Towards more sustainable agri-food chains: a new conceptual framework

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Abstract: Due to pressures such as climate change, globalization, price volatility and scarcity of natural resources, the Flemish agri-food chain is urged to make a transition towards more sustainable production. How to organize such a transition, given the various stakeholders involved, and how to monitor progress still remain important challenges. This paper presents a new conceptual framework that follows an integrated chain approach to help address these challenges. First, it tackles the complex ecological and socio-economic challenges along the chain and its members (agriculture and food industries), and second, allows for decision support to chain members and policy.

This framework combines two existing theoretical frameworks. The first framework is global chain value analysis (GCVA) of Gereffi (2005) which has its roots in institutional economics. GCVA categorizes five governance types of value chains (markets – modular – relational – captive – hierarchy) based on three variables: (i) the complexity of information and knowledge transfer required to sustain a particular transaction, (ii) the ability to regulate transactions, and (iii) the capabilities of actual and potential suppliers. The second framework, which was first formulated in ecological economics by Lawn (2001), extends the set of traditional economic resources to various forms of capital in the production system. These are natural (land, water,…), manufactured (buildings, machinery,...), human (labour, skills,…), and social capital (networks,…). The economic system is embedded in the social system which in turn is embedded in the finite ecological system. Throughput of natural, social, human, and manufactured capital allows for the description of agri-food systems in terms of the maximal sustainable use of their stocks and flows.

These two frameworks can be combined to perform an integrated system analysis of the agri-food chain, including the governance structures and the boundary conditions as for example the maximum sustainable use of the various capitals. This paper describes this new conceptual framework illustrated by means of a case study of the agri-food chain in Flanders, Belgium.

Keywords: Global value chain analysis, ecological economics, agri-food chain, sustainability

Introduction

The overall attention for sustainable agriculture has risen during the last decades due to increased concerns about global environmental change and food security (Dicks *et al.*, 2013). These concerns increased as the result of (growing awareness of) pressures such as climate change (Beddington *et al.*, 2012), risks to food security from an increase in the global population and changing dietary habits (Duchin, 2005), the rising prominence of the sustainability agenda amongst consumers and in corporate governance (Lockwood *et al.*, 2010), and the depletion of natural resources (Daily & Ehrlich, 1992).

As in many other regions, the Flemish research, policy, and food industry actors acknowledge these concerns and have increased their attention to the sustainability of food production. As agriculture, food manufacturing, distribution and consumption are thoroughly linked, an integrated chain approach is necessary to monitor sustainability. Flanders is a small region (13.522 km²) with a high urbanization rate and a dense population rate with an average of 462 inhabitants per km² in 2010 (ADSEI, 2013). The Flemish agri-food chain is exposed to pressures such as, a high aging population, urbanization and consolidation. Furthermore, the agri-food chain consists mostly of SME's and focuses on import and export (Samborski, 2013).

To further improve the shift towards a sustainable agri-food chain in Flanders, a transition is required that involves a radical change of societal functions towards a new dynamic equilibrium (Geels, 2002). The changes can occur at the level of institutional organization, and rules and attitudes. A transition is more likely if it is endorsed by all supply chain actors with support of the policy level and the consumers, which still remains a challenge. This paper aims to answer the following three research questions to support decisions of chain members and policy:

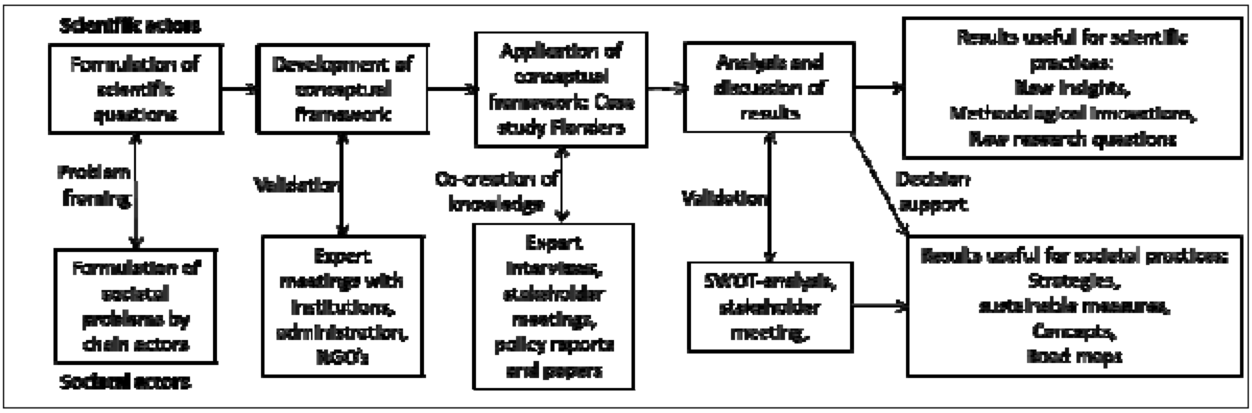
I. Which concepts need to be combined to perform a system analysis of the sustainability of the Flemish agri-food chain?
II. What does the system analysis reveal empirically about the sustainability aspects of the Flemish agri-food chain?
III. How adequate are the existing chain governance types to answer the current sustainability challenges?

Firstly, we combine two frameworks into a new framework that addresses all sustainability aspects in an integrated chain approach. Secondly, we apply this framework for the Flemish agri-food chain to learn lessons about the current sustainability and lastly, we analyze the existing governance types, i.e. the explicit or implicit contractual outline within which a transaction is located, to respond to specific sustainability challenges identified by the system analysis.

Methodology

The overall used methodology is transdisciplinary research. Researchers and societal actors work together to co-create knowledge which allows the continuous alignment and validation of results (Figure 1). Moreover, different forms of triangulation validate the results (Koro-Ljunberg 2008). Firstly, data triangulation is performed by using data derived from different stakeholders. Secondly, methodological triangulation is ensured by the use of different methods to collect and analyze data (e.g. scientific and popularizing literature, interviews, and expert meetings). Lastly, triangulation of researchers is guaranteed for the data analysis and interpretation by four researchers.

Figure 1: Transdisciplinary methodology used throughout the research process



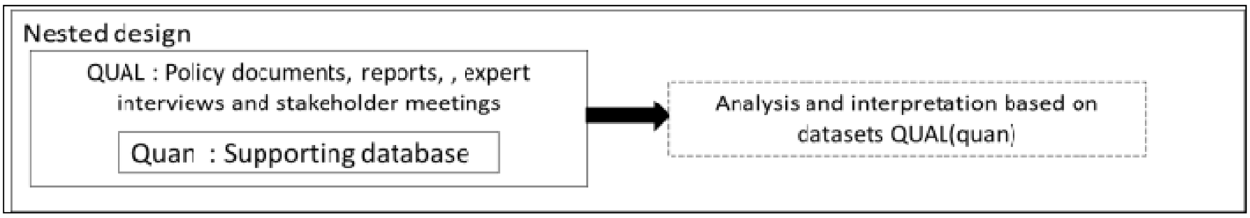
Selection and development conceptual framework

A conceptual framework is developed based on a literature review and the combination of two existing frameworks. The integrated chain approach describes (i) system boundaries, (ii) the different system components and their interrelationships, (iii) the internal and external forces, (iv) the system changes in a multilevel perspective, and (v) the various chain actors (Rotmans, 2003).

System analysis of the Flemish agri-food chain

We used the nested design as illustrated in Figure 2 which is part of mixed methods as defined by Mortelmans (2013). The nested design uses both qualitative as well as quantitative data but one of the two is secondary and covers a particular part of the research question.

Figure 2: Nested design used to perform system analysis by applying conceptual framework

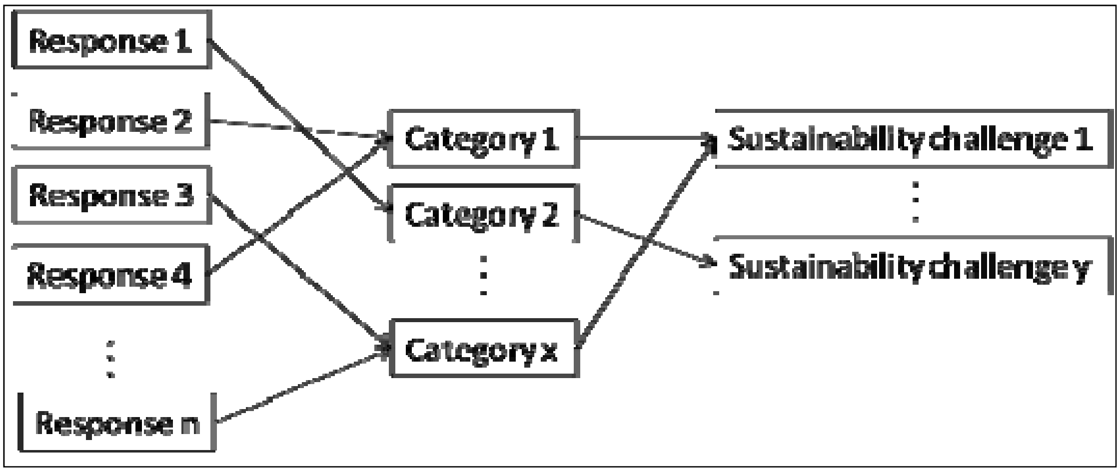


We built an extensive qualitative database based on the collection of policy documents, reports, and information about existing initiatives and projects (see below for details). Moreover, we organized two stakeholder meetings with actors of the agri-food chain, i.e. input suppliers, agriculture, food manufacturing, distribution, and policy and NGO's actors. Additionally, we had five expert meetings with academic scientists and chain experts and conducted interviews with key chain actors. Furthermore, we developed a supporting quantitative database based on existing databases such as Statbel, MIRA database and documents of existing projects.

Sustainability challenges

To identify the sustainability challenges, all responses and initiatives originating from the system analysis were listed. These responses were formulated through focus groups, and workshops. We used the categorization technique of open coding (De Mey *et al.*, 2011) and categorized the responses into categories and the categories into sustainability challenges (illustrated in Figure 3).

Figure 3: Illustration of categorization method



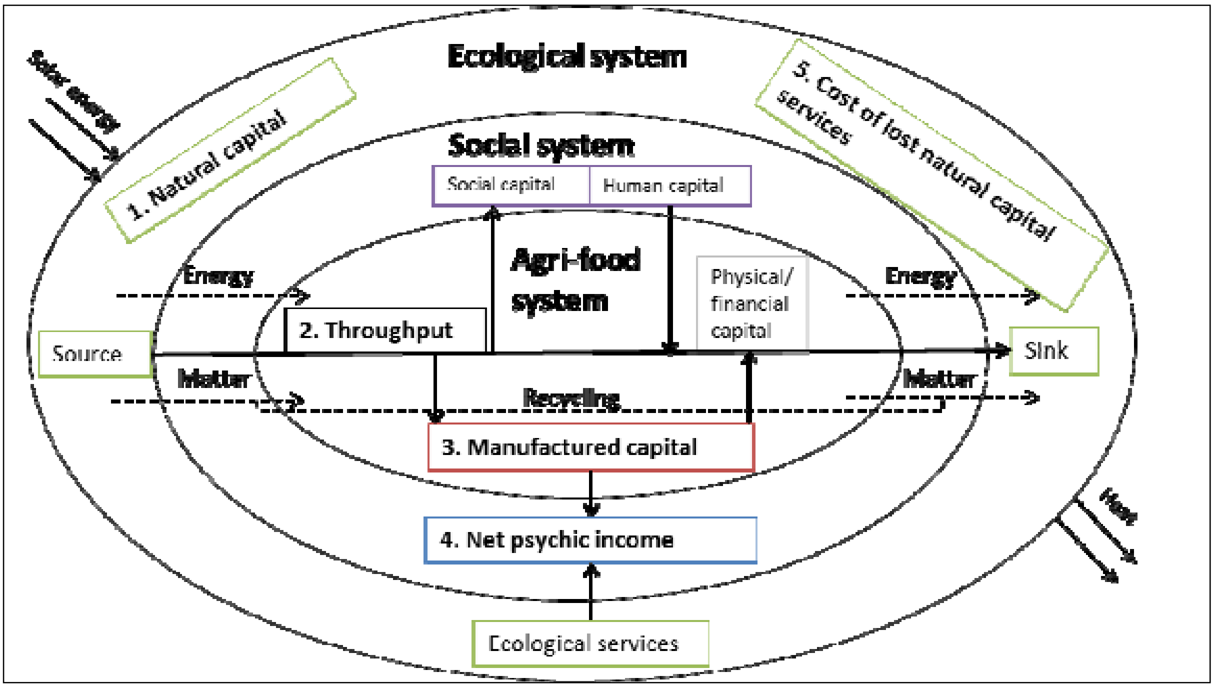
Conceptual framework

We developed a conceptual framework to perform a system analysis to identify the sustainability challenges of the Flemish agri-food chain. Moreover, the existing governance types are identified to address these challenges. The agri-food chain is defined as the full range of value-adding activities from raw material (e.g. seed, water) over the production and marketing phases such as agriculture, food manufacturing and distribution to the final consumption, and disposal after use. Between these different activities also interrelationships exists between buyers and suppliers (Dekker, 2003). This allows monitoring institutional changes and implementing sustainability measures covering the agri-food chain.

The forms of capitals to monitor sustainability

Ecological economics (Daily & Erhlich, 1998; Costanza *et al.*, 1997; Lawn, 2007) extend the set of traditional economic resources used to describe the sustainability state of a system to various forms of capital of the production system. We describe the agri-food chain using the linear throughput representation of a socio-economic activity (Lawn, 2001, Lawn, 2007). It considers the agri-food chain as part of the economic system embedded within the social system which in turn is embedded in the finite ecological system. Five central elements exist to define the different forms of capitals (Figure 4).

Figure 4: Linear throughput representation of the agri-food system (Adapted from Lawn, 2007)



As explained by Lawn (2001, 2007), the first element is natural capital, the resource of all human realizations which has three functions: (i) it generates low-entropy resources or raw materials such as soil and water (source function), (ii) it assimilates the waste, e.g. greenhouse gasses, packaging waste and food surpluses (sink function), and (iii) it provides the earth's life-support services such as biodiversity necessary for human wellbeing (the ecosystem services). The second element is the throughput of material and energy. Low-entropy resources are converted into manufactured output, i.e. food and high-entropy waste products. This conversion to manufactured capital (the third element) may requires multiple components such as machinery and technology (= physical capital), labor, knowledge and skills (= human capital), cooperation and innovation (= social capital). The produced manufactured capital increases - if well-produced - the human wellbeing. This human wellbeing is associated with the net psychic income, the fourth element. The net psychic income is the benefit of a socio-economic activity coming from the consumption of manufactured capital, the participation in economic activities and non-economic activities such as leisure time. The final and fifth element is the cost of lost natural capital services caused by the exploitation, manipulation and conversion of natural capital to produce the manufactured capital.

These five forms of capital are described by using information on resource stocks and flows. Therefore, the throughput of natural, social, human, physical, financial and manufactured capital allows describing agri-food systems in terms of maximal sustainable use of stocks. As a result we can distinguish essential resources (e.g. biodiversity), interchangeable resources (e.g. proteins) and renewable resources (e.g. solar energy), non-renewable resources (e.g. fossil fuels).

Governance of agri-food chains

The first framework allows describing all sustainability aspects of the agri-food chain. However, the explicit focus on the value chain is lacking. We therefore decided to additionally rely on a second framework which focuses on the internal institutional organization of the chain. Governance is the explicit or implicit coordination of a transaction which determines the allocation of financial, material and human resources and how these resources flow through a certain value chain (Gereffi, 1999). A framework that can be used to classify institutional governance types is global value chain analysis (GVCA) (Gereffi *et al.*, 2005). This framework has been a major contributor to our understanding of the working of different value chains and can assist us to reach important insights in which chain member(s) has to implement certain sustainability measures and which possible positive effects these measures can have. GVCA distinguishes governance types based on three variables: (1) the complexity of information and knowledge transfer required to sustain a particular transaction, (2) the ability to regulate transactions, and (3) the capabilities of actual and potential suppliers (Gereffi *et al.*, 2005). The five governance types are markets, modular, relational, captive and hierarchy. Figure 5 presents an archetype of the different governance types with the thin arrows indicating transactions based on price and the thick arrows indicate transactions based on information and control by explicit coordination. Table 1 summarizes the most important characteristics of the different types of governance. Important to mention is that more governance types can exist within one agri-food chain, e.g. a farmer has a captive relation with a food manufacture which supplies in a modular relationship to the retailer.

Figure 5: Schematic representation of governance types (based on Gereffi et al., 2005)

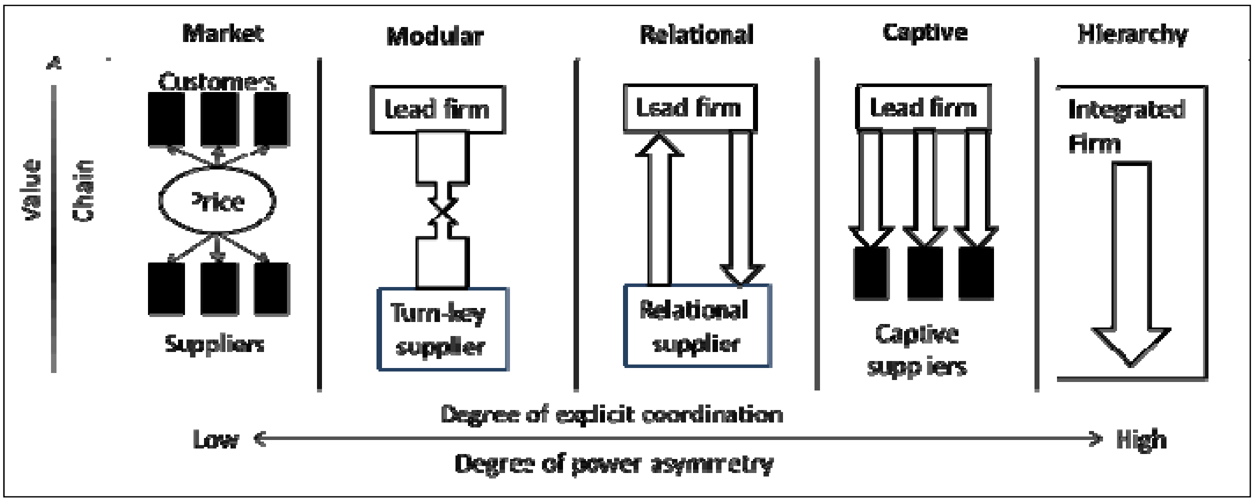


Table 1: Characteristics of governance types (based on Gereffi *et al.*, 2005)

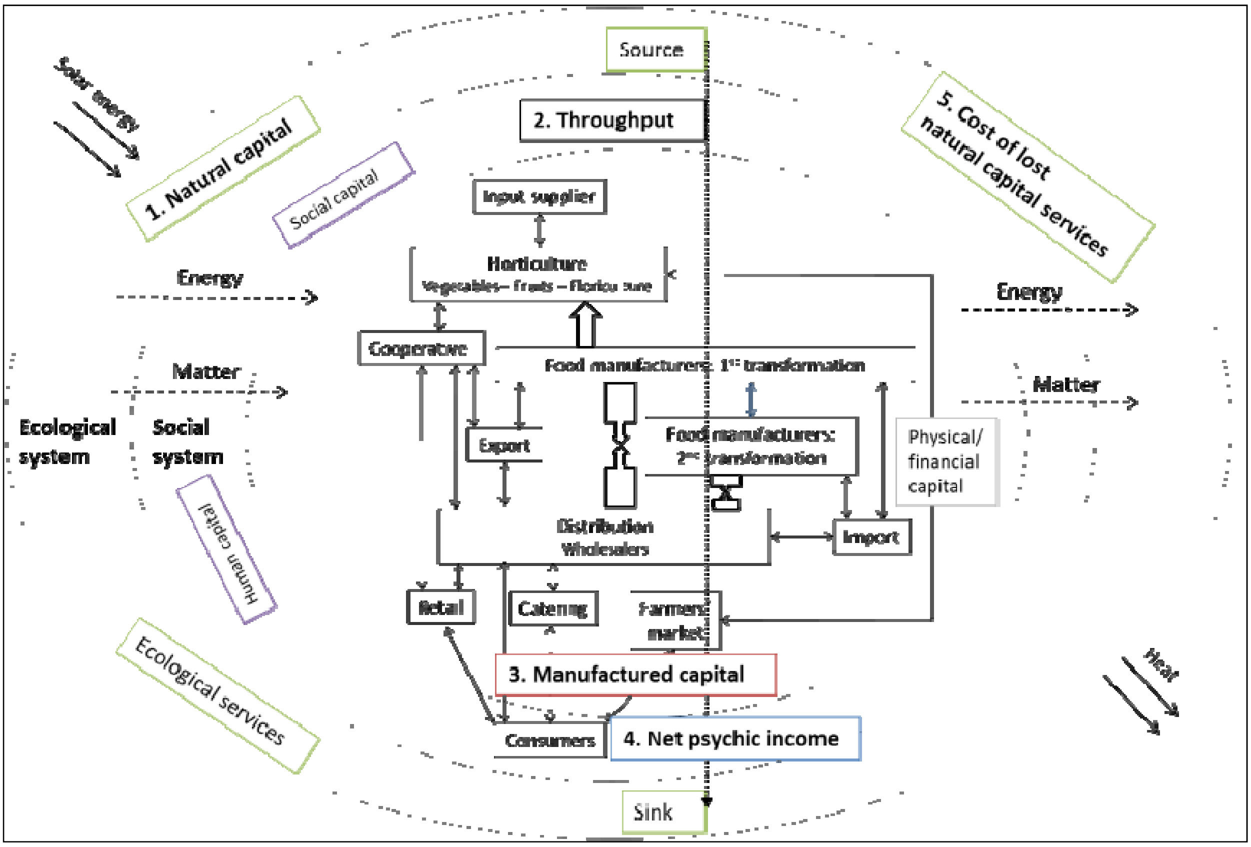
Governance type	Complexity of transactions	Ability to regulate transactions	Capabilities in the supply-base	Degree of explicit coordination
Market	Low	High	High	Low
Modular	High	High	High	↕
Relational	High	Low	High	
Captive	High	High	Low	
Hierarchy	High	Low	Low	High

The GVCA proved its applicability in a wide range of studies, particularly in studies about agri-food chains (Raynolds, 2004), and more specific fresh fruits and vegetables (Dolan & Humphrey, 2000), coffee, cocoa, and tea (Ponte, 2002), as well as fish-based products (Tran *et al.*, 2013). GVCA studies focus on questions of governance, especially exploring how lead firms (e.g., transnational brand-name corporations and large retailers) exercise control throughout the value chain. Therefore, GVCA is important to investigate the institutional structure including the social networks and interrelationships throughout the agri-food chain.

Structure new conceptual framework

To perform the case study in Flanders, a new conceptual framework which combines the two above described frameworks is constructed. The different form of capitals together with the agri-food system embedded in the social and ecosystem covers all sustainability dimensions to perform an integrated system analysis. Additionally, the GVCA incorporates the chain perspective and allows formulating sustainability measures and decision support to chain members and policy. The result identifies key chain members to initiate the transition towards a more sustainable production. The structure of the new conceptual framework which combines the linear representation of the agri-food chain and the different governance types is illustrated in Figure 6. This scheme represents the different coordination structures between the chain members (e.g. modular relation between food manufacturing and distribution) and describes the different used resources (soil, water, labor, energy, technology etc.).

Figure 6: Visual representation of conceptual framework



Integrated system analysis of the Flemish agri-food chain

The Flemish agri-food chain is exposed to major pressures such as globalization, a high aging population, consolidation and urbanization. The first important step in an integrated system analysis is the delimitation of the system boundaries. The system boundaries of the Flemish agri-food chain are defined based on five main chain components, namely (i) input supplier, (ii) agriculture, (iii) food industry, (iv) distribution (wholesale and retail), and (v) foodservices. All the import and export to other regions and/or to other sectors are linked to one of these five system components. Moreover, consumer and consumption itself is considered as one of the main driving forces that influence the agri-food chain. Research and development institutes, NGO's, policy and administration are also linked to the agri-food chain.

System analysis of Flemish agri-food chain

The system analysis is performed based on the capital forms and the central elements of the linear throughput representation. A supporting empiric database was built based on document analysis. This quantitative database is extended with information from qualitative research such as expert meetings and expert interviews. The results of the detailed system analysis are summarized and briefly described below.

Natural capital: The state of natural capital is described by land, water, energy, biodiversity,.... Not only the amount but also the type of source is important. Firstly, Flanders has good growing conditions due to fertile silt soils and favorable agronomic conditions. However, the soil quality described as soil structure, physical and chemical properties declines due to factors such as overfertilization, monocultures, mechanization,… (LNE, 2009). Secondly, the main issue of water is the declining groundwater stock and quality due to eutrophication and leaching. The use of alternative water sources such as the effluent of purified water increases. The food industry uses most water followed by agriculture (MIRA, 2013). Thirdly, energy usage is still high and even increases. Mainly the usage of non-renewable energy sources such as fossil fuels in glasshouse horticulture and cooling in the food industry contributes to high energy use and emissions (MIRA, 2013). However, combined heat and power systems (CHP's) make their ascent (FEVIA, 2011). Agriculture is the highest producer of GHG's, acidifying emissions and fine dust because of the livestock and the use of chemical fertilizers (Platteau *et al.*, 2012). In contrast, the food industry is the highest producer of NMVOS and ozone-depleting substances mainly originating from respectively combustion processes and refrigerant use (Elsen & Kielemoes, 2012). Lastly, biodiversity is under pressure due to factors as monoculture cropping, overfertilization and fragmentation of habitats (Demolder & Peyman, 2012).

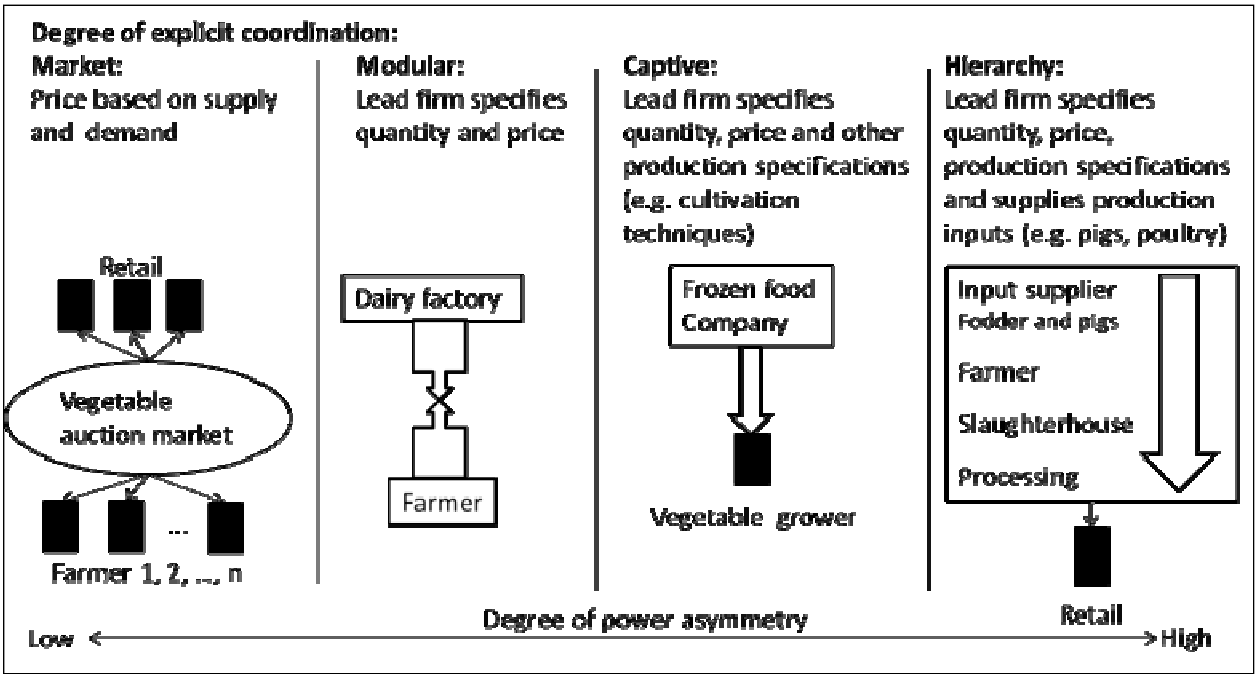
Human capital: The amount and structure of firms, the number of employees and the labor productivity describes human capital (Samborski, 2013). Furthermore, important issues for agriculture are the increasing age and level of education of farm managers and the low replacement rate (Platteau *et al.*, 2012). Although food industry and distribution employ a high number of low-skilled employees, the low interest of people in the agricultural sector and food industry remains a bottleneck to reduce the rather high number of open vacancies (Platteau *et al.*, 2012; FEVIA, 2012). Food industry and distribution differ in the average employees' age. The average age in the food manufacturing increases gradually while the distribution employs mainly young workers (Arthur D Little, 2012; FEVIA, 2012; Konings & Vanormelingen, 2013).

Physical capital: The Flemish agri-food chain focuses on two main strategies for technological innovations, namely substitution and efficiency. Substitution replaces old technologies by newer ones and efficiency ameliorate the ratio of input factors to output factors. Agriculture focuses mostly on improved efficiency with a high degree of specialization and scaling-up (Platteau *et al.*, 2012; Mathijs *et al.*, 2012). The food industry emphasizes on the food factories of the future with smart and flexible production processes (FEVIA, 2011). Although the investment in product and process innovation is rather low, investments in marketing and organization are increasing. Another general trend is the increasing role of information and communication technology (ICT). The implementation of ICT both within and between agri-food chain components increases.

Financial capital: The investment per total revenue and accession of new firms describes financial capital. Within the agri-food chain, agriculture has the highest investments per revenue followed by the food industry and retail. Inflow of new firms in agriculture and food manufacturing is rather low due to the high initial investment costs. Inversely, food distribution has a high entry as well as exit rate as a result of the lower initial investment costs but a competitive market which implies a high turn-over rate (Arthur D Little, 2012; FEVIA, 2012; Samborski, 2013).

Social capital: Social capital includes the horizontal and vertical cooperation. Horizontal cooperation in the agricultural sector focuses on research, development and commercialization of products (Mathijs & Relaes, 2012). The food industry and distribution cooperate horizontal on research and development due to the *Competetive Trading Act*. Figure 7 illustrates the existing vertical governance types found in the Flemish agri-food chain explained with a typical example.

Figure 7: The identified governance types illustrated with an example



Manufactured capital: Total revenue and net value added describe manufactured capital. The Flemish agri-food chain is export and import oriented. 50% of the total revenue of food manufacturing is assigned to export. Export of the agri-food chain focuses for 70% on adjacent regions. An important sustainability issue is that export increases internal land use while import increases external land use (Mathijs *et al.*, 2012; Samborski, 2013).

Net Psychic income: Net psychic income is related to human wellbeing which is thoroughly related to health. The amount of people with overweight or obesity increased steadily over the last years. Obesity is categorized as epidemic by the world health organization (WHO, 2011). In Flanders, 46.9% had overweight and 13.8 had obesity in 2008 and this number is increasing (OECD, 2010). Moreover, some experts state that the physical and emotional distance between the consumer and producer rises which makes food more 'valueless'. To internalize the additional costs of sustainability practices implemented by producers into the prize, consumers should be informed correctly to reduce this emotional distance.

Sustainability challenges originating from the system analysis

Various responses were formulated during workshops and stakeholder meetings with the different chain members and NGO's as a reaction to the above described states and sustainability description of the Flemish agri-food chain. These responses were listed and categorized into eight principle challenges, as shown in Table 2.

Table 2: Eight principle challenges of the Flemish agri-food chain

Nine principle challenges of the Flemish agri-food chain
1. To develop new products, production methods, production sites, markets and chain configurations
2. To increase efficiency and resilience of the agri-food chain by optimizing the existing production and chain configurations and alignment of production and marketing to ecological, economical and social carrying capacity
3. To focus on closing mineral cycles and to reduce losses, undesirable by-products and to valorize by-products
4. To stimulate sustainable relations, knowledge and information exchange and transparency
5. To stimulate reciprocity between the agri-food chain and the consumer by increasing the participation
6. To reduce the use of scarce resources and to increase the use of renewable resources
7. To stimulate the co-creation of knowledge and innovation
8. To focus on the employees' welfare, education and working environment to stimulate the inflow of employment

Governance types to address sustainability challenges

Currently, different governance types exist in the agri-food chain. Not every governance type is equally suited to address the above mentioned sustainability challenges. To assess this, the main characteristics of each governance type, explained in Table 1, can be used. Additional information on lead firms and their relations with the other chain members can be subsequently explored to analyze impacts on the functioning of the chain. This is however beyond the scope of this paper.

For illustrative purposes, we analyze how the existing governance types (Figure 7) can cope with the challenge to stimulate co-creation of knowledge and innovation (challenge 7, Table 2). In case of innovation, both the innovation process and type are important. The innovation process can range from fully closed to fully open innovation. In case of closed innovation, the lead firm has full internal control of the product development path (Almirall & Casadesus-Masanell, 2010). Open innovation on its turn uses purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation (Chesbrough, 2006,1). The innovation type can range from incremental to radical. Incremental innovation introduces minor changes to the existing product or processes and exploits the potential of the established design while radical innovations introduce a different set of engineering and scientific principles that often opens up whole new markets and potential applications (Han *et al.*, 2012).

Which innovation type can be pursued depends on the complexity of transaction, the ability to codify the transaction and the capabilities in the supply chain. While incremental innovations do not add much to the existing complexity and can be easily codified with minor changes to the existing capabilities, more radical innovations demand new sets of principles, new production and marketing configurations. This adds to the complexity of the transaction. It furthermore demands new codification mechanisms and strong capabilities in the supply base. Depending on whether the latter are available or not within the lead firm and supply base, a more open or closed innovation process should be followed. The results of a first analysis are summarized in Table 3.

Table 3: Governance types linked to challenge

Governance type	**Complexity**	**Ability to codify**	**Capabilities in supply-base**	**Type of innovation**	**Process of innovation**
Market	Low	High	High	Incremental	Open
Modular	High	High	High	Incremental & radical	↑
Relational	High	Low	High	Incremental & radical	
Captive	High	High	Low	Incremental*	↓
Hierarchy	High	Low	Low	Incremental*	Closed

* Radical will demand a full reorganization of the lead firm and the supply-base

The governance type *Market* can generally be associated with open innovation, given that all market players equally possess high capabilities combined with low complexity of the transactions. Given that price acts as the main market signal, the possibility to codify transactions is important. All players therefore have an incentive to co-create knowledge and information on new innovations but incremental ones. The *Modular* governance type is best suited for semi-open innovation. As transactions can be easily codified, open innovation is not necessarily restricted to those supply chain partners already cooperating. Due to the complexity of the transaction, potential partners are however restricted to those possessing the required capabilities. In case of the *Relational* governance type, the low capability to codify the transactions demands more dedicated suppliers and buyers, further closing the innovation development cycle. In case of *Captive* and *Hierarchical* governance types, the lead firm develops the innovation in closed form, given the low capabilities in the supply-base.

Discussion

The developed framework captures the complex interdependency between the ecological, social and economic system in a structured way. This allows analyzing the sustainability state of these systems. The conceptual framework can be made more applicable to the agri-food chain, by combining it with principles from GVCA. This also allows analyzing the suitability of current governance types to address identified sustainability challenges. As the above results indicate, the conceptual framework allows performing a system analysis of the Flemish agri-food chain with respect to sustainability.

Given the complexity of the issue at stake, sustainability from an integral chain perspective, the question remains whether all interactions and interdependencies can be properly accounted for with the developed framework. The process of combined qualitative and quantitative research proved helpful to generate and validate obtained results. Further case study analysis should however be performed to demonstrate the general applicability of the framework.

Another remaining challenge is to increase the common understanding of the concept sustainability. Carpenter *et al.* (2001) define resilience as the magnitude of disturbance that can be tolerated before a socio-ecological system moves to a different region of state space controlled by a different set of processes. In contrast, sustainability is an overarching goal that includes assumptions or preferences about which system states are desirable. During the multi-stakeholder process, it became clear that different stakeholder groups have different understandings of the concept sustainability, depending on their values and preferences. Different sustainability paths exist, ranging from radical transitions versus gradual transformations (Geels & Schot, 2007), and different sustainability goals, such as efficiency or sufficiency. It is important to integrate these in the conceptual framework and system analysis to improve its general applicability. These challenges need to be addressed in subsequent research.

Our framework allows to analyze the suitability of different governance types to cope with specific sustainability challenges. We demonstrated this by means of an example. Nevertheless, to obtain a complete overview of the potential capabilities of GVCA, all the challenges of Table 3 should be analyzed and compared in a structured way. Moreover, alternative and new governance types should be studied which might better respond to specific sustainability challenges.

Conclusion

In this paper we describe a combined conceptual framework to perform a system analysis of the Flemish agri-food chain. Our framework is on the one hand based on principles from ecological economy where sustainable food production is defined as the full range of value-adding activities from raw material over production and marketing to consumption disposal in terms of their effects on natural capital, throughput, manufactured capital, psychic income and cost. On the other hand, principles from GVCA are used. GVCA characterizes governance types such as markets in terms of their complexity of transactions, ability to codify transactions, capabilities in the supply-base, and their degree of coordination. This combined approach allows us to cover the most important aspects of sustainability. We then use this approach to discuss different sustainability challenges. We also demonstrate for a specific challenge, the challenge of knowledge-transfer, whether different chain governance types are suited to cope with it. This first analysis appears promising, though further research will be required to increase the validity of this framework.

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