

Public-private partnerships as systemic agricultural innovation policy instruments – Assessing their contribution to innovation system function dynamics



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ABSTRACT

This paper addresses the question how public-private partnerships function as systemic innovation policy instruments within agricultural innovation systems. Public-private partnerships are a popular government tool to promote innovations. However, the wide ranging nature of PPPs make it difficult to assess their effects beyond the direct impacts they generate for the partners. This paper broadens the discussion on the evaluation of PPPs beyond the organisational and financial benefits of the actors involved, and assesses their contribution to the functioning of the innovation system itself. In this paper, we utilise an innovation system perspective that focusses on how PPPs influence the dynamic interplay of innovation system functions and how these functions form a set of feedback loops that constitute an ‘innovation motor’. We compare the innovation history of four cases that differ in their strategic policy goals, either working on agricultural sustainability, or on the international competitiveness in the Dutch agricultural sector. The results show the strengths and weaknesses of different types of public-private partnerships as systemic instruments and their capability to orchestrate other types of innovation policy instruments.

1. Introduction

It has become more and more recognised that solving the persistent and complex problems facing the agricultural sector is beyond the reach of a single actor alone. Such profound changes, that require more than simple technological fixes, are called system innovations, or transitions and they require the involvement of various kinds of stakeholders in processes of social change (Poppe et al., 2009; Knickel et al., 2009). As a result agricultural innovation policies are being promoted in which multidisciplinary and intersectoral groups are organised into networks to collaboratively work on innovation and the transition towards sustainable agriculture (Beers and Geerling-Eiff, 2013; Hermans et al., 2015).

Public-private partnerships (PPPs) are prominent examples of such collaborative endeavours in which private actors pool their resources with public sector organisations, such as government agencies and universities, in a long-term collaborative engagement, with the aim of providing added value for all parties involved (Bovaird, 2004; Osborne,

2000; Van der Meer, 2002). However, despite their general popularity PPPs also have their problems and not all PPPs realise their full potential (Klijn and Teisman, 2003). Within the agricultural sector, PPPs have become increasingly popular within the mix of policy instruments aimed at promoting innovation, and they have been mentioned as a solution to counteract interaction problems between actors (Lamprinopoulou et al., 2014; Turner et al., 2016).

However, the empirical analysis of how PPPs work out in Agricultural Innovation Systems (AIS) is limited. In particular, how they help to orchestrate individual innovation policy goals and policy instruments. In this paper we try to remedy this problem by investigating PPPs as a systemic innovation policy instrument, in short as a systemic instrument. These systemic instruments target problems from a systems perspective and are not focused on a particular actor or a single innovation policy instrument (Crespi and Quatraro, 2013; Smits and Kuhlmann, 2004; Wieczorek and Hekkert, 2012). The main question this paper addresses is: how do PPPs influence the innovation system functions within the Dutch AIS by acting as a systemic

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instrument?

With this paper we aim to make both a theoretical and methodological contribution to the study of PPPs in Agricultural Innovation Systems. The theoretical contribution is the development of a framework to compare the implications that different types of PPPs have, from a systemic perspective. Many evaluations of PPPs only focus on the effectiveness of the partnership in terms of the organisational and economic benefits for the participating actors, but not for the broader society, or the broader innovation system (Akullo et al., 2018). The methodological contribution lies in the application of a dynamic perspective of innovation system functions (Bergek et al., 2008; Hekkert et al., 2007) and innovation motors (Suurs and Hekkert, 2009; Suurs, 2009) for the purpose of policy evaluation. Recent work by Kruger (2017a) and Sixt et al. (2018) focussed on the application of a functional-structural analysis within AIS, however, examples for the application of the idea of innovation motors within the agricultural domain are still lacking.

This paper is structured as follows. First, we will discuss the role of PPPs in innovation and derive a typology of different configurations and uses of PPPs in agricultural innovation processes. Subsequently, we will discuss the methodology we used to assess the contribution of PPPs in changing the innovation system functions and their dynamics into so-called ‘innovation motors’. We will analyse four cases of new fields and agricultural innovations that have emerged in the Dutch AIS in the last 20 years: 1) energy producing greenhouses, 2) green genomics, 3) sustainable animal husbandry, and 4) food and nutrition. The paper ends with a discussion of the most important implications of our results for innovation theory and policy.

2. Theoretical framework

2.1. Public-private partnerships

A number of authors have promoted the use of PPPs within AIS to combine the capabilities of the private sector with the intellectual resources of research institutes to address some of the complex problems of the agricultural sector (Hall, 2006; Hartwich et al., 2005; Spielman and Von Grebmer, 2006; Spielman et al., 2010). Partnerships for innovation can have private and public benefits that are related to partnering and also to the innovation that is being developed, see Table 1.

In order to link the different kinds of PPPs to the different types of change within the AIS we make a distinction between three different, but interrelated elements of PPPs. We will discuss these three elements below.

- 1 **The policy objectives of the PPP** are part of the broader policy strategy, meaning the combination of policy objectives and the principles and plans to achieve them. Process-oriented objectives are related to the way stakeholders interact within the innovation system. Process-oriented objectives are therefore often defined in terms of outcomes like capacity building, learning or stakeholder

buy-in (Hermans et al., 2011; Rogge and Reichardt, 2016). PPPs are sometimes categorised as soft or communicative policy tools (Bemelmans-Videc et al., 1998; Borrás and Edquist, 2013). However, as illustrated in Table 1, they can also contain content-oriented policy objectives defined in certain outputs regarding environmental, social or economic issues.

- 2 **The governance of the partnership** deals with the institutions and structures of authority, the way decisions are being made, what kind of contributions are expected of the partners and what they can expect to gain in return. Provan and Kenis (2008) made a distinction between participant-governed partnerships, where the decisions and responsibilities are shared between members, and brokered partnerships. In the case of a brokered partnership the governance occurs through a single organisation which functions as the network broker. The organisation that leads the network can be a network partner, but sometimes a new independent organisation is established with the specific purpose to administrate the collaborative partnership (Klerkx and Leeuwis, 2009).
- 3 **The composition of the partnership** says something about the range of public and private actors involved in the PPP. In a narrow definition of a PPP, only actors with a similar background or originating from the same economic sector are participating. In a broad definition of a PPP, not only government agencies, research and businesses are included, but also community and voluntary organisations (Bovaird, 2004). Each of the different actors in a partnership has its own institutional logic and values and these differences can be both a source of frustration and problems, but can also lead to creative ideas and potential solutions (Beers and Geerling-Eiff, 2013; Akullo et al., 2018).

By considering these three elements we employ a very broad operationalisation of a PPP. In this paper PPPs are thus seen to cover a wide range of different types of partnerships between public partners (policy makers and scientists) and private partners (like business managers, sector representatives and citizens) to foster (agricultural) innovations. Each of these public or private partners contributes to the collaboration, either financially or ‘in kind’, but we don’t consider a minimum level that this contribution has to take.

2.2. Innovation system functions and innovation motors

To assess the contribution of PPPs to innovation processes, we have adopted a functional perspective of innovation systems. The innovation system perspective provides an analytical framework to study technological change as a complex process of actions and interactions among a diverse set of actors engaged in generating, exchanging, and using knowledge (Freeman, 1988; Lundvall, 1992; Edquist, 1997). Depending on their specific focus, innovation systems can have different geographical (national, regional), sectoral or technological boundaries (Hekkert et al., 2007; Markard and Truffer, 2008). As Klerkx et al. (2012) have argued, AIS can be studied both at an overall agricultural

Table 1
Potential benefits of partnering.

	Innovation	Partnering
Public benefits	<ul style="list-style-type: none"> ● Environmental and/ or social benefits from sustainability innovations ● Contribution to economic growth ● Contribution to the knowledge economy ● Increased employment opportunities 	<ul style="list-style-type: none"> ● Joint/ social learning ● Improved relevance through contact with real problems ● Maintaining research infrastructure and capacity ● Complementary (private) funding ● Reduced time lags in the adoption of technology
Private benefits	<ul style="list-style-type: none"> ● Increased production and productivity ● Reduction of costs and risks ● Development of new products and market opportunities 	<ul style="list-style-type: none"> ● Innovative capacity increases ● Complementary (public) funding ● Access to knowledge, technology and other partners ● New marketing and distribution channels ● Publicity

Based on Hall (2006); Hartwich et al. (2005); Spielman and Von Grebmer (2006).

Table 2
Overview of innovation system functions in AIS.

F1. Entrepreneurial activities:	Entrepreneurs transform the potential of new knowledge, networks and markets into specific actions to generate new business opportunities. Turner, Klerkx, Rijswijk, Williams and Barnard [10] argue that lobbying for funding, or trying to change institutional structures are part of entrepreneurial activities within AIS as well.
F2. Knowledge development:	Knowledge development drives many new innovations. The results of knowledge development can take many forms, not only peer-reviewed papers, but also the project reports and sometimes other tangible artefacts produced. Knowledge development therefore does not only take place in formal research institutes and universities, but may also be done by the other actors within the AIS (Hermans et al., 2015).
F3. Network formation and knowledge diffusion:	The knowledge network performs an important function in making information exchange easier. The more connections between actors within a network, the more easily knowledge is disseminated. The AIS literature emphasizes the importance of platforms and networks for upscaling and outscaling of agricultural innovations (Kilelu et al., 2013; Hermans et al., 2017).
F4. Guidance of Search:	This function represents the selection function between various technological options. In a positive scenario there is a convergence of expectations about these technological options between stakeholders. This convergence can happen more or less naturally over time, but it can also be promoted, for instance through design exercises (Groot Koerkamp and Bos, 2008).
F5. Market Formation:	New technologies have difficulty competing with established ones, especially in the early phase when reliability and performance have not yet been extensively proven. Therefore it is often necessary to create (niche) markets, for instance by measures that promote a demand for the new product and create consumer awareness (Binnekamp and Ingenbleek, 2006).
F6. Resource Mobilisation:	Different types of investments are necessary for an innovation to develop, for example capital for the funding of basic research, subsidies for the further development of technologies and innovative market concepts, but also non-financial investments such as time (Fischer et al., 2012).
F7. Support from Advocacy Coalitions:	The emergence of a new technology often leads to resistance from established actors. Actors need to raise a political lobby that counteracts this inertia. Advocacy coalitions can be a catalyst for this by influencing the innovation agenda, lobbying for resources and favourable institutions (Roep et al., 2003; Hermans et al., 2016).

Source Hekkert et al. (2007) and Turner et al. (2016).

sector level within a country [see: Hermans et al., 2015; Lamprinopoulou et al., 2014; Turner et al., 2016 for examples], but they can also be considered as a kind of Technological Innovation System (TIS) by focussing on a particular new technology that develops within the AIS, [see Kruger, 2017a, Amankwah et al., 2012; Kruger, 2017b for examples]. In this paper, we apply the second perspective: we view the Dutch AIS as a broad Sectoral Innovation System, which can host a number of different Technical Innovation Systems. This means that we view our cases as a set of (non-representative) samples of TIS, related to some of the new technological fields and technologies that were developed within the Dutch AIS in the last two decades.

This functional approach of innovation systems is especially suitable to track the development of newly emerging technologies within TIS. The idea is that in order for an innovation system to function well, a number of activities has to take place within the system. In this study we use the seven innovation system functions derived by Hekkert et al. (2007), see Table 2. The seven innovation system functions are not independent of each other, but they interact. How a certain function is fulfilled determines the way that other functions can be fulfilled. In a positive scenario, certain functions develop alongside each other through a process of ‘cumulative causation’: a virtuous cycle constituted as a positive feedback loop through which momentum for change is being built up (Suurs and Hekkert, 2009). If particular system functions recur in a repetitive ordered sequence this implies a cyclic mechanism: a motor of innovation.

Fig. 1 illustrates how changes in one function can lead to changes in

another function. The changes in the second function can create positive effects in a third function, and so on. Following the terminology of systems thinking we define an innovation motor as the occurrence of a feedback loop between two or more innovation system functions. Hence, an innovation motor consists of a circular chain of arrows which indicates that part of the outputs of a function are eventually routed back as inputs in its point of origin. In Fig. 1 three different innovation motors, based on three different feedback loops are depicted. The red arrows illustrate an innovation motor that starts with the government identifying a certain problem (F4) and providing funds for research into solving this problem (F2). This scientific solution is subsequently being diffused to farmers and other entrepreneurs (F3) who adopt it into their farm management practices (F1). This in turn will lead to interest in improving the technology (F4) and new, private, resources are made available to do more research and the whole cycle starts again. Another possible cycle (blue dotted arrows) can be identified for technologies or solutions that are controversial, or require a change in institutions, rules and regulations to become competitive. In such a case an important role is played by a supporting coalition who lobby and influence the social discourse (F7). Resources are acquired (F6) to perform some sort of an experimental pilot study where new knowledge is created (F2), a small number of pioneers takes up the innovation (F4), strengthening the supporting coalition and lobby for more and larger experiments where the experiments can be scaled up. After these initial steps another cycle can be formed (of black arrows) when the market starts to develop. Here the entrepreneurs form a lobby group in order to persuade the government to set favourable regulations for the new emerging market. In turn, these influence the entrepreneurial activities.

With seven different functions there are many different combinations and feedback loops that can be potentially formed. From these examples it should be clear that these cycles depend on the type of new technology being developed and that they will change with different development stages. As a final point, it has to be noted that these cycles do not necessarily have to be positive and reinforcing. It is equally possible that a vicious cycle is constituted, when changes in one function lead to a reduction in the performance of, or weakening of other functions.

2.3. The role of public-private partnerships as systemic instruments

The concept of systemic policy instruments was introduced as a supplement to the traditional market failure approaches for innovation policy. In the market failure approach, innovation problems were blamed on market imperfections that would hinder the selection of technological superior options (Metcalf, 2005). Innovation policy instruments of a financial (e.g. taxes and subsidies), regulatory (e.g. legislation) or communicative nature were used to create a ‘level playing field’, or provide users with better information to allow a rational choice between different competing options. However, it was found that in some cases, ‘correcting the sub-optimal innovation mechanisms required acting contrary to conditions of perfect competition’ (Weber and Rohrer, 2012). This meant that the rationale and goals for the use of policy instruments changed towards more attention for problems related to the different components of the innovation system: the quantity and capability of all actors involved in the generation of innovations, the intensity of interactions between them, the presence and application of hard and soft institutions, and of the availability of physical, financial and knowledge infrastructures (Smits and Kuhlmann, 2004; Wieczorek and Hekkert, 2012). Solving potential systemic problems require appropriate policy mixes and the orchestration of these policy mixes so that individual policies become aligned and may reinforce each other (Borrás and Edquist, 2013; Flanagan et al., 2011; Reichardt and Rogge, 2016).

In this paper we argue that PPPs may function as a systemic policy instrument, by enhancing connections and alignment between innovating actors in innovation systems. However, the distinction

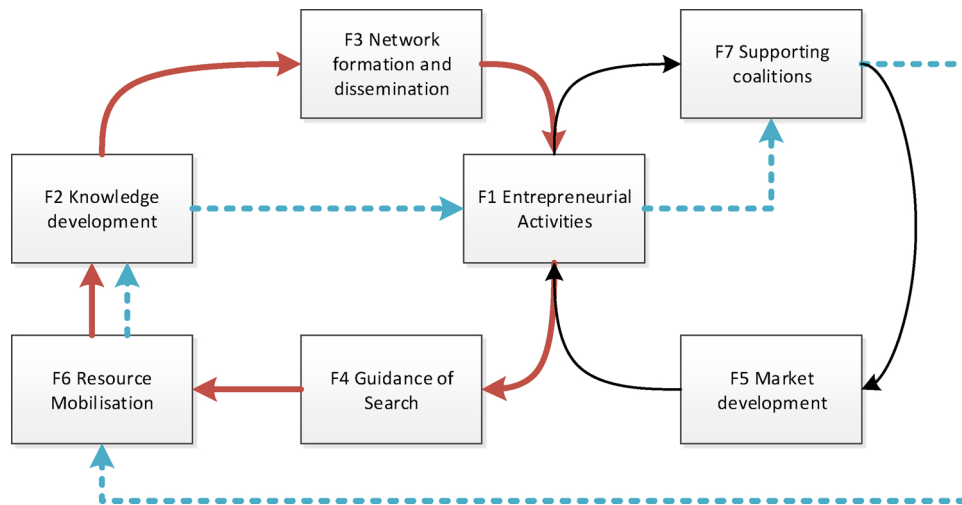


Fig. 1. Three innovation motors (adapted from Hekkert et al., 2007).

Table 3
Relationship of events, policy instruments and interventions as related to innovation system functions.

Function name and description	Types of events, policy instruments and interventions
F1 Entrepreneurial activities:	<ul style="list-style-type: none"> ● Participation in innovation projects ● Investments in new technology
F2 Knowledge development:	<ul style="list-style-type: none"> ● Scientific research projects ● Scientific papers published ● Technical reports ● Patents ● New designs, maps and prototypes
F3 Network formation and knowledge diffusion:	<ul style="list-style-type: none"> ● Dissemination activities: workshops, courses and training ● Information networks, platforms and dedicated internet sites
F4 Guidance of Search:	<ul style="list-style-type: none"> ● Shared vision documents ● Agreements and disagreements between partners and between partners and other actors ● Claims on behalf or against a certain technology
F5 Market Formation:	<ul style="list-style-type: none"> ● Subsidies ● Tax breaks ● Rules and regulations that directly affect certain production processes
F6 Resource Mobilisation:	<ul style="list-style-type: none"> ● Public and private sources and investments
F7 Support from Advocacy Coalitions:	<ul style="list-style-type: none"> ● Lobby activities ● Public pressure on actors to deal with a certain issue

Based on (Hekkert et al., 2007; Suurs and Hekkert, 2009).

between the three traditional types of policy instruments (financial, regulatory and communication) becomes blurred as PPP can help to orchestrate other innovation policy instruments of an economic or regulatory nature as well. The question we ask in this paper is how do different types of agricultural PPPs influence innovation system functions and the emergence and/or support of certain innovation motors.

3. Methodology

3.1. Case selection

The Netherlands has a long tradition of organising public-private partnerships for research and innovation (Hessels and Deuten, 2013; OECD, 2004), especially within the agricultural domain (Spiertz and Kropff, 2011; Spoelstra, 2013). From an initial list of 50 potential cases

we selected four cases, based on two criteria: 1) a long-term involvement of PPP programmes, and 2) The PPPs consisted of at least three partners from business, government agencies and research institutes (including universities). We selected four different cases that have utilised a number of long-term PPP programmes for innovation in the Dutch agricultural sector. Two of the cases focussed on the specific policy aim of developing a new sustainable technology: 1) Energy producing greenhouses, and 2) Sustainable animal husbandry concepts, and two cases were selected where the policy aim was to contribute to the economic competitiveness of the Dutch AIS: 3) Green Genomics, and 4) Food and Nutrition. For all four cases a lot of information on the innovation processes has already been collected through other studies and evaluations and these data offered a rich source of descriptions of the various events that shaped the AIS, see Appendix A for an overview.

3.2. Event history analysis

A chronological timeline was constructed for each case. This timeline included the various innovation programmes promoting PPPs, (external) historical events and the most important actors involved in these programmes and events. The events in the timelines were checked with 3 to 7 experts familiar with the individual cases through in-depth interviews. Open interviews were done that took between 1 and 1.5 h. Themes that were covered in the interviews covered a) the role of the expert within their own organisation, b) the functioning of the PPP that they were involved in, or had knowledge about, c) the place of the PPP within the broader timeline (before and after) and d) other events that shaped the sector and the innovation process.

The resulting timeline was subsequently analysed from the perspective of the seven innovation system functions using event history analysis (Suurs and Hekkert, 2009; Poole et al., 2000). Table 3 gives an overview of the different innovation system functions and the type of events we have used to operationalise the functions. A narrative was constructed in which the functions were related to each other and from this narrative the feedback loops between the functions were distilled. For each of the cases, different phases were identified for which a number of functions coagulated in a number of interacting feedback loops. In order to highlight the sequence of these causal loops, we divided the innovation history into a number of different phases in which certain causal loops played a dominant role. However, it is important to note that the boundaries of these phases are rather fluid with certain causal loops, slowly building up and gradually taking over from one phase to the next.

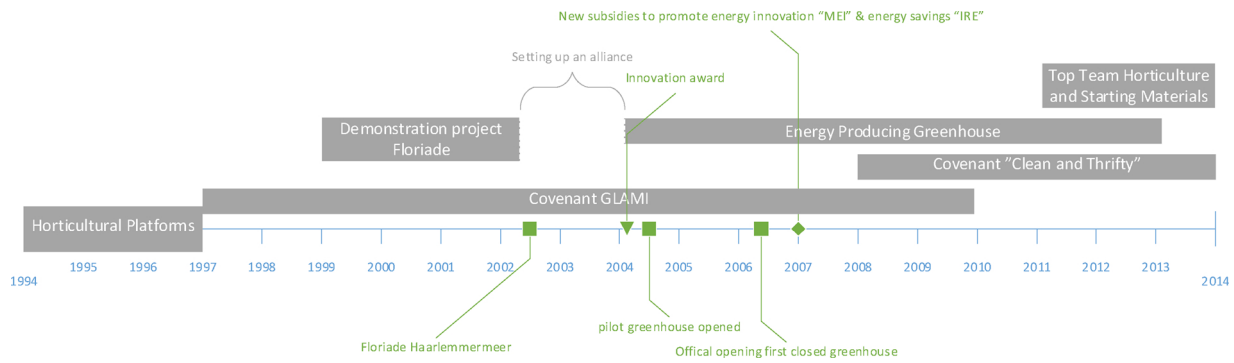


Fig. 2. Timeline for Energy Producing Greenhouses.

4. Results

In this section we will present the results from our investigation. For the sake of brevity we will only give a short description of the most important events in the timeline and we will focus on the combination of the different PPPs that we identified and the question of how the innovation system functions have constituted different feedback loops in the different phases. A full description of the event history analysis and the translation of the events in the timeline into the seven individual innovation system functions can be found in the in Appendix B.

4.1. Energy producing greenhouses

The Dutch horticulture sector consists of three major product groups: greenhouse vegetables (mainly cucumbers, peppers and tomatoes), cut flowers and pot and bedding plants. In addition, installation engineering and construction are important greenhouse related activities. With increasing national and European regulations, rising energy prices and the debate about sustainability, the sector was forced to continuously innovate, aiming to achieve increased production, greater production efficiency and value creation. As the costs of energy at many companies increased to more than 30% of the total production costs, there was a lot to be gained. In 2004 a sector wide public-partnership was created around the very ambitious goal to turn a greenhouse from a net importer of energy into a net producer of energy. Fig. 2 shows some of the most important sequences of events and policy instruments which occurred during the development of the Energy Producing Greenhouses. Table 4 provides a description of the different types of innovation partnerships which were implemented during this time.

4.1.1. Patterns in innovation functions development

We distinguish three phases in the innovation history, see Fig. 3. The first phase is a mobilisation phase. In this phase there were two weakly developed loops associated with the two different actor networks that were active. Both loops started with an increasing concern for the environment and influenced the direction for innovation and policy. The first loop was provided by the early horticultural platforms that resulted in the GLAMI covenant. The platforms created the direction of search (F4) and at the same time strengthened and formalised the network ties between government and the horticultural sector (F3). The second loop was driven by the firms and consultants who were responsible for the entrepreneurial activities (F1) which resulted in the first proof of principle of a closed greenhouse shown at the Floriade in 2002. In this loop new applied knowledge was developed (F2) concerning the question how to combine already existing technologies in a new design.

The second phase was a mobilisation and learning phase. This phase started with the run up to the PPP of the energy producing greenhouses. The image of an energy producing glasshouse functioned as a strong guidance of search (F4) that directly and indirectly influenced the other functions. This mobilisation motor ran on the energy of a small group of supporters who strongly believed in the possibility of an energy producing greenhouse and was fully committed to mobilise the support and the needed resources. When resources finally became available the programme started and boosted the research and practical experiments (F2 Knowledge generation), network formation and dissemination (F3). The search was further guided by the definition of transition paths. Some entrepreneurs became involved in the experiments (F1), but in general entrepreneurial activity was low and strongly subsidised with public money by the programme.

Table 4
Public-Private Partnerships in Energy Producing Greenhouses.

English Translation / Description	Policy goal	Financing (public vs. private)	Governance	Composition
National platform of governmental agencies and horticultural sector (1994-1997)	Platform for discussion and consultation	Public	Civil servants in the lead	Civil servants with representatives of sector organisations
Covenant Horticulture and Environment "GLAMI" (1997-2010)	Reduction of environmental pressure	Public	Government in the lead	Civil society, sector organisations, local governments
Demonstration project at Floriade (1992-2002)	Pilot / proof-of-principle	Publicly subsidised project	Shared	Research and consultancy
Energy producing greenhouse (2004-2007)	Development and diffusion of knowledge	25% private co-funding through sector organisation	Public private board (shared governance)	Sector organisations, researchers, growers, government
Covenant "schoon en zuinig" (clean and thrifty) (2008-2012)	Reduction of environmental pressure and energy use	Mix of public and private (25% private co-funding through sector organisation)	Government in the lead part of governmental ambition and work programme	Ministries and representatives of the horticultural sector
Top team Horticulture and Propagation Materials (2011- present)	Stimulate entrepreneurial activities	Public money matched with private money.	Tripartite governance (in order of influence): government, businesses and knowledge institutes.	Knowledge institutes, sector organisation

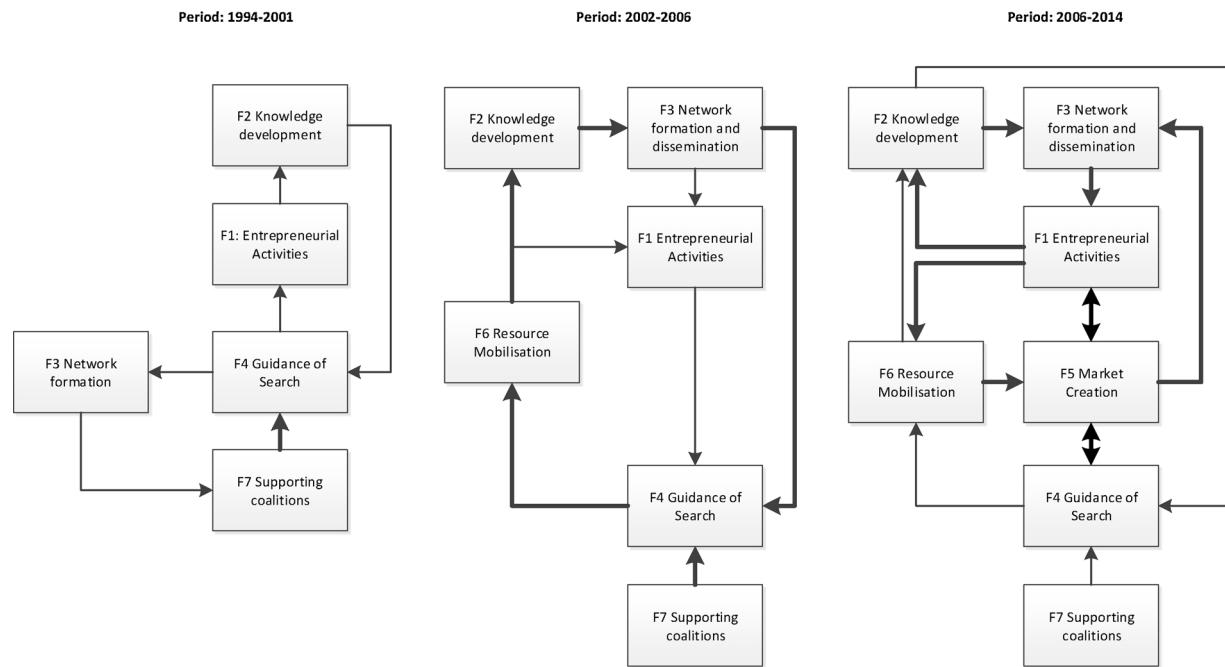


Fig. 3. Innovation motors in Energy Producing Green houses.

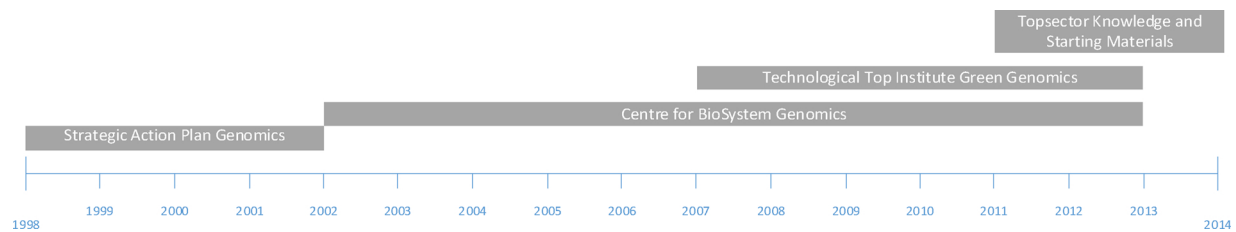


Fig. 4. Timeline for Propagation Materials and Green Genomics.

The last phase resembled a take-off phase. The entrepreneurial activities (F1) formed the core of several loops that generated investments and promoted market creation on the one hand and practical knowledge and improvements of the technology on the other. At this point the technology was far enough developed to be promoted with other financial policy instruments like tax breaks and subsidies (F6) that helped in the creation of a market for new greenhouse concepts (F5). Suppliers, entrepreneurs and researchers were enabled to create new networks and diffuse knowledge (F3).

economic crisis of 2008 hit the sector: entrepreneurs were less eager to invest in new greenhouses due to economic crisis and less encouraging results from research. In the background the knowledge development loop that was supported by the PPP called Top Team Horticulture and Propagation Materials. This PPP was still running although at a considerable lower pace: funds and research interests were shifted away from the closed greenhouse technology, thus reducing new knowledge development.

However, before actual take-off could take place, the effects of

Table 5 Description of public-private partnerships in Propagation materials and genomics.

English Translation / Description	Policy goal	Financing (public vs. private)	Governance	Composition
Strategic Action Plan Genomics (1998-2002)	Vision development	Mainly public (exact amount not available)	Government firmly in the lead	Scientists, government advisors and captains of industry
Center for BioSystems Genomics (CBSG) (2002-2013)	Development of the knowledge economy, training of high skilled personnel	Mix of public and private financing (92 ME; private investments approx. 12%)	Shared governance between science and businesses, but a knowledge institute (WUR) was the official programme leader	Large (multinational) enterprises (13) together with knowledge institutes and two sector organisations
Technological Top Institute Green Genetics (2006-2013)	Development of the knowledge economy, stimulating participation of SMEs	Mix of public and private (40 ME, 50-50 public-private)	Independent foundation (NAO) with shared governance, although science is still dominant	Knowledge institutes, sector organisation Plantum and approx. 140 companies involved at project level
Top Consortium Knowledge and Propagation Materials (2011-present)	Stimulate entrepreneurial activities	Public money matched with private money	Tripartite governance (in order of influence): government, businesses and knowledge institutes	Knowledge institutes, sector organisation Plantum

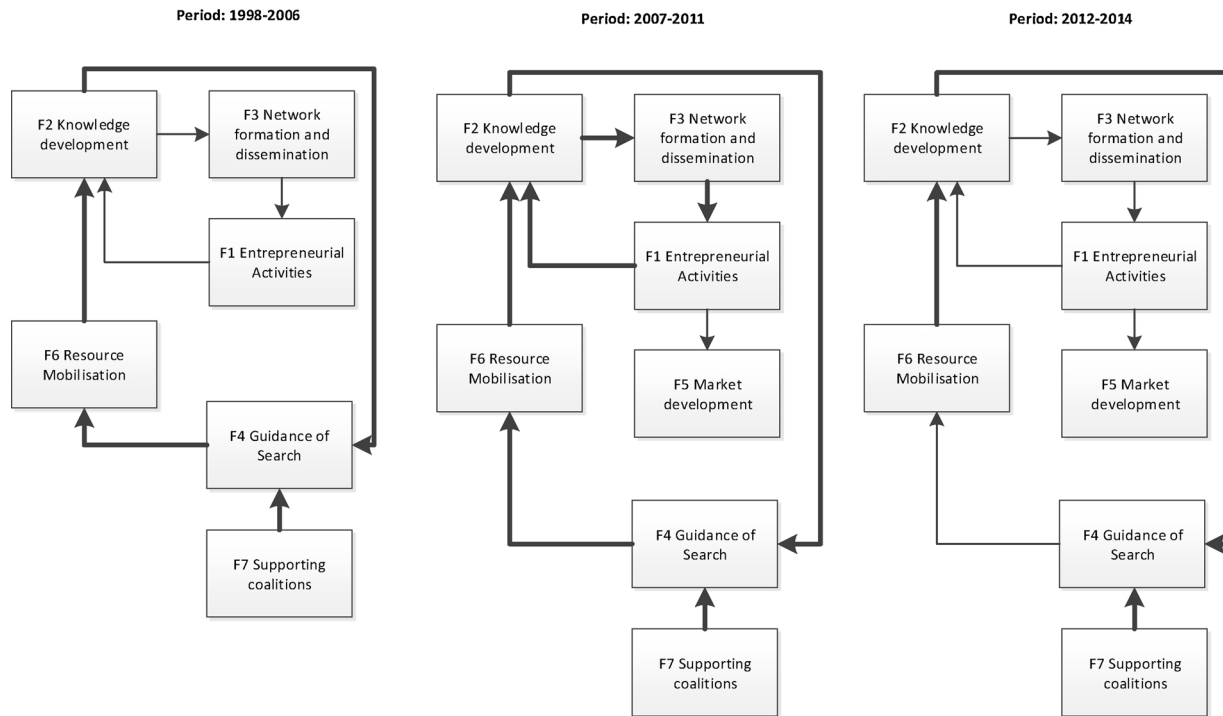


Fig. 5. Feedback loops in Propagation Materials and Genomics.

4.2. Propagation materials and genomics

The sector of propagation materials deals with seeds, bulbs, reproduction via tissue culture, strike cuttings and cultivation (De Jong-VanTuil and Oostra, 2009). In 2010 this sector was comprised of about 300 specialised businesses which employed an estimated 8,000–10,000 people in The Netherlands. The total revenue was estimated at over 2 billion euros, of which 1.6 billion euro through exports. The sector is knowledge-intensive. Investments in R&D amounted to approximately 390 million euros in 2010. The percentage of employees working in R&D in the raw materials sector exceeded 30% (Bakker et al., 2011). There has been frequent collaboration between companies, research institutions and universities. The timeline in Fig. 4 shows that the government’s support for PPPs was substantial in this sector, while Table 5 provides an analysis of these PPPs

4.2.1. Patterns in innovation system functions dynamics

We distinguish three phases in Fig. 5. The first phase includes the run up and establishment of CBSG. The dominant cycle during this phase started with a lobby to convince the government to invest more in genomics research (F7). There was a consensus about the direction of

the innovation system to develop in (F4). A significant public investment was made as a result in the development of fundamental knowledge on Genomics (F6). The establishment of the public-private partnership CBSG stimulated three functions at once: F2 Knowledge development, F3 Network Formation and Dissemination, and F1 Entrepreneurial Activities. However, F3 network formation and F1 entrepreneurial activities were still relatively small (13 enterprises participated). After a successful evaluation CBSG was granted a second period of public investments (F6).

In order to strengthen the network formation function, a new public-private partnership was established: the Technological Top Institute Green Genomics. This marked the starting point of the second phase in 2007. The PPP TTI-GG complemented the fundamental research conducted within CBSG. A robust network appeared with over 100 companies of all sizes, which applied the new knowledge somehow in their production processes (F1), and it increased the availability of qualified labour (F5). The sector representatives lobbied together with the other participating partners for the continuation of a new round of budget for the TTI-GG (F7).

After 2011 the final phase was initiated by the introduction of the Top Sector Policy which caused the replacement of the PPPs CBSG and

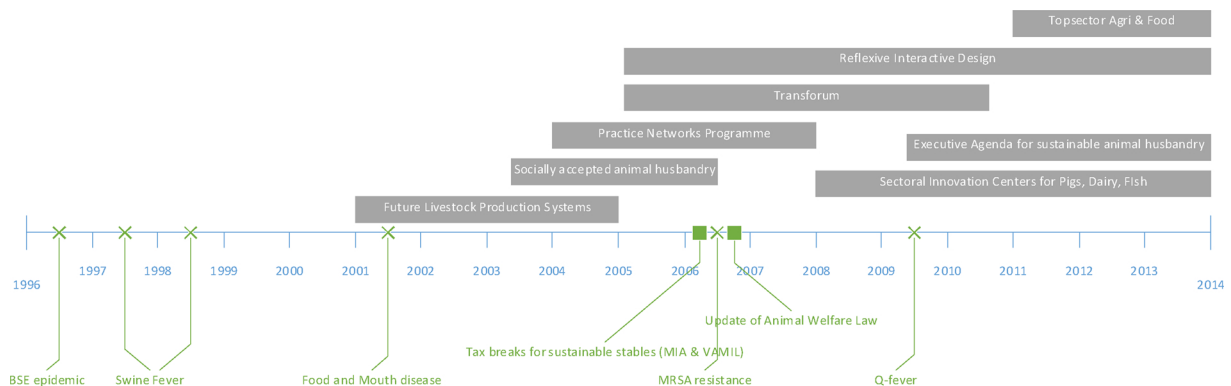


Fig. 6. Timeline for sustainable stable concepts in animal husbandry.

Table 6
Description of public-private partnerships in animal husbandry.

English Translation / Description (timeframe)	Policy goals	Governance: Financing (public vs. private)	Governance: division of power	Composition
Future Livestock Production Systems (2000-2004)	Process: develop new vision	Publicly financed (exact amount not available)	Scientists as executive project leaders	Civil servants, researchers, businesses and NGOs are engaged at project level.
Socially Accepted Animal Husbandry (2003-2006)	Develop new vision and designs	Publicly financed (2.5M Euro annually)	Scientists as executive project leaders.	Civil servants, researchers, businesses and NGO at project level
Practice Networks Programme (2004-2008)	Stimulate innovative networks	Publicly financed (8.5 M euro for 4 years). Small private investments in projects, but very low financial risks for entrepreneurs.	Project appraisal initially done with farmer unions, consultants and an animal welfare NGO. Later only scientists and the civil servants from the Ministry were involved.	Farmers together with researchers and/or consultants
Reflexive Interactive Design (2005-2014)	Development of interactive design method for stables with stakeholders	Publicly financed; scientist in the lead; sector starts to contribute	Scientists as executive project leaders.	Broad: companies, animal welfare NGOs, farmers and scientists
Sectoral innovation centres for pigs, dairy, fish (2008-present)	Stimulation of knowledge diffusion	Mix of public and private: sector organisations participate in the financing of these centres.	Brokered governance through independent new organisations.	Organised along animal product chain (pigs, hens, and cows). Important roles for farmer unions together with (provincial) governments and researchers
TransForum Innovation Programme (2005-2010)	Stimulate entrepreneurial activities, networking and capabilities	Publicly financed from Natural Gas Revenues; matched funding at project level to a maximum of 45%.	Brokered network governance through new independent organisation	Agro businesses; animal welfare organisations, farmers unions (Kombi partners)
Executive Agenda for Sustainable Animal Husbandry (2009-present)	Develop vision and strengthen network ties	50/50 public vs. private money	Covenant: shared governance with tight organisational control	Government, Animal Welfare NGOs, Agro-business and Farmer Unions
TopSector Agri&Food (2011-present)	Stimulate entrepreneurial activities	Public money matched by private money.	Businesses and sector organisations in the lead	Government, Agro-business, Science

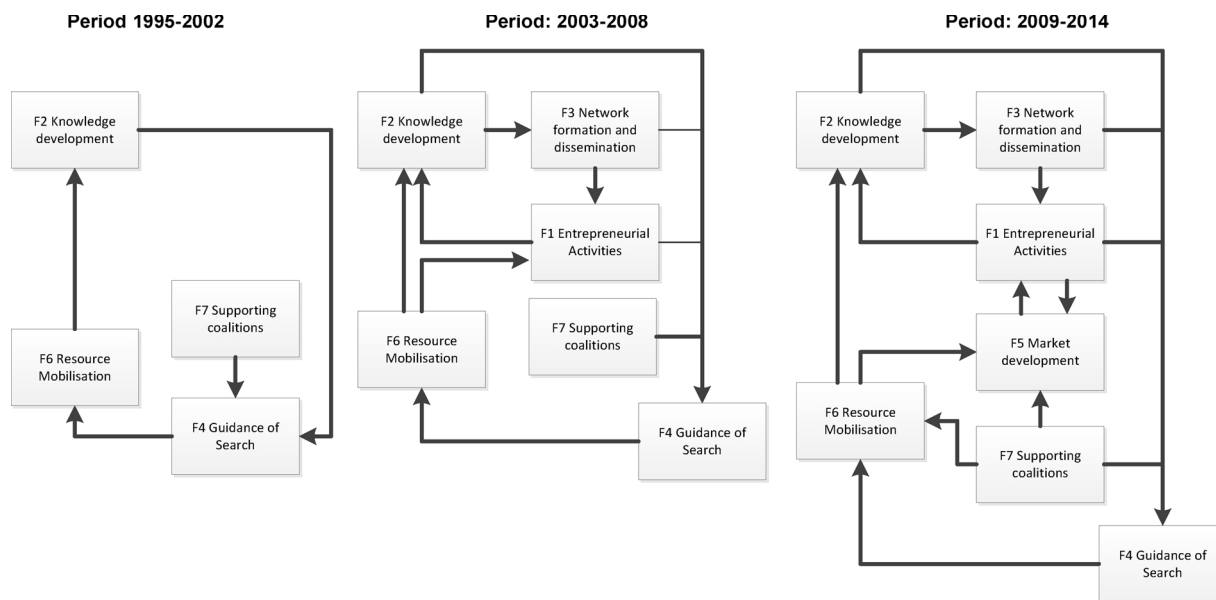


Fig. 7. Feedback loops in sustainable stable concepts for intensive animal husbandry.

TTI-GG. A new consortium was formed which was directly linked to this new Top Sector Policy (the Top Consortium for Knowledge and Innovation in Horticulture and Propagation Materials). The vision on the future of the collaboration between research, industry and the government started to diverge. The government wanted more industrial commitment through private (financial) investments, while participating businesses accused the government of being unreliable because of the ending and replacement of the two successful PPPs with a new consortium, including an adjusted public-private financial model with less public budget available. During this time the sector experienced a shift from a strong publicly financed model, to a more privately co-financed model. Several actors argued that the amount of participating companies would decrease because of less public investments. It was expected that this were to reduce the network building function and the feedback loop that depended on it. It was also thought to negatively influence the entrepreneurial activities and market development. This weakening of the links between functions is indicated in Fig. 5 by the thinner arrows in the third period (2012–2014) compared to the second period (2007–2011). The resulting innovation motor of the Top Sector Policy therefore looks more like the first phase and less like an innovation motor of the second phase.

4.3. Sustainable animal husbandry concepts

The intensive animal husbandry sector in the Netherlands has been the subject of a societal debate for many years. At the end of the 1990s the sector was considered to be in a particularly bad shape. A series of veterinary diseases (BSE and swine fever) had lasting impacts for the afflicted farmers and generated a lot of negative publicity, see Fig. 6.

Under increasing public pressure, the Ministry of Agriculture initiated a series of research programmes into alternative stable concepts for the intensive animal husbandry sector. These research programmes gradually evolved into full PPPs for innovation, see Table 6.

4.3.1. Patterns in innovation system functions dynamics

In Fig. 7 we distinguish between three different phases. The first phase ran from 1995 to 2002 and saw a gradual built up of the pressure on the sector to make a change. These external forces that were the result of the various veterinarian crises, translated into pressure on the government to intervene (F7). Public funds were made available for the development of new knowledge in a number of research projects (F2). Important functions are the visioning process and the national debate in this phase. This sets in motion a feedback loop that is dominated by research (F2) and creating a common vision (F4).

The next phase took relatively short time and was dominated by the Function F3: Network Formation through the Practice Networks Programme. Entrepreneurial activities (F1) were stimulated and at the same time this programme provided an important source of new knowledge through learning-by-doing and knowledge circulation. However in this phase the entrepreneurs still didn't have to take a lot of risk and their contribution to Resource Mobilisation (F6) was relatively low. Supporting coalitions (F7) together with researchers continued to steer the directions of search (F4).

In the final phase all the functions are present, but not all the causal loops are yet connected. Entrepreneurs became interested in some of the developed sustainable stable concepts and through the TransForm programme their activities were facilitated (F1). Market development (F5) is stimulated through the use of government subsidies for

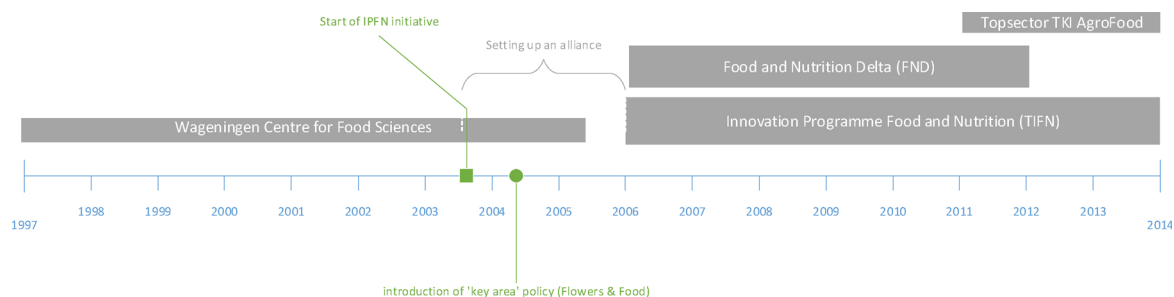


Fig. 8. Timeline Food and Nutrition.

Table 7
Description of public-private partnerships in Food and Nutrition.

English Translation / Description	Policy goal	Financing (public vs. private)	Governance	Composition
Wageningen Centre for Food Sciences (WCFS) (1997-2005)	Stimulate strategic, business oriented research	Public	Companies decide on promising themes, researchers work them out	Research institutes and businesses
Innovation Programme Food and Nutrition I: Top Institute Food and Nutrition (TIFN) (2006-2014)	Develop excellent knowledge to stimulate position of Dutch companies; Knowledge as export product	134 ME (2006-2010); 33 ME private, 31 ME academic pp investment, 70 ME public	A management board and one programme advisory board (PB) with representatives from all partners. From 2011 the PB was reformed into several thematic boards.	20 partners from the private sector and 6 research institutes
Innovation Programme Food and Nutrition II: Food and Nutrition Delta (FND) (2006-2012)	Apply knowledge and fasten innovations and stimulate demand for innovations.	63.5 ME, public (2006-2010); after 2011 no longer continued	29 organisations involved in planning or participating in the board; 429 businesses participated in one of the FND projects.	Government agencies, research institutes, businesses
Topsector Consortium for Knowledge and Innovation (TKI) (2011-2014)	Stimulate entrepreneurial activities	15 ME public, 25 ME private, 20 companies involved.	Tripartite governance (in order of influence): government, businesses and knowledge institutes	20 companies involved

sustainable stable concepts. However, a problem for the further development of the market and make a shift towards a full market motor was the absence of any real consumer demand for more ‘sustainable animal products’. The establishment and continuation of the “Executive Agenda” Roundtable (F7) therefore remained an important initiative in the absence of a steady market demand.

4.4. Food and nutrition

The Dutch Agro-food industry has an important position within the Dutch economy. In terms of Value Added and labour productivity, the Dutch food industry holds a top rank within the European Union (LEI, 2008, 2011). In order to protect this position a number of PPPs have been introduced since the end of the 1990s, see Fig. 8. In these PPPs Dutch multinational corporations, SMEs, government agencies and research institutes participated, see Table 7. These PPPs focused on the ‘post-harvest’ part of the production chain.

4.4.1. Patterns in innovation system function dynamics

We distinguish two phases, see Fig. 9. In the first phase the fundamental knowledge development loop started with the establishment of the WCFS. Although large multinational corporations were part of the PPP and had some influence on the type of research done, the developed scientific knowledge had a limited potential for practical application. Therefore, we have only indicated a single loop in this phase that ran through research, guidance of search and resource mobilisation.

In the second phase, the policy goal became to broaden the R&D knowledge infrastructure. In 2006 two new PPPs started. Knowledge development was prioritised within the TIFN which continued the same knowledge development loop from the previous phase. However, within this loop a new loop started to run with the establishment of the Food and Nutrition Delta (FND). Knowledge diffusion and network building (F3) were an important part of FND. However, these loops hardly reinforced each other because the knowledge development in TIFN and the knowledge diffusion in FND remained separate in practice. After 2012 the FND PPP integrated in the Top Sector Policy’s Top consortium for Knowledge and Innovation on Agro & Food (TKI A&F).

5. Discussion

In this paper we investigated the different ways in which PPPs act as systemic instruments in the Dutch AIS. The methodological contribution of this paper is derived from the dynamic application of the innovation system functions approach, combined with the concept of innovation motors which links the seven innovation system functions. Through the study of the feedback loops in different time periods, we showed that functions in turn affected other functions and thereby we argued how the direct and indirect effects of the PPPs and other innovation policy instruments, interventions and external events, contributed to changing the overall functioning of the TIS. By applying this approach, we unravelled some of the effects that different forms of PPPs have had on the development of innovations aimed at contributing to either sustainability or competitiveness goals. In this section we will first assess how different types of PPPs can coordinate and be coordinated with other policy instruments. Subsequently we will discuss how PPPs can act as policy systemic instrument and finally we look at the advantages and disadvantages of our methodological approach.

5.1. Different kinds of PPPs within the innovation policy mix

With regard to the question of how different types of PPPs can coordinate other policy instruments we have to make a distinction between policy measures that are orchestrated within the PPP and policy measures that are implemented in conjunction with the PPP within the broader innovation policy mix.

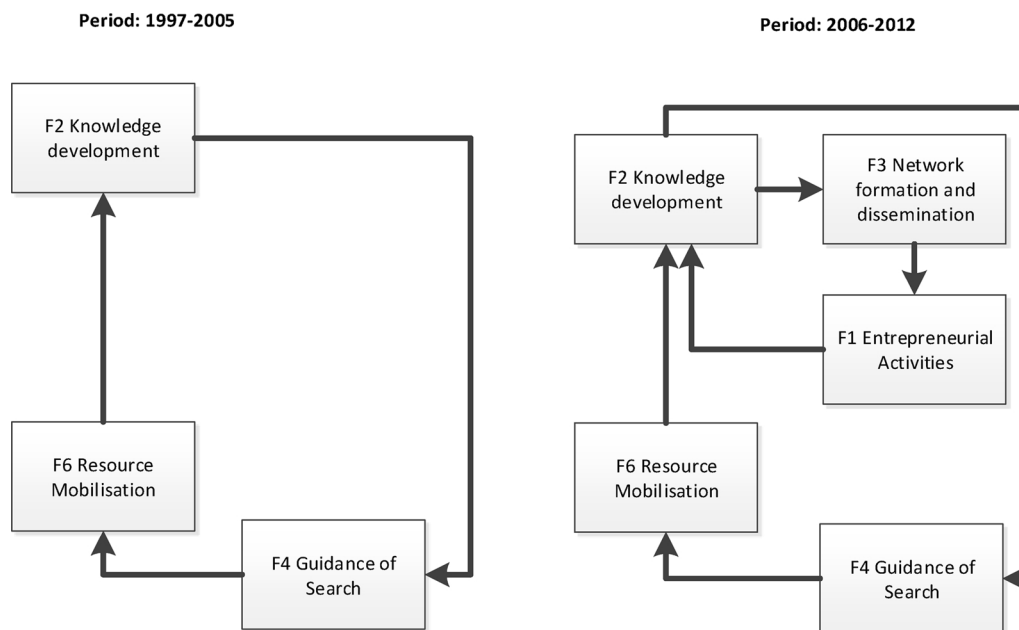


Fig. 9. Feedback loops in Food and Nutrition.

Table 8 provides an overview of the different types of PPPs (in terms of policy goals, governance and composition) we have identified within the four cases. From the 12 different combinations of goals, governance type and composition that are theoretically possible, we see that four combinations have never actually occurred in the 21 PPPs we found. It seems that the combination of a specific policy goal (i.e. related to environmental, social or economic issues) with a broad composition that also includes NGOs is not popular. In other words, such content-oriented PPPs are likely to include only those actors who have a direct stake in the outcomes of the PPP. However, it is important to note that with four cases we only had a limited sample and therefore we cannot draw any conclusions about the prevalence of these different types of PPPs in the Dutch agricultural sector as a whole.

Table 8 shows that the majority of the PPPs in our cases have been utilised for what we have dubbed ‘process goals’, i.e. as communicative policy instrument with process criteria related to knowledge development, learning and vision creation. Here, the PPPs used and orchestrated other policy instruments to support the PPP itself. For instance, within a PPP subsidies are made available that benefit the stakeholders of the PPPs. In these cases, the criteria for funding of innovative ideas are decided and applied within the PPP itself. However, contrary to the often heard governmental discourse of ‘putting businesses in the driver’s seat of innovation policy through PPPs’, government played a major role in the actual governance arrangements of many PPPs through its selection of participants, and criteria for funding, especially in the early phase of each of the four cases. Scientists of universities and other public research institutes also played an important role in the

governance of PPPs. According to our interviews they were supposed to act as the neutral guardian of the common good within the PPPs (resembling ideas formulated by Schut et al., 2014), but their presence and leading role also explains the heavy focus of many PPPs on knowledge development. Although the orchestration of regulatory instruments within a PPP was not so popular, the example of the Energy Producing Greenhouses illustrates that content driven PPPs with agreed norms for environmental sustainability targets related to energy consumption and a reduction in the use of pesticides can be successfully implemented by a dedicated, narrow network.

Apart from the orchestration of policy instruments for use and support within the PPPs, the PPPs have also been used in conjunction with other policy instruments within the broader innovation policy mix. In this case the financial and regulatory measures are applicable to all entrepreneurs and not just the actors active within a PPP. The cases show that once a particular innovation has been developed and successfully applied within a PPP, such generic policy instruments can help to diffuse the new technology within the sector. The sustainable animal husbandry and the energy producing greenhouses provide examples of the introduction of subsidy schemes that were aimed at promoting the broader adoption of the new technologies within the sector. It is often a task of PPPs themselves to put the need for such additional policy instruments on the agenda, or make sure that existing policy instruments are used and aligned to the goals of the TIS they are connected to. At the same time PPPs require a long time commitment of all partners involved and PPPs are therefore susceptible to changes in the political preferences that challenge the continuity or their focus, as the

Table 8

Number of different types of PPPs in the cases.

Source: Tables 4–7

	Policy goal:		Content		Total (%)
	Narrow composition	Broad composition	Narrow composition	Broad composition	
Governance:					
Shared	2	1	1	0	4 (19%)
Lead organisation	5	4	1	0	10 (48%)
New administrative organisation	6	1	0	0	7 (33%)
Total (%)	13 (62%)	6 (29%)	2 (9%)	0	21 (100%)

introduction of the Top Sector Policy in some of the cases showed.

5.2. PPPs as systemic policy instruments

As discussed in Section 2.3, PPPs can be defined as systemic policy instrument in the sense that they influence the innovation system functions and thus are sometimes able to target a number of systemic problems at once. The cases show how PPPs influence both the quantity and quality of interactions within the TIS as well as assist in engaging new actors and improving the capabilities of the existing ones. They enhance actor participation in the AIS and overcome system failures due to disconnects between public and private parties and get private parties more involved in innovation for public goods.

PPPs are especially effective tools to stimulate innovation functions that are important in the early phases in the development of a TIS: knowledge development, network building and guidance of search. However, different types of PPPs do this in different ways and the guidance of search function plays a central role. The main difference between our cases has been between the sustainability-oriented policy goals of the Animal Husbandry case and Energy Producing Greenhouses and the competitiveness driven policy goals of the Green Genomics and Food and Nutrition cases.

Although the term sustainability is considered to be a fuzzy concept with multiple meanings in rural innovation projects (Hermans et al., 2012), our analysis suggests that the sustainability-oriented PPPs were able to tackle transformational system failures (Lamprinopoulou et al., 2014; Weber and Rohrer, 2012) such as the directionality failure regarding the goal and direction of the transformation process, policy coordination and reflexivity. In the sustainability-oriented cases, the PPPs were initially used to create a common vision which required time investment. These findings are in line with the literature on innovation networks that states that multidisciplinary teams are more innovative (Beers and Geerling-Eiff, 2013; Schot and Geels, 2008) but at the same time can suffer from the large 'cognitive distance' between members (Nooteboom et al., 2007) making it more difficult and therefore more time consuming to reach a common vision.

In the competitiveness-oriented cases a shared vision was almost immediately present and this shared vision materialised in the establishment of the PPPs and their focus on the creation of new knowledge that could give participating companies an edge on the international market. According to the evaluations, the PPPs were successful in this regard. However, the nature of the sector itself, its production methods and the relationships between the actors hardly changed. More ties were created between organisations and social distances between actors decreased, but the private funds never exceeded the public funds in the PPP and the sector still has a 'science push' attitude towards innovations.

In all our cases an important role was played by the (lobbying for) public funds. Public funding was leading with regard to knowledge mobilisation within the early phase of the innovation system development. Sometimes in a later phase, private funding began to play a more significant role in stimulating the various innovation system functions. The question therefore remains whether these positive effects will disappear again once the public funds run out. This concern echoes some of the criticism by the earlier OECD evaluation of PPPs in the Netherlands which criticised the absence of some sort of an exit strategy for government participation within the large scale PPPs (OECD, 2004). Our results therefore suggest that PPPs are less capable of stimulating innovation functions necessary for the final market development and consumer demand. The implementation of additional policy instruments alongside PPPs is therefore necessary for that stage of the TIS development.

5.3. Value of the application of the innovation system functions perspective

In this paper we have used the concept of the innovation motor to

show the way different functions can positively reinforce each other and provide the internal dynamic of the TIS to steer an innovation from the development phase towards successful take-off. In our analysis, we focussed on the identification of different feedback loops in different phases. However, we have refrained from labelling these feedback loops into a number of archetypical innovation motors. This is a slightly different approach compared to the work of Suurs (2009) and Suurs and Hekkert (2009), who identified four successive innovation motors that they labelled the Science and Technology Push Motor, the Entrepreneurial Motor, the System Building Motor and the Market Motor.

We have two main reasons for not defining particular motors. The first reason has to do with the difficulty in identifying the different phases in the event history analysis. In many cases a clean break between phases can't be properly identified and phases partly overlap. For instance, the setup of some of the large PPPs (for instance in the Food and Nutrition case, but also in the Energy Producing Greenhouses case) took several years to start. This means that some functions already start in an earlier phase, but become visible and dominant in another phase. The second reason why we limited ourselves to the analysis of feedback loops and the combination of feedback loops into some archetypical innovation motors, has to do with the definition of the innovation system functions themselves. When working with the different innovation system functions, it became clear to us that it is sometimes difficult to separate two functions clearly, or that a function can have multiple meanings. For instance, the function F3 - Knowledge Diffusion and Network Building - combines two different activities that are not necessarily the same. Similarly F4: Guidance of Search includes two different processes: the emerging process of the convergence of expectations, which often occurs in collaborative projects, but also active vision building. There is a trade-off here between simplification and the explanatory power of the set of innovation system functions.

Despite the disadvantages of the concept of the innovation motor, we still find the idea of innovation motors to be a very attractive and a useful metaphor but we particularly value the methodology of identifying feedback loops. This method was very helpful in the structuring of our thinking about the dynamics of the innovation system functions in the innovation histories of the cases and we argue that this method is especially valuable in making the direct and indirect effects of certain policy interventions visible.

6. Conclusions

This paper dealt with the question how different types of PPPs act as systemic policy instruments and influence the different innovation system functions the AIS. Sustainability-oriented cases are associated with process-oriented policy goals and broader networks. These type of PPPs are capable of creating more profound changes within the TIS with new forms of institutional governance and configurational relationships compared with the competitiveness-oriented PPPs.

The main conclusions are that PPPs are especially suitable as systemic policy instruments in the early phases of the development of an emerging TIS. This is because they stimulate innovation system functions such as knowledge development, network building, diffusion and guidance of search, that play an important role in these early phases. However, our results suggest that PPPs are less capable of stimulating innovation functions necessary for the final market development and consumer demand. The implementation of additional policy instruments alongside a PPPs is therefore necessary in the later stages of an emerging TIS when market development becomes more important. The learning experiences of the PPPs can help to tailor these innovation policy instruments to make them more effective.

Acknowledgements

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the TRAFOBIT project (031B0020), funded by the German Federal Ministry of Education and Research (BMBF).

Appendix A. Data sources used

For the document analysis we included secondary sources coming from project proposals, evaluation reports, policy documents and scientific papers. In addition, interviews were conducted with people intimately familiar with the projects done., see [Tables A1–A4](#). Interviews were used to check the timelines for any missing events that could have an influence on the developments of the different innovation system functions.

Propagation Materials and Green Genomics

Project reports and evaluations

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Press / newspapers

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Table A1
Interviews Propagation Materials and Genomics.

Name	Organisation
Gionata Leone	CBSG; PRI Wageningen UR
Hans Dons	KeyGene
Kolja Laane	Netherlands Genomics Initiative
Bernard de Geus	TTI Groene Genetica
Marien Valstar	Ministerie Economische Zaken
Jaap Satter	Ministerie Economische Zaken
Thijs Simons	Plantum

Animal Husbandry Case

Project reports and evaluations

- Bureau Bartels (2008). Procesevaluatie innovatieregeling intensieve veehouderij
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Scientific papers detailing some of the approaches of the innovation programmes and PPPs

- Bos, A. P., P. W. G. Groot Koerkamp, J. M. J. Gosselink and S. Bokma (2009) "Reflexive interaction design and its application in a project on sustainable dairy husbandry systems." [Outlook on agriculture](#) **38**: 137–145.
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- Klerkx, L., N. Aarts and C. Leeuwis (2010). "Adaptive Management in agricultural innovation systems: The interactions between innovation networks and their environment." [Agricultural Systems](#) **103**(390–400) ([Table A2](#)).

Table A2
Interviews Sustainable Animal Husbandry.

Name	Organisation
Geert van der Peet	Livestock Research, Wageningen UR
Ger Vos	InnovatieNetwerk
Maarten Vrolijk*	Netwerken in de Veehouderij

* data used from earlier interview.

Energy producing green house

- Roza, C. 2006. Kas als energiebron Innovatienetwerk en Stichting Innovatie Glastuinbouw, Utrecht.
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Table A3
Interviews Energy producing green house.

Name	Organisation
Piet Boekharst	Productschap Tuinbouw
Jolanda Mourits	Ministerie Economische Zaken, Landbouw en Innovatie
Eric Poot*	PPO Wageningen UR
Rob van der Valk*	LTO/Glaskracht
Henk van Oosten*	InnovatieNetwerk

* data used from earlier interviews.

Food and Nutrition
Project reports and evaluations

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Table A4
Interviews Food and Nutrition.

Name	Organisation
Ben Langelaan	FBR Wageningen UR
Kees de Gooier	Food & Nutrition Delta
Marcel de Groot	Ministerie van Economische Zaken
Marc Jansen	Centraal Bureau Levensmiddelenhandel
Onno Franse	AHOLD
Philip den Ouden	Federatie Nederlandse Levensmiddelen Industrie

Appendix B. Detailed event history analysis of the four cases

B.1 Energy producing Greenhouses

The innovation history of the energy producing greenhouses had two different starting points. First there was the national platform for the horticultural sector that was established in 1994. It resulted in 1997 in a covenant (with the acronym GLAMI) between government and the horticultural sector that contained agreed targets for energy, minerals, pesticides and growth light. At the time gas prices were low and saving energy was an unimportant issue for the growers and it got therefore a low priority.

A second starting point is the concept of closed green houses that were developed by a private company called Ecofys. The large horticultural exposition 'Floriade', that is held every 10 years in the Netherlands, provided an opportunity to develop this idea further into a full demo version. A consortium of partners worked together to realise this demonstration greenhouse in 2002 at the Floriade Haarlemmermeer.

The two initiatives came together around 2002 when two organisations that promoted innovation in the agricultural sector (called SIGN and Innovation Network) started to collaborate. Energy was one of the focus areas and they came up with a very appealing metaphor: the energy producing greenhouse. Some technical designers calculated the feasibility of producing energy with a greenhouse and decided to support the idea. Although the idea was met with enthusiasm by the Ministry of agriculture and the sector, it was still hard to find partners willing to invest in the realisation of the idea. It took some strategic manoeuvring, but finally the Ministry of Agriculture, the ministry of Economic Affairs and the Ministry of Housing, Spatial Planning and the Environment promised to fund a PPP under the condition that the Product Board for Horticulture would contribute the same amount of money. In 2004 the idea of an energy producing greenhouse received a national innovation prize: "the Egg of Columbus Award" which further proved the strength of the idea. A pilot project was established at private greenhouse grower. In the same year the PPP called 'Energy producing greenhouse' started. The Energy Producing Greenhouse programme defined seven transition pathways and target values for 2010 and 2020. For each of the pathways several applied research and demonstration projects are undertaken. The programme organised a design contest, built a demonstration centre for energy solutions in horticulture and worked to accomplish a pilot of the closed greenhouse. It remained a challenge to find a balance between the researchers' wish for scrupulousness and the entrepreneurial desire to start as soon as possible. The first closed greenhouse is officially opened by the minister of agriculture in 2006.

In 2007 the Ministry of agriculture set up two financial policy instruments in the form of two subsidies to support energy innovation in the horticultural sector. The first one focussed on the market introduction of closed greenhouse technology, the other one on further adoption of energy innovations. The experiences in the PPP Energy producing greenhouse enabled the Ministry to improve the efficiency of the subsidy scheme. At the same time the horticulture sector sharpened its targets for energy efficiency and CO₂ reduction. The programme got a lot of good publicity and in 2009 more than half of all Dutch growers agreed with the need of reducing CO₂ emissions.

As of 2009, a difficult period for the horticulture sector began. As a sector with an international market the financial crisis seriously affected sales. Due to reduced room for investment, new technology was less quickly applied in practice. Attention shifted from the closed greenhouse to improved growing practices that required less investments.

The top sector policy was introduced in 2011. Although the Energy producing greenhouse was one of the first considerable Public-Private Partnerships and served as an example for the top sector policy. The policy framework was not considered to be beneficial for the further development of closed greenhouse technology, since procedures for application for funding changed and the total budget was reduced (Table B1)

B.2 Propagation Materials and Green Genomics

The starting point for the timeline is the year 2000. At the start of the new Millennium there was a growing fear that the Netherlands was falling behind in the emerging field of genomics, in comparison to other countries. In the year 2000, a Strategic Action Plan was published in which universities and research institutes, backed by industry and policy makers, lobbied for more government investments into this field of research. As a result The Netherlands Organisation for Scientific Research (NWO) was tasked to set up a research programme: the Netherlands Genomics Initiative (NGI). In the beginning there was some worry that genomics might be confused with the far more controversial topic of Genetic Modification and the new Centre for Society and Life Sciences Genomics (CSG) was tasked with organising the public debate and public information about the science field.

The involvement of the government started with the initiation of a commission of 'wise men' that were involved in the writing of the Strategic Action Plan. The Centre for Biosystems Genomics (CBSG) was one of the public-private partnerships that was formed under NGI. In CBSG 13 private parties participated together with a number of universities. The private part of the partnership consisted mainly of large companies and two branch representing organisations. Within CBSG, the participating research institutes were dominant in setting-up and dividing the funds. Participating companies profited through the 'right of first refusal' for any new knowledge that was developed. A choice was made to focus most of the research on two important Dutch crops: tomatoes and potatoes because of their economic importance and their genetic characteristics, which formed a good

Table B1
Function development over time in Energy producing greenhouse.

	F1 Entrepreneurial activities	F2 Knowledge development	F3 Knowledge diffusion and network formation	F4 Guidance of search	F5 Market development	F6 Resource mobilisation	F7 Support of advocacy coalitions
<i>x-axis depicts time since year 2000, y-axis depicts the performance of the innovation system function</i>							
Explanation of development through events	Entrepreneurs first engaged in subsidised demonstrations and pilots. These brought the concept closer to other entrepreneurs. Only when the government installed the subsidies for construction of innovative energy efficient greenhouse more entrepreneurs invested in the concept.	Demonstrations and applied research brought more speed in knowledge development. The larger research projects under energy producing greenhouses gave a boost to knowledge production.	The demonstration at the Floriade expo generated some knowledge diffusion. The PPP Energy producing greenhouses organised information meetings and a website. The Innovation and demonstration centre together with the Network “Synergie” further improved knowledge diffusion.	The GIAMI covenant brings some consensus between private and public parties. The metaphor “energy producing greenhouse” in 2002 brings focus to the search and provides an attractive image that mobilizes the sector. Later specific transition pathways are defined that also help to determine the guidance of search.	Government subsidies support the creation of markets for energy innovations in horticulture and energy efficient greenhouses. The market for energy efficient products among consumers is almost non-existent; The crisis of top sector policy and the ending of the product board, has a negative effect on the market for energy innovations resource mobilisation decreases.	The PPP gave a strong increase in available resources (public and private funding matching each other). An extra subsidy became available providing an extra boost. With the introduction of top sector policy and the ending of the product board, resource mobilisation decreases.	Societal pressure on the horticulture sector was high. The image of the sector has improved considerably over the years. The concern for climate change and thus energy efficiency increases steadily.

Table B2
Function development over time in Propagation Materials and Green Genomics.

	F1 Entrepreneurial activities	F2 Knowledge development	F3 Knowledge diffusion and network formation	F4 Guidance of search	F5 Market development	F6 Resource mobilisation	F7 Support of advocacy coalitions
<i>x-axis depicts time since year 2000, y-axis depicts the performance of the innovation system function</i>							
Explanation of development through events	The amount of entrepreneurs increased from 13 private partners in CBSG, to over 100 involved in the TTI-GG.	Extra investments through the PPPs, stimulated knowledge development and uptake. The number of publications and patents increased.	In 2006, with the formation of the TTI-GG consortium, knowledge diffusion got a boost. The Top Sector policy started its own model and programmes which felt like a regression to the existing public-private networks.	Consensus within the sector has always been high. The establishment of a larger collaborative PPP in 2006 indicated that consensus is still present throughout the sector. However, the sector was not very satisfied with the direction of the Top Sector Policy, which weakened the public-private collaboration.	The goal was to create a better position on the (international) market, through innovation. The PPPs gave a knowledge boost, to close the perceived knowledge gap of the late 1990s. An important result is that more qualified personnel were trained.	In 2006 the government increased its initial financial support. Later, an important source of innovation funds (FES) money from the exploitation of Dutch natural gas reserves) was abolished. As a result of the financial crisis of 2008, the government decreased its financial commitments further.	The set-up of the first large CBSG PPP required some lobbying. A similar peak in the lobby on behalf of the sector can be found before the installation of the TTI-GG PPP in 2006. From 2011 lobbying was undertaken to mitigate some of the effects of the Top Sector Innovation Policy.

Table B3
Function development over time for sustainable animal husbandry.

	F1 Entrepreneurial activities	F2 Knowledge development	F3 Knowledge diffusion and network formation	F4 Guidance of search	F5 Market development	F6 Resource mobilisation	F7 Support of advocacy coalitions
x-axis depicts time since year 2000, y-axis depicts the performance of the innovation system function							
Explanation of development through events	Entrepreneurial activities were almost non-existent until 2006. The combination of PPPs (before 2006) and specific tax breaks (after 2006) changes this.	Knowledge development quickly increased on stable design, animal welfare and landscaping. New designs and prototypes were developed. With the introduction of the Top Sector Policy sustainable stable concepts have taken a back seat.	The number of new networks and new organisations focussed on knowledge dissemination grew, especially between 2008 and 2011 when the sectoral innovation centres were established.	The government, under pressure of public opinion, funded a number of research projects on sustainable stables. Consensus increased stepwise with every epidemic that hit the sector.	Consumer demand for meat produced in 'sustainable stables' is whimsical. After every epidemic/ crisis the demand for organic and other sustainable types of meat peaked, but after the initial scare, the demand collapsed again. However, over time the demand slowly increased.	Over time there has been a shift towards more involvement of private money in the PPPs. After 2010 the government has been forced to cut back their own contribution because of the global financial crisis and subsequent cut backs in government spending.	Support for the industry was initially negative. Over time animal welfare NGOs became actively involved in certification and marketing schemes for more sustainable stables. Their activism shifted slowly up the value chain towards supermarkets and fast food chains.

Table B4
Function development over time Food and Nutrition.

	F1 Entrepreneurial activities	F2 Knowledge development	F3 Knowledge diffusion and network formation	F4 Guidance of search	F5 Market development	F6 Resource mobilisation	F7 Support of advocacy coalitions
x-axis depicts time since year 2000, y-axis depicts the performance of the innovation system function							
Explanation of development through events	The amount of entrepreneurs increased, after FND2 had been established. However, the financial risks taken by firms within the PPPs remained limited. The PPP had the effect of broadening the scope and increasing the ambition of projects.	The sector was already very knowledge intensive. Bilateral partnerships between universities and individual businesses have always been present. The extra investments through the PPPs, knowledge development was stimulated further.	Knowledge diffusion increased significantly with the establishment of the FND activities. Their 'innovation brokers' turned out to be an important instrument. After 2011, FND no longer formed part of the topsector policy.	Consensus within the sector has always been high. The establishment of the PPPs was both a result and driver of this consensus.	PPP actors were already engaged in an existing market. The goal was to create a better position on the (international) market, and use the Dutch knowledge infrastructure more intensively.	In 2006 the government increased its initial support. Later, an important source of innovation funds (FES money from the exploitation of Dutch natural gas reserves) is abolished. As a result of the financial crisis of 2008, the government decreased its financial commitments.	No real difference noted in the advocacy coalition over time.

basis for research.

Around 2006 another PPP was established: the Technological Top Institute for Green Genetics (TTI-GG). The aim of this PPP was to broaden the network of participating businesses and subsectors within the propagation materials branch for knowledge co-creation, exchange and valorising the knowledge in practice. Within the Top Institute for Green Genetics there was a distinction between projects that focused more on fundamental knowledge development, in which researchers were the dominant actors and industry driven projects, which focused more on knowledge valorisation and business. Over the years more than 100 firms participated in one or more projects of TTI-GG. Synergetic effects further increased the knowledge development function. An important effect being the education of skilled labour in the programmes and improvement of educational programmes.

The Top Sector Policy (in 2011) followed the public-private partnerships of CBSG and TTI-GG which ended in the same period of time. Participating companies were disappointed about the loss of experience and the dismantlement of the two PPPs that were thought to be functioning very well ('model examples of strategic fundamental research', according to several influential actors in the propagation materials sector). Their complaint was that, although the Top Sector Policy promised to put companies "in the driver's seat" of innovation, in practice it was the government who steered the process. However with far less financial funds than were made available for CBSG and TTI-GG in the past. The PPPs in this case were designed to help develop the Dutch sector and to catch up with the competition (Table B2).

B.3 Sustainable animal husbandry

The outbreak of a variety of contagious animal diseases at the end of the 1990s (BSE, or Mad Cow Disease in 1996, swine fever in 1997 and 1998 and Food and Mouth Disease in 2001), severely impacted the public opinion of the animal husbandry sector in the Netherlands. In the year 2000 the government, due to mounting societal pressure, initiated a series of policy interventions to investigate and improve the position of the intensive animal husbandry sector. In this initial phase, research and vision development were emphasized and the collaborative partnerships depended on the strong involvement of researchers working with public money. Enthusiasm and interest from the sector were minimal and had to be generated through soft instruments such as participatory techniques and financial incentives in the form of subsidies of research projects such as the programme called 'Future Livestock Production Systems'. This research programme investigated the possibilities for alternative animal husbandry systems and heavily depended on vision development through the method of 'backcasting' (Quist and Vergragt, 2006). Approximately at the same time a national debate was organised on the future of the animal husbandry in the Netherlands.

The Future Livestock Production Systems programme was split up into two closely related programmes: the Practice Networks Programme and the Socially Accepted Animal Husbandry Programme. The Practice Networks Programme stimulated the establishment of small innovative networks of farmers working on innovative solutions for a practical problems they encountered on their farms. After four years of experimentation this programme became institutionalised in the permanent Practice Networks Arrangement of the Ministry of Agriculture. The Practice Networks Programme marked the start of more involvement of private actors. However, researchers and civil servants were still very much in charge of the programme with regards to the operational decisions and division of funds.

One of the ideas developed in the Socially Accepted Animal Husbandry Programme is the concept of an innovative chicken farm. This idea is further elaborated upon by two commercial companies under the umbrella of the TransForum innovation programme (Groot Koerkamp and Bos, 2008; Klerkx et al., 2010). The development of the sustainable 'Rondeel' stable becomes a flagship project that illustrates the possibilities of the Reflexive Interactive Design approach for sustainable stable concepts in other sectors (Grin et al., 2004).

In 2007 a new regulatory instrument is implemented in the form of a new animal welfare policy. One of the policy aims is that in the year 2011, 5% of the stables had to be 'integrally sustainable and animal friendly'. In order to achieve this aim, the construction of these sustainable stables was stimulated through tax breaks. One of the distinguishing features of this policy was that the definition of what kind of stable type was eligible for the tax break would evolve over time. Criteria for sustainable stables in new animal husbandry sector were introduced in later years and the criteria for existing stable types were sharpened. In 2012 the share of new sustainable stables reached 7% (Van der Peet et al., 2012). The Reflexive Interactive Design projects supports the development of the sustainable animal housing further by providing support for the further sharpening of the accompanying regulatory framework for the new class of 'sustainable stables'.

The first example of a public-private partnership in which private participants were expected to also share some significant financial risks is the establishment of the TransForum innovation programme (Veldkamp et al., 2009). This represents a shift in the financial incentives from a subsidy to the sector as a whole, to a subsidy to specific participants who are expected to gain the most from their involvement. During this time the first 'Rondeel stable' became operational.

Over time consensus between different actors within the sector increased. The consensus materialised in the establishment of an Executive Agenda for the Future of Animal Husbandry. This Agenda was a kind of covenant / Round Table initiative that involved the government, farmers unions and large market actors and also includes some animal welfare NGOs. The Round Table has a small budget for doing research and this budget is provided by both the public and private funds.

Around 2011, the Top Sector Policy was also introduced in the animal husbandry sector. A number of new agricultural PPPs were set up under the heading of the Top Sector Policy. However the interest in sustainable stable concepts seemed to disappear somewhat and the chosen PPPs mostly involved 'safe' and 'easy' topics like breeding, nutrients, health and feeds. An ambitious cross-sectoral plan to work on the reduction of the use of antibiotics does not get funded, despite glowing reviews. One of the reasons for this is that money projects from the 'own' sector gets priority over the common projects with other sectors.

Public discussions never let up during this period. Discussions on antibiotics use and the threat of the MRSA (*Methicillin Resistant Staphylococcus Aureus*), "Mega stables", "bloated chicken" in the press and an outbreak of Q-fever among goats (that also caused victims among humans in 2009), kept the pressure on the sector to work on sustainability related issues (Table B3).

B.4 Food and Nutrition

In 1997 the Wageningen Centre of Food Sciences (WCFS) was one of the four Dutch Technological Top Institutes that was funded by the Ministry of Economic Affairs in order to stimulate excellent fundamental research with commercial potential, by use of a PPP in which research and business would participate. In practice the WCSF had a strong focus on fundamental knowledge production and the participation of businesses was limited to the involvement of a couple of multinational corporations.

The sector aimed to develop a broad encompassing knowledge and innovation programme that would benefit both SMEs, multinationals and knowledge institutes. Building on the experiences with the WCFS a group of 60 companies, together with knowledge institutes and the Ministries of Economic Affairs and Agriculture, Nature and Food Security made a start with the Innovation Programme Food and Nutrition (IPFN) in 2003. The aim was to make sure that 1) the most successful food and nutrition innovations would come from Dutch companies and 2) that the Dutch knowledge

infrastructure and institutes became an attractive R&D partner for national and international firms to cooperate with.

In 2006, after a long phase of negotiation and deliberation, two different PPPs were established to support the two goals. The Top Institute Food and Nutrition (TIFN) facilitated pre-competitive knowledge development. The aim was to develop 'knowledge' as a Dutch export product, with Dutch companies as innovative pioneers. The Food and Nutrition Delta (FND) was specifically tasked with the knowledge diffusion to SME companies through subsidies for feasibility studies, collaborative projects between SMEs and border innovation projects that also included research institutes.

In order to make sure that both PPPs complemented each other, an overarching steering group was set up to coordinate plans and research themes. The results of the TIFN in terms of fundamental research output, included: PhD dissertations (62) and peer-reviewed publications with a high impact score (88-162). The collaboration with companies resulted in more focus and cohesion of research in some (potentially) commercially interesting fields.

In the period 2006–2010 the PPP Food and Nutrition Delta supported 198 feasibility studies, 88 SME projects and 87 broad innovative projects that also included research institutes (Enzing and Vullings, 2011). However, it was noted that between 32–38 % of the projects would not have gone through without public support. The majority of the innovation projects would still have taken place, although possibly less ambitious or smaller in size. The value of the support of FND was therefore not in the number of innovation projects, but in enabling participating partners to collaborate more ambitiously. This was also the opinion of the participating companies, of which 75% reported an increase in their innovative capability. They especially valued the role the projects played in network building and making new contacts, compared to generic policy instruments such as subsidies.

Despite a positive review from the external advisory committee, the FND PPP did not continue under the Top Sector policy, TIFN did. (Table B4)

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