of the protein transition, as they represent both European and national long-term visions for the developments towards an increased plant-based consumption and production (Braakman, 2020; Janssen, 2021), meaning a better performance of the guidance of the search (F4). Furthermore, PBD producers and NGOs have actively protested Amendment 171, regarding the "dairy censorship'. Over 333.000 signatures were collected for a petition to renounce the amendment (Kloosterman, Vega-producenten vechten tegen 'zuivelcensuur', 2021b), with positive outcomes that strengthened the function creation of legitimacy/counteract resistance to change (F7). Furthermore, the plant-based niche stepping out of its "dull" image and becoming more mainstream over the years, also improved this function. However, the functions of guidance of the search and creation of legitimacy faced both positive and negative developments over the years, as is shown in Figure 4. As the figure shows, this polarization grows gradually, but increases from the years 2016 and 2017 onwards, which is in line with the developments of the "dairy censorship". In 2021, the network initiative "The protein farmers of the Netherlands" (De Eiwitboeren van Nederland) was founded by FoodvalleyNL, to give substance to the National Protein Strategy, again positively affecting the guidance of the search. By creating more awareness about protein crops and making connections with processors, producers, end suppliers and consumers, they aimed to arrive at a revenue model with fair prices for farmers and other parties in the chain ("Telers van eiwitgewassen verenigen zich", 2021). The visions regarding the protein transitions are being made aware more to the public, for example with supermarkets taking on more responsibility in promoting plant-based diets and with the Dutch national challenge "a week without meat" being changed to "a week without meat and dairy" (Van Woensel, 2022; Kloosterman, 2022g; van den Berg, 2022). While this not yet shows in the actual consumption of plant-based or animal-based products, consumers seem to be increasingly willing to swap meat or dairy products for alternative protein sources (Schotman, 2021). Furthermore, six out of nine Interviewees noted that they believed the visions and expectations of actors involved in the PBD innovation system to be sufficiently aligned to increase the relative consumption and production of PBD alternatives in the Netherlands. In their explanation as to why, consortia, innovation platforms or collaboration projects such as the Protein Cluster, Fascinating and Food Valley were often named, alongside the involvement of dairy incumbents in the protein transition. This involvement of large incumbent organizations also contributed to a clearer vision on how the PBD market and industry should develop, as became evident in the previous section on market developments. Despite these improvements along guidance of the search (F4), the barrier of *misalignments between long-term policy goals and national or EU policies or interventions* is still present in this period. Furthermore, interviewees identified several barriers related to resource mobilization

(F6), that still hamper the PBD acceleration. The first relates to *limited capabilities in use of land,* referring to the already limited and intensively used agricultural land in the Netherlands, and was identified by 44% of the respondents. Furthermore, *limited resources for production* was indicated to be a barrier by one respondent and refers to the risk of having to use for example too much water for production of PBD innovations, making them unsustainable in other aspects. Interviewees indicated that the Netherlands is challenged by its limited available area of land. System actors active in agricultural activities emphasized this by acknowledging the trade-offs that need to be made when opting for the purposes of agricultural land. With this, it was also recognized that there are significant technical complexities when it comes to switching from one agricultural practice to another. Two out of eight respondents also named the current *resource scarcity and high material costs because of the war in Ukraine*, as this conflict put a lot of pressure on current agricultural and food systems. Circumstances such as described here ought to be considered during developments related to the guidance of the search of the PBD innovation system.

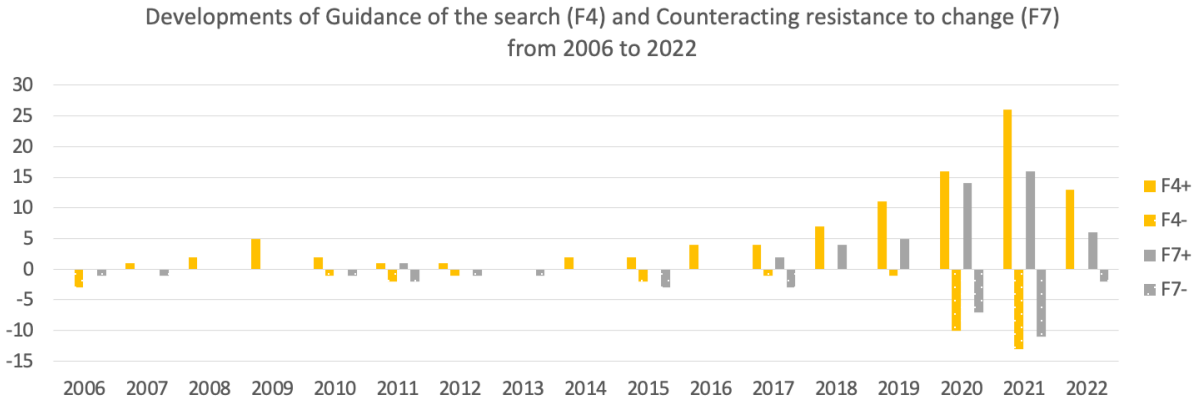

Figure 4. Developments of Guidance of the search (F4) and Counteracting resistance to change (F7) for the PBD innovation system from 2006 to 2022. The X-axis shows each year, the Y-axis shows the number of events from the event-history analysis per function.

4.5 Blocking mechanisms and drivers

During the structural-functional analysis that has been described in this chapter, a total of 18 barriers related to the system functions were identified and described. Of those 18 observed barriers, five were identified as high priority, five as medium priority, and eight barriers as low priority, as depicted in Table 9. The function counteracting resistance to change (F7) accounted for the only barrier that was identified by all interviewees, being *nutritional parity*. Other barriers of this function were of low priority. Within the function entrepreneurial activity (F1), both barriers were of high priority and mentioned by 78% of the interviewees, being *transition from start-up to scale-up* and *missing business model for transition of farmers*. Of the function market formation (F5), the barrier *price differences between PBD*

products and dairy products was mentioned by 78% of the respondents, making it of high priority. The other two barriers were of medium priority. The barrier *information flows/knowledge gap between business & knowledge institutes, and conflicts of interests among system actors* of knowledge development and diffusion (F2 and F3) was acknowledged by 67% of the interviewees. This system function also accounted for one barrier of low priority. The guidance of the search (F4) accounted for one barrier of medium priority, and one barrier of low priority. The function of resource mobilization (F6) contained two barriers of medium priority, and three barriers of low priority. The following section will elaborate on barriers with a high priority and link them to blocking mechanisms of systemic problems that lead to the acceleration of the PBD innovation system, which is also depicted in Figure 5.

The identified barriers may have systemic problems to the diffusion of PBD products in the Netherlands as a result, as several are related to institutional failures. This becomes evident in hard institutional failures of misalignments in governmental strategies and visions versus existing policies. While the Ministry of Agriculture, Nature and Food Quality provided its vision on the protein transition with their National Protein Strategy, current policy instruments seem to lack intervention or inefficiently provide support. While the increased policy involvement, with strategies such as the NPS, is a positive development and even a driver for the PBD transition, it has not yet reached its full potential. Even more so, the embedded supportive policies for the dairy industry contribute to low dairy prices and in turn for price differences compared to PBD products, as they do not benefit of such price supports. The three barriers *transition from start-up to scale-up*, *missing business model for transition farmers*, and *price differences between PBD products and dairy products*, of entrepreneurial activity (F1) and market formation (F5), are all strong barriers as they were all indicated by seven out of nine interviewees. The mentioned hard institutional failures also affect systemic capacity failures for both start-ups and farmers, as these involved actors are locked in a system that provides little incentive to change their current way of business due to the lack of profitability. Even more so, farmers are often subject to the business conducts of large incumbent cooperatives. Involvement of the large dairy incumbents can therefore be seen as a positive development for the PBD diffusion, as such cooperatives can "set the tone" for what and how they produce. More specifically, dairy incumbents have drastically changed their strategy regarding the plant-based transition. While these actors were either not involved in PBD products or actively taking part in the discussion on the dairy censorship in the years 2016-2021, recently various dairy incumbents introduced plant-based products, ingredients, or strategies. For the functions knowledge development and diffusion (F2 and F3), capacity and weak network failures can be identified for the barrier *information flows/knowledge gaps between business and knowledge institutes, and conflicts of interests among system actors*. As explained, this barrier comprises the disparities between fundamental and applied research, alongside the difficulties certain system actors experience

in gaining access to information or networks. This issue thus includes the capacity related systemic problem of actors having difficulties to learn from others on the one hand, and weak network problems because of the low connectivity between system actors on the other. However, during the interviewees, one of the respondents noted that there currently are several programs of field labs running to research where and how this valorization takes place. This shows positive interactions in these functions as well. Finally, the barrier of *nutritional parity* from creation of legitimacy (F7) has been identified as the strongest barrier, as both newspaper articles as well as all interviewees acknowledged the differences in nutritional value and other characteristics between PBD and dairy products. This can be related to the systemic problems of capacity, presence, and quality failures, as high technological costs of innovation and low prices support are part of the reason these PBD products are not yet up to quality standard compared to regular dairy products, which in turn affects the resistance to change of consumers.

Table 9. Overview of the barriers to acceleration of the PBD innovation system, linked to the corresponding systemic problems that are hampering further development.

Function	Barrier	Frequency	Priority	Structural Element	Type of systemic problem	Description of the links between the systemic problems
F1. Entrepreneurial activity	Transition from start-up to scale-up	78%	++	Actor & Institution	Capacity & hard institutional (presence & weak capacity) failures	Start-ups often mis-prioritize certain aspects when scaling up their business, miss financial support, and the process of scaling-up itself is very lengthy and formal in the Netherlands. This leads to start-ups having difficulties or taking a long time to transition to scale-up.
	Missing business model for transition of farmers (partially due to competition foreign countries with low crop prices)	78% (+NPS)	++	Actor & Institution	Capacity & hard institutional failures	Farmers are not receiving enough guidance or support in the transition to different agricultural practices, often leaving them to not be able to change their business in a profitable manner. This transition is also hampered by lower crop prices in other countries and low subsidy support from the Dutch government.
F2&F3. Knowledge development & diffusion	Information flows/knowledge gap between business & knowledge institutes, and conflicts of interests among system actors.	67%	++	Actor & Network	Capacity & Weak network failures	Disparities between fundamental and applied research and entrepreneurial developments, as well as certain actors not being part of networks or collaborations for PBD developments
	Information provision to consumers	33%	-	Network/Interaction & Institution	Strong network & soft institutional failures	

F4. Guidance of the search	Misalignments between long-term policy goals and national or EU policies or interventions	44%	+	Institution	Soft and hard institutional failures	
	Common vision/responsibility of involvement large incumbents: sustainable or greenwashing?	22%	-	Actors, Network/Interaction Institution	Soft institutional failures	
F5. Market Formation	Conservative investment culture in the Netherlands	44%	+	Institution	Soft institutional failure	
	Consumer demand & intention gap	56%	+	Actors, Institution, Network/interaction	Capacity, soft institutional & weak network problems	
	Price differences between PBD products and dairy products	78%	++	Institution/actor	Hard institutional & capacity failure	With production of dairy products being supported by European and national policies, and PBD products not receiving such support, prices of PBD products are much higher. Furthermore, these high prices also affect the consumer demand.
F6. Resource mobilization	Lack of governmental support through subsidies	44%	+	Infrastructure & Institution	Presence & hard institutional failure	
	Lack of financial resources & high costs of technological innovations	33%	-	Infrastructure & institution	Presence failures	
	Resource scarcity and high material costs because of war Ukraine	22%	-	Other	Other	
	Limited use of land	44%	+	Infrastructure	Presence failures	
	Limited resources for production	11%	-	Infrastructure	Presence failures	
	Lack of talents in NL	22%	-	Actors	Presence failures	
F7. Resistance to change	Nutritional parity	100%	++	Actors, Network/Interaction & Infrastructure	Capacity, presence & quality failures	Existing PBD innovations on the market are not yet of sufficient quality. With high technological costs of innovation and low price support, these products are not yet up to quality standard compared to traditional dairy products, causing resistance to change.
	Resistance dairy industry	11%	-	Network/Interaction	Weak network failures	

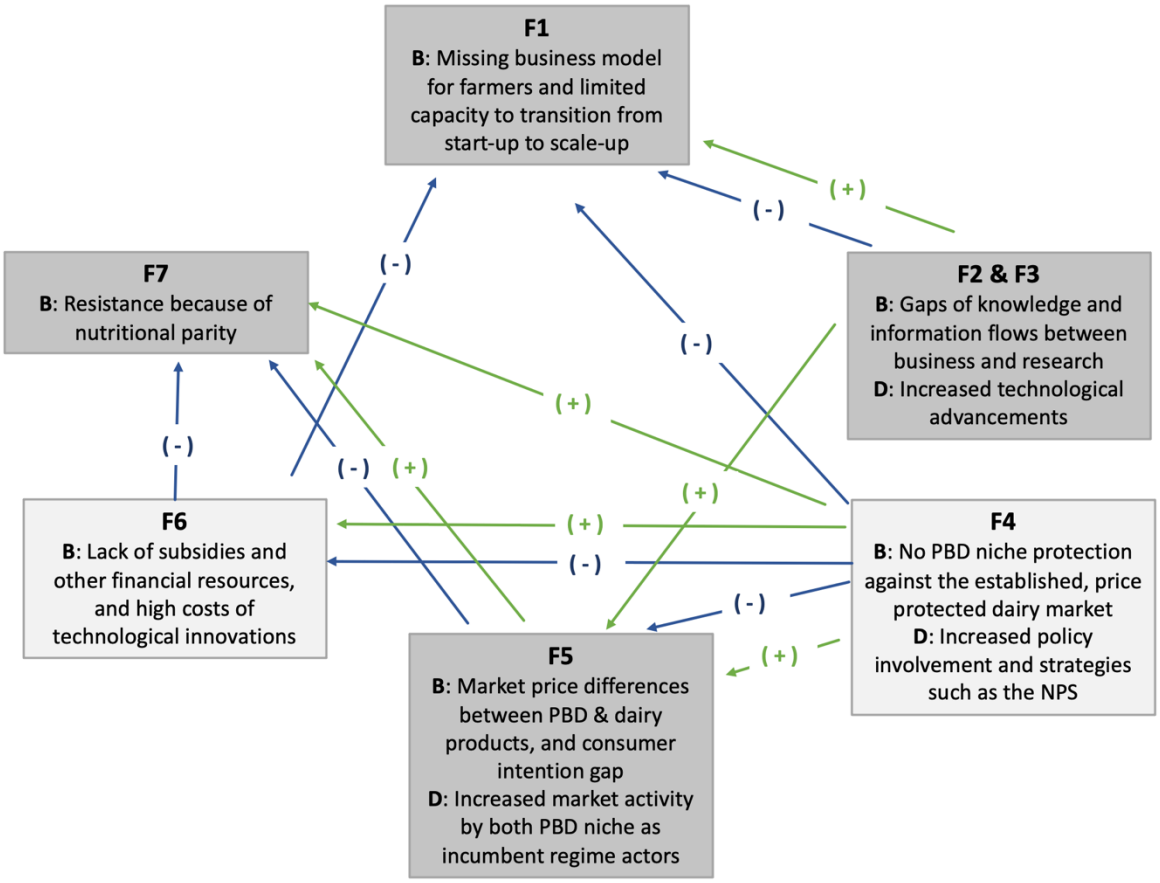

Figure 5. Blocking mechanisms and drivers to the acceleration of the current PBD innovation system in the Netherlands. "B" indicates a blocking mechanism, "D" indicates a driver. The blue arrows indicate blocking mechanisms between two functions, the green arrows indicate stimulating mechanisms between functions. Functions with dark grey indicate that they include barriers of high priority, and lighter grey indicates the inclusion of either medium or low priority.

Based on Figure 5 and on the theoretical notions of technological innovation systems, the identified blocking mechanisms and drivers to the PBD innovation system cannot be seen as independent from one another. Rather, the systemic barriers are related and each failure has its effect on another barrier. For example, the blocking mechanisms of entrepreneurial activity (F1) are strengthened by interplays of barriers related to lack of financial resources (F6), gaps of knowledge and information flows (F3), and to a lack of governmental support (F4). In turn, blocking mechanisms of guidance of the search (F4), do not only affect the innovation system's entrepreneurial activity (F1), but also market formation (F5) and resource mobility (F6). Therefore, while the aim of this study is not to propose intervention strategies, important to consider are conditions either reduce the strength of blocking mechanisms or reinforce driving factors. While the soft and hard institutional failures of guidance of the search (F4) were not identified as high priority, these systemic problems affect blocking mechanisms in three other system functions. Therefore, institutional conditions related to market protection and support for the PBD niche

or the dairy industry, subsidies for PBD development, and governmental strategies and interventions for PBD development can be seen as crucial aspects to the acceleration of the PBD innovation system. While this does not mean this is the only important aspect to be changed, the interdependence of system functions implies that improvement in one aspect can affect the performance of other system functions. This can, so to say, have the "wheel start turning".

5. DISCUSSION

5.1 Theoretical implications

The aim of this study was to research the development and diffusion of the PBD innovation system in the Netherlands, alongside identifying related barriers or systemic problems that prevent this system from further accelerating. This was done by studying both the upcoming PBD niche as well as existing dynamics of the established dairy regime in the Netherlands, with the fundamental theoretical concepts of the TIS framework and systemic barriers at its core. These insights have resulted in three findings or contributions to existing theory.

A first finding relates to the systemic specificities and structure of the PBD and dairy sector versus those of the energy and mobility sectors. TIS in the context of energy or mobility sectors often diffuse through patterns of radical innovations depending on new infrastructures and markets (Bergek et al., 2008; Hekkert et al., 2007; Tziva et al., 2020), where businesses often rely on in-house research and development and scientific innovations by research institutes and universities (Tziva et al, 2020). Furthermore, existing transitions literature, for example of the MLP, suggests that in time these niche technologies may go as far as to overthrow the established regime due to increasing pressures from both the niche and landscape level (Geels, 2002). In the case of the PBD and dairy sector, with a cooperatives' structure and deeply embedded hard and soft institutions, system actors, namely the farmers and smaller producers, are often dependent on actions and strategies of larger incumbents. This creates a situation where those producers can be locked-in, which results in them continuing with their current business and being unable to change. Furthermore, this research shows that transitions in this sector concern an ongoing institutional battle between the TIS and the existing regime. Moreover, this study shows that current established institutions that are benefiting incumbent actors which are unavailable for upcoming niche-technologies, can create a non-level playing field that may hamper niche-actors to scale-up or even hamper a regime shift. This relates to the second finding, which regards the role and dynamics of regime incumbents and existing institutions. The hard institutional failures for the TIS, that support practices of regime actors implies that those need to be changed in order to encourage a regime shift. While policies such as the European Common Agricultural Policy has provided

protection and support for agriculture in the EU, it has also contributed to current price differences between the large dairy sector and the PBD niche. While this study in no way suggests that these strategies should be abolished, it does acknowledge the need for revising and inclusion of more sustainable practices, as current policies are not sufficient to overcome this large differences. This is important because this study also showed that price differences between PBD and dairy products, lack of governmental support, and high costs associated to PBD production are one of the main barriers to the PBD innovation system.

The final contribution of this study regards that despite the mentioned institutional barriers, the technological aspects of nutritional parity remain crucial for the PBD innovation system to accelerate. These aspects cannot be seen as independent from one another, as technological innovation is closely related to high innovation costs, which in turn is linked to governmental support, and public and private investing. However, this research showed that the product itself, thus both nutritional value and organoleptic properties, compared to the dairy variant, is the essential factor for the acceleration of the PBD innovation system. Thus, while several critical systemic problems were identified during this research, the technological aspects that relate to the product quality remain essential for successful development. These technological properties of PBD products also relates to consumer demand. As was became evident during the interviews, nutritional parity is a crucial aspect for the potential increase in demand among consumers. Furthermore, some interviewees indicated that information provision to consumer could be improved for the uptake of PBD products. These aspects also provide implications for the role of consumers in the PBD transitions, as an increased demand is crucial for the market acceleration of the PBD innovation system.

5.2 Future research

As this study represents a single case study, future research could further investigate the implications for technological innovation systems in the food sector. Such research could unpack the institutional context of upcoming niche players and established regime actors and how these niche-regime interactions unfold, and which conditions are necessary for successful development of such a TIS. Moreover, while this research focused on the overall structural-functional characteristics and the accompanied systemic problems of the PBD innovation system, future research could also take on a more governmental perspective and explore the specifics of how certain policies or interventions should be approached for a successful transition. Finally, while barriers of limited land use were mentioned by several interviewees, this research did not focus on the geographical implications or other technological specifics of plant-based dairy alternatives, which could also provide valuable insights for future research.

6. CONCLUSION

This research aimed at studying the developments and diffusion of the PBD innovation system in the Netherlands, alongside the interactions and dynamics of incumbent actors of the established dairy industry. This was done by utilizing the TIS framework and the theoretical concept of system problems to innovation system development, which provided insights on how structural and functional elements of the PBD innovation system evolved and what type of barriers prevent PBD to accelerate on a larger scale. Accordingly, this study aimed to answer the following research question:

What factors are either hampering or stimulating the acceleration of the transition towards the plant-based dairy alternatives innovation system in the Netherlands?

This study concluded that while developments such as increased policy involvement and strategies, increased market uptake by incumbent regime actors, and advanced technological innovations are stimulating factors for the PBD innovation system, several systemic barriers are still present. Out of all the barriers that became evident from the data analysis, the following barriers were deemed as most prominent. The first relates to hard institutional failures that result in misalignments in governmental strategies and visions versus existing institutional policies and instruments for PBD development, alongside the supportive institutional environment for the dairy industry. The embedded institutional support that the dairy industry receives is also reflected in price differences between PBD products and dairy products. These lead to both an unlevel playing field between niche and regime actors as well as to systemic capacity failures for PBD start-ups and farmers. Moreover, the cooperative structure of the dairy industry also leaves Dutch farmers with little bargaining power and little incentive to change their business, creating a lock-in situation for these actors. The increased involvement of large incumbents in PBD products can therefore be seen as a potential watershed event for the uptake of PBD. Second, disparities in knowledge and information flows between industry actors and knowledge institutes are creating capacity and network failures, as there appears to be a low connectivity between fundamental and applied research, but also between system actors. The last, and most prominent, barrier relates to the nutritional parity of PBD products compared to dairy products, as this study identified that the technological properties of product quality are the most hampering factor in larger consumer uptake. This matter combines systemic failures of capacity, presence, and quality of actors, networks, and infrastructure.

In conclusion, not just actors of the PBD niche, but also established dairy regime actors can play a pivotal role in the acceleration of the PBD innovation system. This can be done through disrupting existing

institutional patterns that create large disparities between the dairy and PBD sector and disadvantages for PBD production, while simultaneously overcoming barriers related to business models for farmers and transitions from start-up to scale-up, closing gaps of knowledge between business and knowledge institutes, and overcoming barriers related to high costs of technological innovation and nutritional parity. For example, a starting point for disrupting existing institutional patterns could start with policy interventions or strategies that level the playing field for PBD products compared to dairy products. This can be done through closing the large price gaps by either stimulating the PBD industry with policy support in the form of subsidies or price support, or through adjusting the current price support system for dairy products.

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APPENDIX

Appendix A. Diagnostic questions and indicators

Table 10. System functions, indicators, and diagnostic questions for analyzing the functioning of the PBD innovation system (Hekkert et al., 2011, p.10).

Functions and indicators	Diagnostic questions
F1. Entrepreneurial activity	- Are these the most relevant actors?
- Actors present in industry (from structural analysis)	- Are there sufficient industrial actors in the innovation system?
	- Do the industrial actors focus sufficiently on large scale production?
	- Does the experimentation and production by entrepreneurs form a barrier for the innovation system to move to the next phase?
F2. Knowledge development	- Is the amount of knowledge development sufficient for the development of the innovation system?
- Amount of patents and publications (from structural analysis)	- Is the quality of knowledge development sufficient for the development of the innovation system?
	- Does the type of knowledge developed fit with the knowledge needs within the innovation system?
	- Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next phase?
F3. Knowledge exchange	- Is there enough knowledge exchange between science and industry?
- Type and amount of networks	- Is there enough knowledge exchange between users and industry?
	- Is there sufficient knowledge exchange across geographical borders?
	- Are there problematic parts of the innovation system in terms of knowledge exchange?
	- Is knowledge exchange forming a barrier for the innovation system to move to the next phase?
F4. Guidance of the search	- Is there a clear vision on how the industry and market should develop?
- Regulations, visions, expectations of government and key actors	o In terms of growth
	o In terms of technological design
	- What are the expectations regarding the technological field?
	- Are there clear policy goals regarding this technological field? - Are these goals regarded as reliable?
	- Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties?
	o Does this (lack of) shared vision block the development of the TIS?
F5. Market formation	- Is the current and expected future market size sufficient?
- Projects installed	- Does market size form a barrier for the development of the innovation system?
F6. Resource Mobilization	- Are there sufficient human resources? If not, does that form a barrier?
- Physical resources	- Are there sufficient financial resources? If not, does that form a barrier?
- Human resources	- Are there expected physical resource constraints that may hamper technology diffusion?

- Financial resources	- Is the physical infrastructure developed well enough to support the diffusion of technology?
F7. Creation of legitimacy/ counteracting resistance to change	- What is the average length of a project? Is there a lot of resistance towards the new technology, the set up of projects/permit procedure? o If yes, does it form a barrier?

Note. Adapted from "Technological Innovation System Analysis – A manual for analysts. Universiteit Utrecht: Faculty of Geosciences" by M. Hekkert, S. Negro, G. Heimeriks, & R. Harmsen, 2011, p. 10.

Appendix B. Interview guide

General questions (to be asked to all interviewees):

→*Goal: to create picture of perspectives on overall PBD development, relations/interactions dairy and PBD industries, evolution of PBD in NL, overall drivers, and barriers for PBD acceleration*

- How has your organization experienced the upcoming of the PBD trends in the market over the past years? (Increasing uptake/struggles to break through/popularity among businesses or consumers/etc.)
    - How has it been developing recently compared to five to ten years ago? (How have all these developments changed over time?)
- The Netherlands has one of the largest dairy industries in the world, how do you believe this sector could either contribute or hamper the evolution of the PBD industry? (Is it more of a threat to the PBD industry, or do the existing infrastructures/livestock agriculture offer opportunities for the dairy industry to contribute/switch to plant-based agriculture?
- How do you envision the evolution of the PBD industry and market in the Netherlands?
    - Which parties do you believe to be responsible to carry out the set goals for a larger share of plant-based consumption? (Governmental bodies, businesses, consumers, etc.)
        - How should these actors intervene in this evolution?
    - How do you envision the PBD industry to position itself compared to the dominant traditional cow dairy industry in the Netherlands?
    - What are, in your opinion, drivers or opportunities for the uptake of PBD?
    - What are, in your opinion, barriers or threats for the uptake of PBD?
- Do you believe the visions and expectations of actors involved (think of large diary/ PBD businesses, PBD startups, research centers, governmental bodies, farmers, consumers, etc.) are sufficiently aligned to increase the relative consumption of PBD in the Netherlands? If not, what are those misalignments and how do you believe these contrasts of interest hamper the development of the PBD industry and markets?

- Do you experience a lot of resistance towards the integration of PBD? And if so, by who and to what extent? And does it form a barrier for PBD development?
    - How does your organization deal (or plan to deal) with these forms of resistance?

SPECIFIC QUESTIONS PER ACTOR CATEGORY

→ *Goal: to create insights on various category-specific perspectives on PBD developments and niche-regime interactions, and drivers/barriers for PBD acceleration.*

Government bodies/ policy and supportive programs

- What programs already exist in your organization, that could stimulate entrepreneurship within the PBD niche, uptake of PBD products, or the switch to more sustainable/plant-based ways of business?
- If there are any, in what other ways do you believe your organization could further contribute to stimulating businesses and consumers to start in or switch to plant-based dairy production or consumption? (What sort of subsidies/programs/courses/advice panels/ etc.?)
- The intentions in the NPS to have diets become more plant-based instead of animal-based, has of course consequences for the many dairy farmers and businesses in the Netherlands. How should these actors be included in this transition?
    - How do you expect these actors to react to this transition? What kind of drivers or barriers do you believe to be present?
- How do you envision the future PBD market in the Netherlands and how do you think this will affect the Dutch dairy industry?
    - How could existing infrastructures and markets of the dairy industry complement the development of the PBD industry?
- To what extent is governmental intervention needed to support PBD development? (Subsidies PBD niche/stricter quotas or rules dairy industry/pricing animal-based products/etc.)

Knowledge institutes

- Do you believe the amount and quality of knowledge development in the Netherlands to be sufficient for the development of the PBD industry and how would you evaluate the flows of knowledge exchange between science, industry, and consumers?
    - What are the strengths in terms of PBD knowledge development and exchange in the Netherlands?

    - What are problematic parts in terms of PBD knowledge development and exchange in the Netherlands?
- How do you expect technological innovations to develop in the upcoming years?
    - Are there clear and supportive policy goals regarding this technological field?
    - How would you envision current policy and regulations need to be adjusted to better support these developments?

Educational organizations & programs *AND* PBD supportive organizations (PPP/intermediaries)

- In what ways does your organization support developments within the transition to PBD uptake? What actors are your target group? Why this target group?
- How do you believe your organization could otherwise contribute to stimulating businesses and consumers to start in or switch to plant-based dairy production or consumption? (Educational programs/conventions/online marketing/etc.?)
- Is the amount and quality of knowledge development in the Netherlands sufficient for the development of the PBD industry and how would you evaluate the flows of knowledge exchange between science, industry, and consumers?
    - What are the strengths in terms of PBD knowledge development and exchange?
    - What are problematic parts in terms of PBD knowledge development and exchange?
- How do you expect technological innovations to develop in the upcoming years?
    - Are there clear and supportive policy goals regarding this technological field?
    - How would envision current policy and regulations need to be adjusted to better support these developments?

Supply – PBD startups and companies

PBD startups and companies

- How has your organization positioned itself in the current market? How do you expect to grow/develop your business in the coming years?
    - Who is your target group? Why?
- What barriers has your organization encountered for the uptake or acceleration of PBD products to the market?
    - What interventions or support do you deem necessary to overcome these barriers?
- (How) does your organization experience influences, pressures, or current regulations/institutions/infrastructure from the Dutch dairy industry?
    - Do these form a barrier for developments of PBD?
    - How could, in your opinion, these barriers be overcome?

- What types of attitudes regarding PBD has your organization noticed among (possible) consumers? Are they resistant or willing to change?
- Are there any aspects of the Dutch dairy industry that could create opportunities for the development of PBD? (Existing infrastructure/farms/existing cooling mechanisms for cow dairy production/etc.)

*Established dairy incumbents and market actors **AND** PBD producers and material suppliers **AND** Service providers*

- How do you envision the future of the PBD market and is your organization going to be involved in these developments?
    - If yes, for what reasons is your organization involved in this transition? Why and where do you see potential? *OR* if no, why has your organization decided to not (or not yet) be involved in this transition?
- (How) does your organization experience influences or pressure from the PBD industry and markets?
    - Do these form a barrier for developments in your organization?
- (How) does your organization see opportunities and possibilities to collaborate with actors from the PBD industry?

Appendix C. Informed consent questions

Each interviewee was asked the following questions before conducting the interview:

Before starting the interviewing, I would like to inform you and ask permission of the following:

- *The data that is collected from this interviewed will be obtained and stored for scientific purposes*
- *The collected, completely anonymous, research data can be shared and re-used by scientists to answer other research questions*
- *This interview will recorded in order for the researcher to transcribe for scientific purposes*
- *You have the right to withdraw your consent to use the data*
- *You have the right to see the research report afterwards*

Do you agree with this?