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Knowledge and network resources in innovation system: How production contracts support strategic system building

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ABSTRACT

Alternative technologies development requires overcoming knowledge deficit in Technological Innovation Systems. New systems building operates through strategic modes, including partner and intermediary modes, which intentionally develop organizational and network resources. Our objective is to deepen the understanding of these collaborative strategies, by analyzing the role of contracting in value chains on the development of organizational and network knowledge resources for system building. Drawing on the case study of the grain legumes sector in Europe, which is critical for agrifood sustainability, we analyze how production contracts (PC) support partner and intermediary system building modes. Results show that PC are deliberately chosen to overcome knowledge deficit: PC foster knowledge resources at the organizational level by securing investment, and at the network level by increasing socio-technical interactions, data sharing, workforce, training and advice. This study contributes to a better understanding of collaborative system building modes and could be further developed to any sector.

1. Introduction

Sustainability transition requires developing alternative technologies in order to reverse the lock-in that prevails in most sectors (Bolton and Foxon, 2015; Klitkou et al., 2015). The way alternative technologies are developed is mainly analyzed through the technological innovation system (TIS) - a set of actors that interact through a system of resources (Markard and Truffer, 2008; Smith et al., 2005, Farla et al., 2012). This literature highlights how creation and coordination of new business opportunities will go ahead "*if actors pre-commit to a new technological path, persuade others to follow, and set in motion a chain of joint commitments*" (Sarasvathy and Dew, 2005). Understanding both how these networks are structured and how they support new systems building is of significant interest for transition governance.

In that way, Musiolik et al. (2012, 2020) gave special attention to the role of formal network for system building; formal network being defined as *"organizational structure with clearly identifiable members where firms and other organizations come together to achieve common aims"* (Musiolik et al, 2012:1034). These authors distinguish three generic modes of strategic system building: i) the "single mode" in which no collaboration is required; ii) the "partner mode" in which several independent actors coordinate complementary resources to create system resources; iii) the "intermediary mode'' in which several actors set up a new organization for creating network and further system resources (Musiolik et al., 2020). The choice of mode depends on the resources initial availability and distribution in the innovation system. But these formal strategic network dynamics are still under-analyzed. In particular, a deeper

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understanding of the "partner mode" and ''intermediary mode'' would benefit to the TIS and sociotechnical transition literature.

The way independent actors jointly commit to advance towards a common goal, and the rules and modalities under which they operate for their transactions on goods and services, have been extensively studied by Neo-institutional Economics studies. These studies show how independent actors can benefit from more coordinated forms of organization, called "hybrid organizations" or "hybrid forms", when their transactions are uncertain and require specific investments (Williamson, 2010; Ménard, 2021, 2018). In the context of an emerging TIS in which transactions concern new goods or processes (that are often relying on alternative technologies and knowledge[1]), the investments for creating new resources are much more uncertain, and highly specific if the market is not yet developed. Such a situation may prevent the actors from investing by fear of opportunism (risk of hold-up), and therefore it requires stronger formal bounds within the value chain networks, that sustain investment and learning for alternative goods and underlying technologies (Ménard, 2021; Klein and Sykuta, 2010). From this literature on "hybrid forms" we advance that the relations and organizational structures that the actors choose within the value chain network are crucial for their involvement in a transition path.

In that regard, we propose to extend the analysis of the "partner and intermediary modes" developed in transition studies (Musiolik et al., 2020) with the Neo-Institutional Economics approach of "hybrid forms" (Ménard, 2021; 2018) for a deeper understanding of network resources creation in value chain networks, and further system resources development supporting transition paths. "Hybrid forms'' refer to various contractual arrangements fostering joint-decision and common resources development across the value chains, notably sub-contracting, procurement contracts or the so-called production contracts. These contractual arrangements are already well documented in the economics and management literature as a way to align goals within value chain networks, but their role in TIS building needs to be analyzed.

The objectives of this paper are to explore the role of one type of contractual arrangement – the production contracts – in network resources building, and to better understand the ways partner and intermediary modes of strategic system building function through these formal arrangements. We define "production contract" (PC in the remaining of the paper) as: *a formal agreement between two (or more) firms whose objective is to efficiently frame the production and the exchange of goods (or services) under mutually agreed specifications on prices, quality, and production conditions*[2]. Our case focuses on agrifood value chain networks, in which production contracts have long been acknowledged as a way to efficiently coordinate transactions (Ménard, 2018), and more recently as a way to engage agrifood actors towards more sustainable farming practices (Cholez et al., 2020). It is acknowledged that farmers are embedded in various knowledge networks supporting changes on farming practices (Sutherland and Labarthe, 2022; Ingram, 2015), but the role of value chain network in knowledge development remains understudied. PC are advanced as a lever of knowledge development on alternative technologies/crops in the French agrifood sector (Cholez, 2017, 2020). But those studies do not analyze how PC enable network resources building, contributing to further TIS development. Hence, in this paper we develop an original framework combining the TIS literature on system building modes and the literature on hybrid forms to analyze how inter-organizational arrangements, and especially PC, contribute to knowledge resources building among actors of value chains, supporting the development of a new TIS.

We apply our conceptual framework to the case of PC used in several European grain legume value chains. These field crops are increasingly recognized for contributing to the environmental sustainability of the agrifood sector (e.g., Cusworth et al., 2021a, 2021b). However, accounting for only 2% of field crops in Europe and facing many lock-ins (Magrini et al., 2022; Magrini et al., 2016; Weituschat et al., 2022), the grain legumes TIS has not been developed, and the value chain actors must rely on their own strategies to benefit from the complementarity of resources and/or develop new ones to increase the production and use of these crops. By analyzing the PC used in these alternatives value chains, we show that actors strategically use these contracts to coordinate their activities, and by doing so, constitute a formal network. Results highlight that (i) PC foster knowledge resources development at the organizational level by securing investment; and that (ii) PC develop knowledge resources at the network level by enhancing interactions and joint investment.

Our study provides contributions for both academics and practitioners. First, our work brings new insights in the literature of transition studies by understanding strategic levers by which value chain actors create joint commitment in transition pathways. In particular, our results are a first attempt to open the black boxes of system building modes through the underlying governance structures - here PC - that support the "partner or intermediary modes" of system building. Second, our study contributes to the management and economics literature on "hybrid forms"; and it fills the gap of how contracting for goods enables knowledge building and transfer (Gobbato, 2013), while until now most studies on knowledge development through formal contracts have principally focused on R&D contracts or license contracts (Arena et al., 2012; Arora et al., 2004). Finally, since production contracts users constitute easily identifiable networks, these results are interesting for practitioners and public policies to target and support the development of alternative technology networks for sustainability transition.

The paper is structured as follows. Section 2 presents the analytical framework to analyze PC through a TIS perspective. Section 3 introduces the empirical field of our study and explains the methods of analysis of six European formal networks based on PC for grain legumes. Section 4 presents the results. Section 5 discusses the key findings and implications, and concludes.

[1] The term 'alternative' refers to knowledge, technologies, products and processes that differ from the ones developed in the incumbent socio-technical system, and that are developed within niches according to transition studies literature (Ingram, 2015).

[2] Whereas marketing contracts (defining price and delivery conditions but not production conditions) are quite well defined by laws, there is no official or legal definition of production contracts in Europe. In practice, they could also be considered as a particular form of "supply contracts" (UNIDROIT et al., 2015).

2. An analytical framework on production contract and network resources in TIS building

To conceptualize the role of PC in TIS building, we first review theoretical insights on system building modes (2.1); we then disentangle the mechanisms by which PC contributes to TIS building by fostering network resources, and especially intangible ones such as knowledge (2.2).

2.1. Theoretical perspectives on system building modes

A TIS refers to the *"set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology"* (Markard and Truffer, 2008, p.611). This dynamic process can be emergent and uncoordinated (Bergek et al., 2008), but also be the result of strategic activities undertaken by actors, referring to the concept of "strategic system building" (Musiolik et al., 2012). In the latter, innovating actors intentionally join their resources to create a new market, develop new norms and standards, or reinforce the legitimacy of a technology. The creation of institutional or organizational structures in the TIS is therefore deliberate. An increasing number of studies tried to understand the underlying mechanisms of such system building, distinguishing various modes.

Musiolik et al. (2020) show that different modes of strategic building exist, and that they depend on the resources availability and distribution in the TIS (so-called resources constellation). This idea relies on earlier development in the strategic management literature, in which resources are at the core of the firm's competitive advantage and can be strategically developed both within firms, as highlighted by the resource-based view (Barney, 1991), and at the inter-firm level, as highlighted by the relational-based view (Dyer and Singh, 1998) in the management literature. Resources are both tangible assets (like equipment) and intangible assets (like knowledge) of strategic values.

Scholars classify resources as to who has access to them: referring to *organizational resources* (OR) when only one organization has access to it; or *network resources* (NR) when only the organizations that are members of a formal network have access to it; and *system resources* (SR) when any organization interacting within the TIS can access it. SR are non-excludable (by the network) and can benefit all actors involved in the TIS, with, for instance, standards, support programs or testing facilities (Musiolik, 2020). In addition, the review of TIS literature shows that strategic system building can result from individuals or organizations/firms that deploy their own resources to change the system (Hughes, 1979), but also from networks of actors (Sarasvathy and Dew, 2005; Musiolik et al., 2012, 2020).

Finally, Musiolik et al. (2020) differentiate between three modes of system building. First, the "*single mode*" refers to situations in which the resources for system building already exist and are under the control of one organization/firm/actor. In that case, this organization detects the problem in the TIS and deploys its own resources to develop a solution. Second, the "*partner mode*" describes situations in which the resources for system building exist but are dispersed and under the control of several organizations (i.e., firms or actors). In that case, organizations prefer to collaborate with the ones having complementary resources. Third, the "*intermediary mode"* is chosen in situations in which the resources for solving issues in the TIS do not yet exist. As for the partner mode, the organizations collaborate as well, but go a step further to jointly create a new organization, considered an intermediary organization[3], in order to tackle network resources development.

The actors at the core of these system building modes are called "system builders" (Hughes, 1979). Entrepreneurs can play a key role as a system builder, but they are rarely able to shape a system on their own (Sarasvathy and Dew, 2005; Musiolik et al., 2012). Several types of actors can therefore act as system builders, such as companies, public agencies or customers (Musiolik, 2020). System building is a dynamic process, in which the system builders identify TIS deficits such as lack of technical knowledge, issue in market formation, etc.; and then develop a single or collective strategy to develop system resources (i.e., strategic system building), depending on the availability and the distribution of initial resources. The new system resources created in this way should therefore improve the system and reduce earlier deficits.

Although the system building mode approach highlights the dynamic dimension in the resources building process, it does not say much about the concrete organizational structures used by the actors of the partner or intermediary modes to develop network and system resources. We consider PC as a way to fill this gap because they are used by value chain actors to strategically organize market creation, contributing to new system building.

[3] This term of "intermediary organization" has different meanings in the literature: for instance, see Kivimaa et al. (2019) on various types of intermediaries in transition studies, or Cholez et al. (2020) on especially the role of organizations mediating the transactions between farmers and processors in agrifood chains. But here by "intermediary organization" we mean a formal structure developed by a network of actors to co-create network resources.

2.2. The role of production contract in partner and intermediary system building modes

PC is a particular governance structure (i.e., organizational arrangement) that frames the exchanges between the actors of a value chain. The concept of "governance structure", introduced in Williamson seminal works on transaction cost economics, refers to the mode of organization of a transaction on tangible goods between actors, the way it is negotiated and executed (Williamson, 2010)[4]. In this paper, we argue that PC is not only a governance mode of bilateral transactions on tangible goods, but also a mode of system building since it enables the development of organizational and network resources, of tangible or intangible nature, that constitute the first steps of a new system building.

In the agrifood sector, the term PC is mostly used for referring to the agreements between actors of the value chains regarding the conditions of crop production (set up before the production starts) and the future marketing conditions. Other terms, such as contract farming, can also be found in the literature, especially when agribusinesses contract directly with farmers[5]. In other sectors, the conclusion of contractual arrangements on the production process (prior to the production) between suppliers and buyers is also common, but mostly generic terms such as procurement contracts, supply contracts or even sub-contracting are used. The governance mechanisms are similar and involve a higher degree of coordination between the actors of the value chains, compared to spot market transactions.

PC establish commonly agreed rules formalized and written on a signed document; and are completed by relational joint commitment between stakeholders (Baker et al., 2002). In this article, we use the term PC to refer to (i) the arrangements formalizing the mutual commitments between the actors of a value chain, and (ii) the various processes involved in contracting, such as negotiation, monitoring and adaptation between the parties.

PC implementation in value chains can be considered an entrepreneurial action, involving at least two organizations that deliberately chose to coordinate their production in an explicit and strategic way. By doing so, PC support resources coordination and creation among value chain actors, contributing to strategic system building. Therefore, the community of buyers and suppliers who implement these PC in their value chain network are system builders (SB). PC allow to go beyond a single actor strategy, as it involves a network of value chain actors, referring to partner or intermediary modes of system building according to Musiolik et al. (2012). In that regard, PC should be chosen by actors when existing resources are distributed (distributed agency) and/or when new resources are needed (developing agency) (Musiolik et al., 2012). In other words, PC is characteristic of a collective strategic system building mode, under which value chain actors pre-commit to a new path by setting in motion a chain of joint commitment.

To continue, we disentangle the micro-mechanisms by which PC act as a system building mode in TIS: by considering that PC can be used both as a partner mode to coordinate dispersed organizational resources between value chain actors (buyers and suppliers of goods); and as an intermediary mode to develop new network resources in a TIS. Fig. 1 illustrates this conceptualization of PC as a support for strategic system building in which (i) at least two organizations can coordinate in developing their own organizational resources (i.e., partner mode), or (ii) at least two organizations also jointly create network resources through an intermediary organization as the results of the PC links (i.e., intermediary mode); both modes could induce system resources building.

In addition, while PC have long been studied as regards to their ability to develop and secure tangible resources (such as production factories and equipment), recent studies suggest PC also foster intangible assets development such as technical knowledge about the production (Cholez et al., 2017; 2020). But these studies do not link this knowledge dynamics to TIS building. Since intangible resources deficit is a key issue in TIS building (notably in relation to knowledge production and legitimation of technology) (Hekkert, 2007), we propose to focus on the role of PC on *knowledge resources* development, by analyzing their creation and shaping, being either organizational or network resources.

By *knowledge resources* we refer to both codified/explicit and tacit knowledge[6] on the production and marketing of the goods under PC. We distinguish four main variables informing on sociotechnical mechanisms of knowledge development within the value chain network: (i) research and development activities (R&D); (ii) training or technical advisory services; (iii) workforce allocation (iv) and learning by doing. R&D has long been considered a prerequisite to innovation and knowledge development in the TIS literature (Suurs et Hekkert, 2009). In addition, accumulation of internal knowledge through learning-by-doing (Van den Bergh et al., 2007), as well as external knowledge, through advisory services or hiring of new human capital, also allow to develop the knowledgebase, both within an organization (Bergek et al., 2013) and within a network of organizations (Boghei and Magnusson, 2018).

We argue that when knowledge resources are in deficit in the system and/or dispersed (i.e., "the resources constellation" according to Musiolik, 2020), the PC -underlying the relationship between organizations in the value chain- enable the coordination of existing dispersed knowledge resources, as well as the creation of new knowledge, contributing to the development of the knowledge base. This

[4] The Transaction Costs Economics (TCE) initiated by Williamson (e.g., 1991) remains a fundamental framework for understanding the links of inter-firm exchange of goods or services. This theory revealed various governance structures, mainly determined by the degree of specificity and uncertainty of inter-firm exchanges (Williamson, 2010). When dealing with the development of new goods requiring alternative technologies, the transaction specificity and uncertainty is increasing; and from the TCE point of view, hybrid forms based on formal contracts should prevail, as acknowledged in various sectors of activity (Klein and Sykuta, 2010; Ménard, 2018).

[5] In contract farming scheme from those countries, some agricultural inputs or credits are often provided by the buyer to the farmers, but this is not necessarily the case for PC in developed countries.

[6] Tacit knowledge refers to the competences, skills and know-how of actors that are not formalized notably through written documents. If this distinction is used in economics (Polanyi, 1958) and knowledge management literature (Nonaka and Takeuchi, 1995), we do not refer to it further in our analytical framework since we consider that tacit and codified knowledge remain intrinsically related.

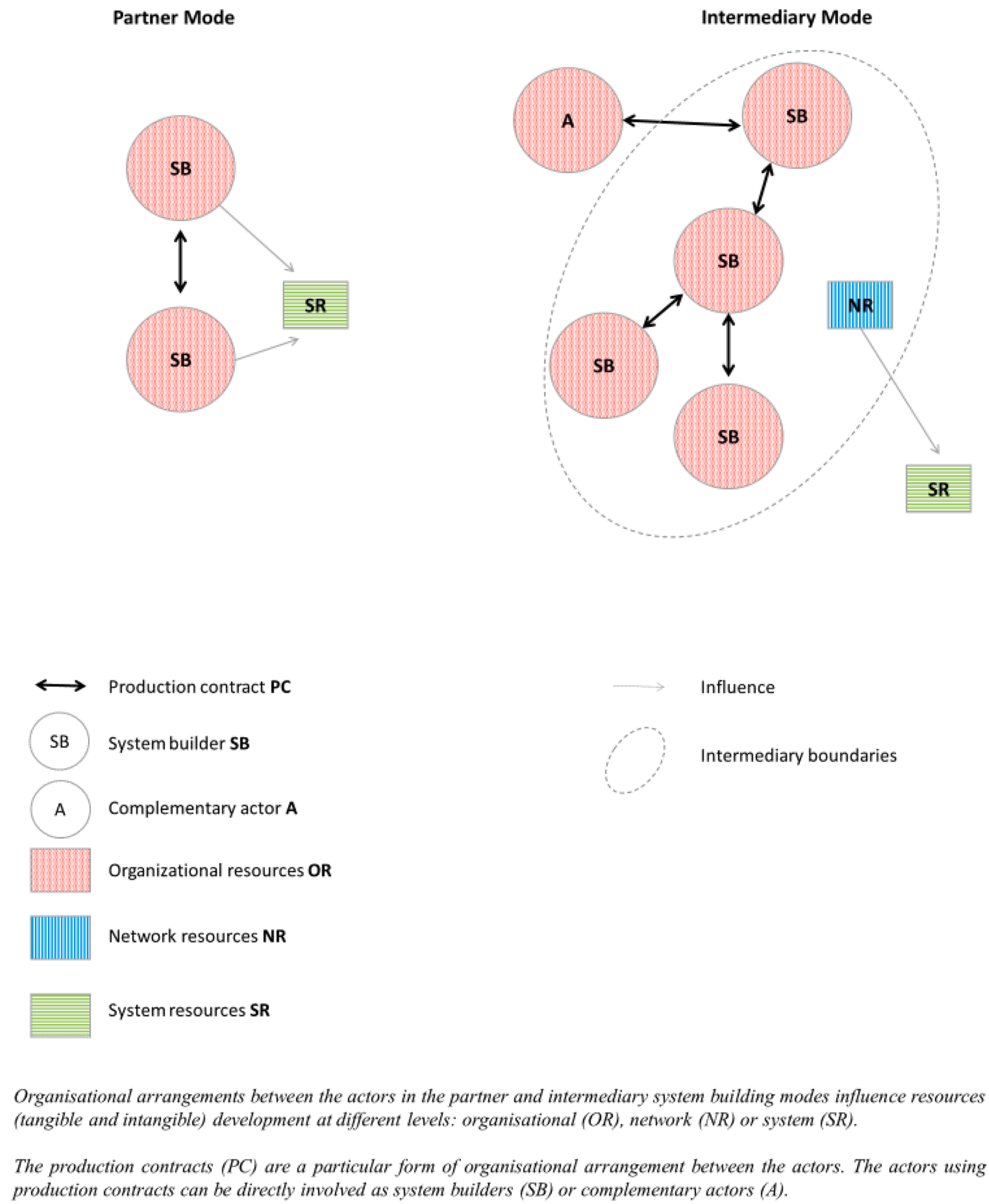

Fig. 1. Production contracts in the partner and intermediary strategic system building modes, inspired by Musiolik et al. (2020).

development of knowledge happens both at the organizational level (i.e., organizational resources, henceforth named OR) and between the organizations at the network level (i.e., network resources, henceforth named NR) as illustrated in Fig. 2.

Indeed, organizational theories on PC enable us to advance on the reasons why PC allow knowledge OR and NR development. PC

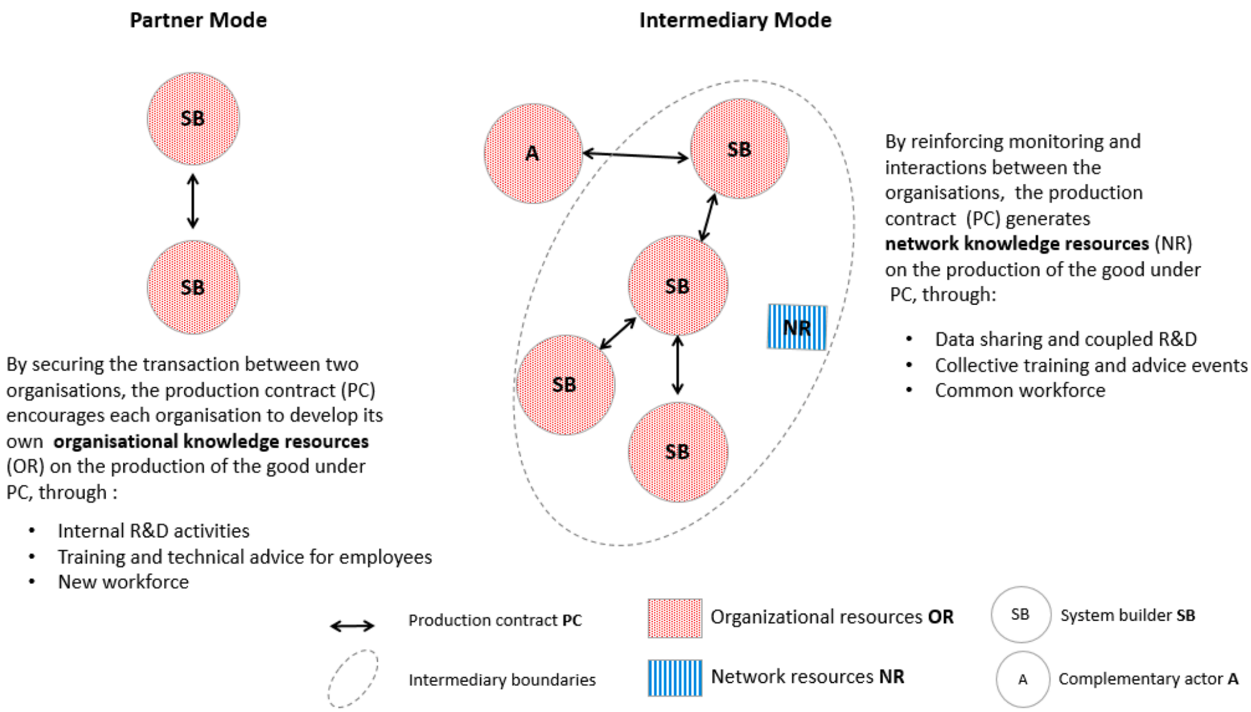

Fig. 2. Generation of organizational and network knowledge resources through production contracts.

constitute agreements framing the transaction of a good, as well as the way this good is produced. PC offer some guarantees to the contractants that would not exist in a standard/spot market relationship, and by doing so PC secure the respective investments of farmers, storage organizations and processors (Bijman, 2008; Bogetoft and Olesen, 2002; Cholez et al., 2020; Ménard, 2018; Klein and Sykuta, 2010). Knowledge resources development requires investment, and PC secure the investments that each organization may engage in R&D activities, learning-by-doing devices, using technical advice, hiring new employees or reorganizing the initial workforce within the existing staff. This way, PC contribute to the development of knowledge resources at the organizational level (OR in Fig. 2).

Moreover, apart from the investment-securing function of contracts, organizational theories recognize that contractualization in value chains contributes to the transfer of information as well as to the generation of more social interactions between the contractors compared to spot market relationships (Lumineau et al., 2011; Mayer et Argyres, 2004). These increased social interactions generally are the result of the rules agreed upon by the contractors over time (Mayer et Argyres, 2004). The development of such inter-organizational routines is also known as a prerequisite to social learning-by-doing within the value chain (Li et al., 2010; Lumineau et al., 2011; Van den Bergh et al., 2007).

For PC in particular, the literature shows that the routinized inter-organizational interactions aim in the first place at monitoring the production process and adapting to unforeseen conditions (Cholez et al., 2020; Bogetoft and Olesen, 2002). The repeated interactions for PC setting (including initial negotiation of the contracts clauses, monitoring during the production process, adaptation and renegotiation, conflict resolution) contribute to technical knowledge exchange between buyers and suppliers (Cholez et al., 2020). In addition, the actors may choose to collectively capitalize on the technical knowledge exchanged during those interactions, and to link the PC to other devices aimed at developing the knowledge base within the network (Cholez et al., 2020). More specifically, the PC may be linked to the development of joint R&D activities and shared data infrastructure. This may involve (non-systematically) the creation of a new intermediary organization to formalize these joint activities between the actors under PC. In that case, a joint allocation of workforce could also be observed with a dedicated person, paid by the contractors, to monitor the PC process (Cholez et al., 2020).

In addition, the PC may be linked to the implementation of collective technical training and advice. So far, the contract farming literature largely supported the idea that PC enable unidirectional transfer of knowledge to the farmers, by linking the PC to the provision of mandatory or voluntary technical advice, training, or assistance (Bijman, 2008; Mugwagwa et al.,2020;). Apart from that, a vast literature also focused on the multidirectional knowledge flows in which farmers participate to support changes in their farming practices, including within producer organizations (Groot-Kormelinck et al., 2022), farmers peer groups and communities (Sutherland et al., 2017), and through various technical advisory channels (Sutherland and Labarthe, 2022). Acknowledging that farmers form diverse knowledge networks in relation to new agricultural practices (Klerkx et al., 2017; Cofré-Bravo et al., 2019), this literature remains scarce on the combination of collective knowledge dynamics through networking and vertical coordination in value chains; even though a preliminary study shows that PC can be linked to collective training and events stimulating the network of actors under

PC (Cholez et al., 2020).

In this paper, we therefore consider that by reinforcing monitoring and interactions between the organizations under PC, PC contribute to the development of knowledge resources at the network level (NR in Fig. 2).

Finally, the resources created in each organization (OR) and within the value chain network (NR), may have various degrees of specificity, meaning being specific to these relationships and not redeployable to other partners (from other value chains) without costs. We assume that the less specific the knowledge assets created, the more they diffuse in the broader TIS (Hekkert, 2007). But even in case of high specificity, knowledge development constitutes a knowledge base for larger system building that could not have emerged without the initial commitment of the actors secured by PC.

To sum up, we consider that PC foster organizational knowledge resources development by securing the transaction and the related investment, encouraging each organization to invest in developing its own knowledge resources (OR). And we also argue that the parties under PC may decide to foster network knowledge resources (NR) by encouraging collective inter-organizational interactions linked to the PC. Hence, PC can be used both in the partner and intermediary modes strategies. Ultimately, the knowledge developed, being OR and NR, should diffuse in the larger system and reduce the initial knowledge deficit, required for TIS building[7].

3. Material and methods

We choose to use a multiple case studies approach because it fits the novel nature of our research question and allows the study of a contemporary phenomenon in the making (Eisenhardt, 1989; Yin, 2014). Furthermore, no large dataset existed to analyze PC: those data are private, of strategic interest to stakeholders and thus remains confidential, constituting a major research challenge to study contractualization in value chains, as highlighted by Sykuta and James (2004). It prevented us from running an analysis on secondary data and justified developing an original research design.

Hence, our research design draws on the interpretative social science tradition (Stake, 2010). Our analytical framework provides guidance for data collection and exploration, and for sense-making about processes and patterns related to PC in value chains. First, we explain why grain legumes value chains are relevant cases to study the mechanisms by which a TIS is built thanks to resources developed through PC (3.1). Second, we present our operationalization of the conceptual framework to collect and analyze the data (3.2).

3.1. Case description: the grain legume innovation system in Europe and the emergence of grain legume value chains under PC

Grain legumes (also called pulses) are field crops from the Fabaceae (Leguminosae) family including soya, pea, lupine, etc. They are used both for food and feed, yielding from grains of variable size, shape, and color with a pod. Grain legumes are produced all over the world. We selected the European grain legumes innovation system as our empirical case for several reasons.

First, the TIS on grain legumes in Europe is characterized by a deficit in market formation, knowledge production and legibility issues. This deficit results from a lock-in situation analyzed in several works (e.g., Meynard et al., 2018; Magrini et al., 2016; Cusworth, 2021a; Magrini et al., 2022; Weituschat et al., 2022): for decades the European agrifood system essentially developed around some major crops (like wheat and maize), creating a lock-in situation particularly difficult to reverse for developing alternative crops supporting more sustainable agricultural systems. Although many varieties could be cultivated in Europe, grain legumes only account for 2% of field crops. But since the International Year of Pulses in 2016 (the United Nations resolution A/RES/68/231), the European Commission has been giving more importance to developing them (European Commission 2018). Legumes are increasingly recognized as a major lever in the sustainability transition of the agrifood system (e.g. Semba et al., 2021; Weindl et al., 2020): for food, they are very good substitutes for animal-based proteins, therefore contributing to protein transition; for feed, they will decrease soya imports so that Europe can be autonomous in high-protein crops for livestock; their cultivation reduces the environmental impact of agricultural systems as they do not require nitrogen fertilizers, and so, contribute to the reduction of greenhouse gases (Voisin et al., 2014; Willett et al., 2019; Tziva et al., 2020). However, legumes face a strong lock-in resulting from past public policies that give preference to soya imports and animal-based protein consumption instead of developing a diversity of legumes in Europe, as explained by Voisin et al. (2014) and Magrini et al. (2016). Consequently, the innovation capacity of the grain legumes sector in Europe is weak and essentially based on niche-innovations.

Second, innovations on grain legumes value chains requires the coordination of different knowledge bases, from genetics to food processing, involving upstream and downstream stakeholders for the development of "coupled innovations" (Meynard et al., 2017). Little dissemination is available regarding the knowledge on those crops (Zander et al., 2016; Zimmer et al., 2016). Hence, the challenge to favor system building on these alternative crops is to engage stakeholders to invest in them along the value chain. The last reason is that we could draw on one previous study on production contracts in grain legume value chains conducted in France which highlighted that technical knowledge development is a core issue for value chain building (Cholez et al., 2020).

This research took place in the context of the European research project H2020 LEGVALUE. The TIS deficit was the starting point for the creation of this project on grain legumes value chains. The project revealed how existing legume value chains in Europe progressed mostly by creating their own resources to develop legume cultivation. They rely on PC to initiate the coordination of such

[7] The extent to which the OR and NR influence the SR, depending on their specificity, is beyond the scope of the current article and will not be analyzed in the remaining of the article. The idea of a retroactive loop between the generation of new SR and the reduction of initial knowledge of the TIS (suggested by Musiolik et al., 2020 in his conceptual framework) should benefit from further conceptual development and empirics.

resources , since market spot mechanisms failed in developing grain legume value chains. Only recently, thanks to the collaborations developed through several European Research projects (H2020 programs), a network of researchers, technical institutes from different countries and practitioners created the LIN (Legume Innovation Network) in 2021[8] in order to promote and diffuse R&D results from those programs. Our analysis is part of this ambition.

With the support of the European research project consortium H2020 LEGVALUE, we identified and selected six grain legume value chains where PC was implemented. Each case was selected according to the expertise of professional organizations and technical institutes of the country (France, Latvia and Portugal). The selected cases differ in terms of countries (four cases from France, one from Latvia and one from Portugal), grain legume species (pea, fababean, soya and chickpea) due to various climatic and soil conditions in these countries, production modes (organic or conventional) and outlets (food or feed). Despite these differences, the cases share similarities as regards the knowledge deficit and the low status of the legume crop in their country (Table 1)[9].

In those value chains[10], PC are mainly used by upstream actors[11]. Therefore, in our study we consider three types of actors: the farmers that are producing grain legumes, the storage organizations that collect, store and market grain legumes[12], the processors that process and transform grain legumes into food or feed products. PC are most often initiated by the processor with its direct suppliers i.e., the storage organization (called PC1 henceforth). The storage organizations then adapt the PC to implement them with their direct suppliers i.e., the farmers (called PC2 henceforth). This scheme enables the processor to contract for a large volume of crops with a storage organization. It is then the responsibility of the storage organization to gather the required volume by contracting with several farmers. Rarely, the processor sources its raw materials by realizing the PC directly with farmers (called PC3 henceforth). See Supplementary Material for a visual representation of this PC scheme linking the actors of the value chain.

3.2. Data collection and analysis for each case

As explained above, one case corresponds to the inter-organizational relationships between three main actors linked by PC in a value chain. While most of studies on PC generally focus on the farmers; our approach enables to triangulate the data from the perspective of farmers, storage organizations, and processors. We collected the data by combining a semi-qualitative survey addressed to one of each of the three main stakeholders structuring each value chain under study (a farm; a storage organization; a processor) as well as additional sources of information (to be explained later).

Table 2 presents the variables addressed in the survey to address the concepts linked to our analytical framework. The survey was based on 72 open or closed questions distributed across different sections: general information on the respondents, the production contract characteristics and management, the tangible resources for producing grain legumes (like investment in equipment and facilities), the knowledge on producing grain legumes, with the distinction between organizational and network levels, and one synthesis section. The questions were formulated in English. A first version of the survey was tested by several operators previously interviewed in order to ensure that the questions (avoiding theoretical terms) were easily understandable by the respondents and fit our analytical framework. The grid-survey is available on open repository (Magrini and Cholez, 2021). The survey was implemented on-line and filled out by the respondent with our assistance by phone or video call: this assistance helped us to check their understanding of our questions, and to contextualize their answers by collecting additional information on their rationales.

Additional sources of information for triangulation included: preliminary interviews with agricultural professional organizations engaged in the H2020 LEGVALUE project (n=6); post interviews with these same professional organizations to get additional information in case of inconsistency in the data collected by the survey (n=2); firm reports; press releases; publicly available documents; and participatory workshops conducted during the LEGVALUE project (2017–2021). Additional discussions were held during the workshops with the stakeholders under study. Their later answers in the formal survey allowed us to compare these with the first evidence from discussions in the workshops, as the survey questions were similarly formulated for each stakeholder.

All the data collected was structured following a thematic analysis based on our analytical framework and concepts (Table 2). We used an Excel data set to organize the data. Cross-cases analysis allowed us to identify regularities among the different cases to reveal how PC in the value chains support organizational and network resources. The next section presents the results, and qualitatively explores how the cases fit into our analytical framework; while in section five, we discuss broader implications from the initial evidence of our case studies to strengthen propositions for future studies.

[8] https://www.true-project.eu/legume-innovation-network/

[9] Latvia 's percentage of grain legume species increased much more between 2007 and 2017 than France and Portugal but has substantially less land area in acres.

[10] We define a value chain by the succession of technological steps from farm to fork, and the actors involved in these technological steps

[11] Particular forms of production contracts involving downstream actors exist, for instance between consumers and farmers in community supported agriculture. They are generally implemented for fruit and vegetables production, but are, to our knowledge, never found in field crops value chains. In addition, as far as we know, the wholesalers and retailers in the food sector do not use production contracts *per se* with the processors, so we decided to focus this research on upstream actors only.

[12] These storage organizations can be private-owned or farmers-owned (i.e., cooperatives). Farmers can also directly sell their crops to a processor, avoiding intermediaries, but this is very rare in European agrifood chains.

Table 1
Presentation of the six value chains (VC) case studies.

Country Grain legume crop	France chickpea	Portugal chickpea	France fababean	Latvia pea	France pea	France soya
% of the grain legume crop in the arable land of the country in 2007[a]	n.a.(confidential area)	0.2	0.3	1	0.9	0.2
% of the grain legume crop in the arable land of the country in 2017[a]	0.1	0.1	0.4	12	1.1	0.8
Case study name	Chickpea VC in France	Chickpea VC in Portugal	Fababean VC in France	Pea VC in Latvia	Pea VC in France	Soya VC in France
Outlet	food	food	feed	food	food	feed
Agricultural mode of production	conventional	conventional	conventional	organic	conventional	conventional
Label	no	no	no	organic	no	no

[a] Data calculated from Eurostats.

Table 2
Analytical concepts and variables addressed in the survey.

Analytical Concepts	Concept delineation	Variables addressed in the VC case study
Knowledge Resources constellation	The knowledge resources constellation is defined by: - the initial knowledge availability on the crop and the transformation of knowledge base over time; - the distribution of knowledge on the crop across the stakeholders of the VC and the transformation of knowledge base over time.	- Perception of the level of technical knowledge on the crop (i.e., all the knowledge required for producing, storing, transporting, and transforming the crop) for each organization at the launching of the value chain and nowadays[a] - Difference in the level of technical knowledge perception across the stakeholders
Knowledge resources	The knowledge resources development relates to all the investment made for developing the technical knowledge on the alternative technology: here minor crop like legumes.	- R&D activities[b] and patents - Training and technical advice[b] - Data collection on the production processes along the value chain - New workforce allocation
Organizational resources	The knowledge resources above mentioned are organizational if the access is exclusive to one organization, excluding all the other value chain actors	- Access of R&D outputs limited to the organization members - Access to technical advice or training limited to the organization members - Data collection is done on the production processes and accessible only by the organization members
Network resources	The knowledge resources above mentioned are network ones if they are shared beyond the organization boundaries, and that all the value chain actors under PC have access to it.	- Access of R&D outputs is possible beyond the organization boundaries for value chain actors under PC - Access to technical advice or training is possible beyond the organization boundaries for value chain actors under PC - Data collection is done on the production process along the value chain, and value chain actors under PC have access to it

[a] The level of technical knowledge was asked for ten items (varieties choice, soil tillage, seedling, harvest, crop rotation, ecosystem services, collect, storage, technological processing) according to a Likert scale from 1 to 4: 1 no knowledge at all, 2 some knowledge but not reliable for the value chain, 3 reliable knowledge to be strengthened, 4 reliable knowledge very well adapted.

[b] The outputs of R&D and technical advice were also characterized regarding to its specificity level and whether it could be used reliably for other outlets, other production regions, or even other crops. The specificity of R&D and technical advice outputs was qualified with declarative statements, according to a scale from 0 to 3, based on additional cost forecasting: 0: the output can be reused for other purposes without any costs; 1: with few costs for adaptation; 2: with important costs for adaptation; 3: the output cannot be reused at all.

4. Results

The main findings show that PC are deliberately chosen by stakeholders according to the initial resources availability and distribution in the TIS; and that PC function as an initiator for system-building mode, as PC define collective rules for securing investment in new organizational resources, and also enhance interactions for network resources development.

4.1. The knowledge deficit perception in the TIS

The system builders (F-farmers, S-storage organizations and P-processors) identified systemic problems in the grain legumes sector when they launched their value chains (VC). One main problem was the knowledge deficit in the grain legumes TIS (also recognized in the workshops of the LEGVALUE project). Their perception of the initial knowledge availability on the crop and of its evolution over time are reported in Table 3 by means of a Likert scale indicator. It shows that most of respondents perceived progress of the technical knowledge base on the crop (concerning the production, the storage and the processing of the grains) as their respective value chain developed.

We asked for their perception of the knowledge availability (on the items above) retrospectively at the launching step of the value chain ("Initial" line) and today (i.e., in 2020 when carrying out the survey): the score difference was calculated for each one ("Learning" line).

Indeed, at the launching step of the VC, the perception of knowledge level on crop production of all the system builders (F-Farmer; S-Storage Organization; P-Processor) was less than 3, indicating they either had no knowledge at all when they started, or knowledge was insufficiently reliable for the outlet of the VC or the production region. No major differences appear across the different species (soya, chickpea, fababean or pea) concerning this TIS deficit in knowledge. The two exceptions are: (i) the farmer in the pea VC in Latvia who declared he already had reliable knowledge and previous experience of this crop before the launching of the VC in 2018; (ii) the storage organization in the chickpea VC in Portugal that declared he had sound experience. For all the other actors, perception of a low knowledge base when launching the value chain is consistent with previous studies showing that the grain legumes TIS suffers from technological lock-in resulting in knowledge deficit (Magrini et al., 2016).[13]

To sum up, at the launching of the grain legume value chain, coordinating knowledge on crop production, harvest and storage was necessary, as well as processing techniques on grain legumes. It concerns a knowledge deficit shared between farmers, storage organizations and processors alike. The "learning scores" (difference between today level of perception -year 2020- and the initial one) are mostly positive. Learning by doing over time may partly explain this improvement and was encouraged by the strategic actions of the value chain actors. The next section analyses how the implementation of PC helped developing knowledge at the organizational and network levels, contributing to a reduction of the initial knowledge deficit.

4.2. Production contract implementation in the cases

Table 4 presents the PC chosen by the actors in their value chains (VC). The chickpea VC in France, the chickpea VC in Portugal, the fababean VC in France and the pea VC in France rely on "a chain of production contracts" meaning that we observe a sequence of a PC between the processor and the storage organization (henceforth named PC1), and a PC between the storage organization and the farmer (henceforth named PC2). In the pea VC in Latvia, no storage organization exists, thus the processor directly contracts with farmers (henceforth named PC3). In the case of the soya VC, the storage organization implements PC with the farmers (PC2) and it also shares part of its capital with the processor. Therefore, no formal PC exists between the processor and the storage organization, but joint planning on production and sales is made before the crops are sown. These joint agreements influence the PC proposed by the storage organization to the farmers. In three cases, the actors under PC also participated in collective arrangements formalized as an intermediary organization[14]. In the Portuguese chickpea VC, the storage organization is member of CERSUL (Agrupamento de produtores de cereais do sul, S.A.) being a group of several storage organizations involved in field crops VC. In the fababean VC, the storage organization and the processor are members of GTO (Graines Tradition Ouest), an association created by the processor and several storage organizations, farmers and seed producers, in order to support the grain legume VC. For the soya VC, the storage organization is member of the SICA Extrusel, a society created by several storage organizations and processors (feed manufacturers) to support the soya VC. Those collective arrangements support the PC implementation by bringing together stakeholders that are sometimes competitors on the market, but that operate in the same fields and have common interest in collaborating in niche market development, in compliance with antitrust regulation.

All the above-mentioned PC types (PC1, 2, 3) are one-year contracts that are signed before the grain legume crop is sown. They define clauses on price formation, clauses on production practices (such as a restriction on the choice of varieties, and sometimes constraints on pest management) and clauses on the quantity and quality of the final product that will be bought. By doing so, the PC guarantee supply for the buyers and an outlet for the farmers. By signing the contracts, the contractors mutually commit to the predefined activities. Their reciprocal engagements secure the investments that the contractors need to realize for the production, the storage and the process of the crop under PC. The PC also leave some space for requirements adaptation over time. Reaching a common agreement while maintaining flexibility to adapt in case of unforeseen events, requires various talks; the frequency depending on each case. Table 5 summarizes the frequency of such talks, that are mostly bilateral (between two contracting partners) or collective when taking place within the intermediary organization.

To sum up, in all cases, the PC implementation combines commonly agreed rules in the formal contract and routinized interactions to (re)negotiate, monitor the production process, and adapt the rules over time if necessary. The frequency of interactions is therefore higher compared to simple market spot impersonal transactions. In addition, we observe that the talks for PC1 (between processors and storage organizations) are more frequent than the talks for PC2 (between storage organizations and farmers) suggesting that PC, and

[13] We commented here the knowledge resources availability. Note that the knowledge resources distribution across the VC actors is variable. For instance, in the chickpea VC in France and Portugal, there is a higher score difference between the storage organizations and the processors, as compared to the other VC cases.

[14] The intermediary organization is a formal entity gathering the actors under PC, and sometimes also some actors that are indirectly linked to the PC such as input suppliers for grain legumes cultivation.

Table 3
Technical Knowledge (TKN) level perception for each organization in the six case studies.

Case studies name	Chickpea VC in France			Chickpea VC in Portugal			Fababean VC in France			Pea VC in Latvia		Pea VC in France			Soya VC in France		
Organization acronym	F	S	P	F	S	P	F	S	P	F	P	F	S	P	F	S	P
Initial																	
TKN CROP PRODUCTION	2,1	2,7	1,1	2,9	3,0	1,0	2,1	2,9	1,4	4,0	2,3	n.a.	1,9	1,3	2,3	2,6	2,6
TKN COLLECT STORAGE	3,0	2,0	2,0	4,0	2,5	1,0	4,0	3,0	1,0	n.a.	3,5	n.a.	2,0	2,0	2,0	3,0	3,0
TKN TECHNOLOGICAL PROCESSING	1,0	2,0	3,0	n.a.	4,0	4,0	1,0	2,0	2,0	n.a.	2,0	n.a.	1,0	2,0	2,0	1,0	1,0
Today																	
TKN CROP PRODUCTION	3,7	3,0	1,4	4,0	4,0	1,0	3,7	3,0	3,4	4,0	3,6	n.a.	2,7	2,6	4,0	4,0	4,0
TKN COLLECT STORAGE	4,0	4,0	2,5	4,0	4,0	1,0	4,0	3,0	3,0	n.a.	4,0	n.a.	3,5	3,0	3,0	4,0	4,0
TKN TECHNOLOGICAL PROCESSING	2,0	3,0	4,0	n.a.	n.a.	n.a.	1,0	3,0	4,0	n.a.	4,0	n.a.	3,0	4,0	3,0	4,0	4,0
Learning																	
TKN CROP PRODUCTION	1,6	0,3	0,3	1,1	1,0	0,0	1,6	0,1	2,0	0,0	1,3	n.a.	0,9	1,3	1,7	1,4	1,4
TKN COLLECT STORAGE	1,0	2,0	0,5	0,0	1,5	0,0	0,0	0,0	2,0	n.a.	0,5	n.a.	1,5	1,0	1,0	1,0	1,0
TKN TECHNOLOGICAL PROCESSING	1,0	1,0	1,0	n.a.	n.a.	n.a.	0,0	1,0	2,0	n.a.	2,0	n.a.	2,0	2,0	1,0	3,0	3,0

Legend: Each system builder (F-Farmer; S-Storage Organization; P-Processor) was requested to indicate the level of technical knowledge for ten items considered as crucial in the agricultural sector: varieties choice, soil tillage, seedling, harvest, crop rotation, ecosystem services, collection, storage, technological processing); according to the following Likert scale: 1 no knowledge at all; 2 some knowledge but not reliable for the value chain; 3 reliable knowledge to be strengthened; 4 reliable knowledge very well adapted. Then, an average score was calculated for the first eight items relative to crop production, one for the collection and storage items and another one for the technological processing item, n.a. meaning not answered: the respondent did not know how to answer (i.e., no clear opinion). The learning score is the difference between today's knowledge level and the initial knowledge level.

Table 4
Production contract (PC) implementation in the cases.

Case study name Types of PC implemented	Chickpea VC in France PC1, PC2	Chickpea VC in Portugal PC1, PC2	Fababean VC in France PC1, PC2, PC3[a]	Pea VC in Latvia PC3	Pea VC in France PC1, PC2	Soya VC in France PC2[b]
Launching of the contractual scheme	2008	2015	2014	2018	2007	2016
% of the crop supply under contract						
for the storage organization	95	70	80	n.a.	50	95
for the processor	40	100	40	100	confidential	n.a.
Intermediary organization gathering the actors under PC	no	CERSUL (Agrupamento de produtores de cereais do sul, S.A.)	GTO (Graines Tradition Ouest)	no	no	SICA Extrusel

[a] In the fababean VC in France, the processor makes direct contracts with farmers (PC3) for 10% of its supply.
[b] In the soya VC in France, there is no PC1 but there is a quasi-integration between the processor and the storage organization within an intermediary organization (SICA), and therefore, internal agreements on crop production and transaction do exist.
n.a. means not applicable because of the structure of the value chain.

Table 5
Frequency of talks linked to the production contract (PC) implementation and monitoring.

Case study name	Chickpea VC in France	Chickpea VC in Portugal	Fababean VC in France	Pea VC in Latvia	Pea VC in France	Soya VC in France
Frequency of talks per year for PC1	3	at least 5	4	n.a.	3 to 4	at least 4[a]
Frequency of talks per year for PC2	1	4 to 7	1	n.a.	1 to 2	1
Frequency of talks per year for PC3	n.a.	n.a.	3 to 4	at least 2	n.a.	n.a.

[a] In the soya VC in France, there is a quasi-integration between the processor and the storage organization within the intermediary organization (SICA), and then, several interactions do take place to define internal agreements on crop production and transaction. n.a. means not applicable because of the structure of the VC.

subsequent system building, is mostly driven by processors. Moreover, the VCs with intermediary organizations (Chickpea VC in Portugal, Fababean VC in France, Soya VC in France) also rely on more interactions, on both bilateral and collective talks, while the talks between the two contracting parties in the other cases are always bilateral.

4.3. Knowledge resources and their development through PC

In addition to reinforcing the interactions between the actors of the value chains (VC), we observed that the PC implementation strategically supports the knowledge development on grain legumes. Table 6 presents a range of knowledge resources that are linked with PC implementation. Knowledge resources used or created by the system builders to develop their grain legume VC, refer to (i) R&D activities[15]; (ii) training and technical advice; (iii) data collection on the production processes along the VC; (iv) new workforce allocation. We observe variation in these resources across the cases, with some resources being mainly organizational while others are network resources. Network resources include (i) R&D outputs when coupled/joint R&D projects exist within the VC; (ii) mandatory data collected along the production process and exchanged between the VC actors; (iii) all the technical advice and training that are accessible to all (but only) VC actors under PC; and (iv) joint allocation of workforce between the VC actors under PC. The resources that are shared, with an access limited to the network of the VC actors under PC, are underlined in Table 6.

First, R&D activities related to the crops under PC are implemented by the VC actors themselves in all cases, except in the chickpea VC in Portugal, where the R&D was carried out by the National Agronomic Research Institute specifically for variety selection. In all the VC, research activities aim, on the one hand, at developing knowledge on crop production dimensions like variety selection, pest management seedling, and on the other hand, at developing knowledge on crop technological processing like trituration to increase nutritious or protein value of the final product. In five cases, we observed that the knowledge developed in R&D is shared by at least two of the VC actors under PC, which means that the actors are building network knowledge resources.

Second, data collection during the production process was found to be mandatory, as stated in the contract clauses. Our results show that in four cases (chickpea VC in Portugal, fababean VC in France, pea VC in Latvia, and pea VC in France) the data collection on

[15] R&D outputs refer to the patents or the knowledge created due to R&D projects, and concern the choice of varieties, soil tillage, seedling, crop and pest management, crop rotation and crop system redesign, evaluation of agronomic and environmental services, storage, technological processing, grain quality.

Table 6
Knowledge resources portfolio in the value chains.

Case study name	Chickpea VC in France	Chickpea VC in Portugal	Fababean VC in France	Pea VC in Latvia	Pea VC in France	Soya VC in France
Research & development						
R&D activities on crop production	yes, about variety selection, pest management, N management; seedling (by F and S)	no	yes variety trial, seedling density and grain quality (by F, S and P)	yes on variety, soil tillage, grain quality	yes on variety trial and grain quality (by S and P)	yes on variety, seedling, pest management (weedling), grain quality (by the F and S)
R&D activities on crop processing	yes by P	no	yes, and patent developed by the P	yes by F on primary processing, and P on dry processing and protein content	yes (by S and P) and patents debeloped by the P	yes on extrusion and trituration processes (by S and P)
External source of knowledge mobilised for crop production and processing	regional agricultural extension services and seed producers	national agricultural research institute	farmer network group, animated by national agricultural extension services	national agricultural research institute	national agricultural research institute	network gathering national extension services, technical and research institutes and several intermediary organizations
Data collection						
Mandatory data collection about the crop production or processing	no mandatory collection on agronomic items; P collects data on technological processing and grain quality, internally	S collects data on 6 agronomic items, on collect, storage, technological processing and grain quality; and P collects data on storage technological processing and grain quality, internally	S and P collect data on 6 agronomic items and grain quality	P collects data on 1 agronomic item (harvest) and storage	S collects data on 7 agronomic items, collect, storage and grain quality; and P collects data on 2 agronomic items (variety, pest management), technological processing and grain quality	S collects data on 6 agronomic items, P collects data on collect, storage and technological processing and grain quality
Volontary data collection about the crop production or processing	S collects data on collect and storage internally and grain quality	S collects data on 2 agronomic items	S and P collect data on agroenvironmental services	P collects data on 3 agronomics items	not mentionned	not mentionned
Technical advice & training						
Technical advice devices for the crop under PC	technical newsletters, phone assistance, on-site bilateral advice	technical newsletters, phone assistance, webplateform; on-site bilateral advice	on-site bilateral advice	on-site bilateral advice and web plateform	technical newsletter, phone assistance, bilateral advice	technical newsletters, phone assistance web plateform, bilateral advice
Collective on-site events involving farmers, the storage organization and the processor (i.e. demonstrations, visits, meetings, either on the farm, at the storage organization or at the manufactory sites)	yes, 2 to 3 times a year; access to some events is limited to the stakeholders under PC	yes, 4 to 20 times a year	yes, 1 to 2 times; only for stakeholders under PC	yes	yes, 1time a year only for stakeholders under PC	yes, 3 times a year

(*continued on next page*)

Table 6 (*continued*)

Case study name	Chickpea VC in France	Chickpea VC in Portugal	Fababean VC in France	Pea VC in Latvia	Pea VC in France	Soya VC in France
Workforce						
Employee hiring and/or workforce reallocation for the crop development	employee hiring by P for manufacturing line	employee hiring by S for agronomic advice	employee hiring and workforce reallocation by P, and shared workforce in theintermnediaryorganisation	employee hiring by P	employee hiring by P for manufacturing line	employee hiring by S and P, and shared workforce in the intermediary organisation

F-Farmer; S-Storage organization; P-Processor
*the data underlined correspond to network knowledge resources, while the remaining are organizational resources

the crop production practices is also shared between the storage organization and the processor. Among those cases, the fababean VC in France seems remarkable because the processor collects up to six agronomic items on crop production. The data accumulates at the level of the VC and within the intermediary organizations (GTO in particular), contributing to reducing the initial knowledge deficit on varieties, yield and farming practices; and thus helping the actors to adapt their practices and reframe the contract requirements accordingly.

Third, technical advice and training related to the crop under PC are used in all cases. The technical advice is disseminated by newsletters, phone assistance, web platform, face-to-face bilateral advice, as well as through collective events allowing for social interactions between peers and/or stakeholders across the VC. Access to those devices can be limited to the stakeholders under contracts (in that case being a network resource), but not necessarily. For instance, some collective events can also be open to everyone, in order to diffuse the knowledge outside the network and motivate new stakeholders to join.

Fourth, new workforce was allocated by the storage organizations and/or the processors in all cases, confirming the need to invest in new competences at the organizational level for developing the VC under PC. In addition, in two cases with an intermediary organization (fababean VC and soyabean VC in France), the VC actors under PC jointly participated financially to appoint someone at the level of the network.

Overall, the four considerations mentioned above reinforce the idea that, in less intensive technological sectors, PC enable to sustain investment, particularly for knowledge resources development, without using direct R&D contracts which is more frequently observed in high-intensive sectors to protect high specific investments. In addition to their securing effect, PC foster interactions, as well as data collection and sharing within the network of VC actors under PC. Results confirm that PC in our cases support knowledge resources development both within each organization and within the network of actors under PC. Table 7 presents the actor's perception across the cases, confirming the role of PC on knowledge dynamics in the VC[16] in all cases.

5. Discussion and Conclusion

5.1. Key findings and contribution to the literature

Our study contributes to the Technological Innovation System (TIS) literature by reinforcing previous studies showing that formal networks play an important role in system building. We analyzed the use of PC in value chains to initiate formal strategic system building mode by fostering knowledge development. By focusing on the actors' intentional strategy, our study reveals that governance of transactions through PC allows the development of organizational and network resources -especially knowledge resources-, that are required for alternatives technologies such as grain legume production. The literature on 'hybrid forms' has already suggested that contracting for goods can generate knowledge dynamics in value chains (Gobbato et al., 2013), but our study is a first attempt to apply an analytical framework to understand the role of PC in knowledge resources development, by building bridges between organizational theories and TIS literature. This analysis opens several avenues to further explore system building within the agricultural sector or for other sectors.

We were able to reveal several underlying micro-mechanisms of those formal networks concerning resources development. We showed that (i) PC foster knowledge resources development at the organizational level by securing investment; and that (ii) PC develop knowledge resources at the network level by enhancing interactions and joint investments. By showing that PC networks serve strategic network resources development, we broaden the conceptualisation of contractualization in value chains and its role in sociotechnical transitions. While contractualization in value chains has been extensively studied through neo-institutional economics, especially the transaction costs theory mainly focusing on securing material investments by organizations, our study widens this perspective by highlighting the role of contractualization in shaping network resources, both tangible and intangible, with these

[16] In addition to the knowledge dynamics, our study suggested that PC enable the development of network resources to improve the reputation, the visibility and the legitimacy of the grain legume VC to the consumers and public policies. The study of these system resources could be further analyzed in future research.

Table 7
Perceived effect of using production contract (PC) on knowledge dynamics.

Case study name	Chickpea VC in France			Chickpea VC in Portugal			Fababean VC in France			Pea VC in Latvia		Pea VC in France			Soya VC in France		
Organization acronym	F	S	P	F	S	P	F	S	P	F	P	F	S	P	F	S	P
The use of PC in your VC enabled to:																	
Foster investment for technical knowledge development specific to the VC	4	3	4	n.a.	3	3	3	2	4	n.a.	3	n.a.	4	3	4	4	n.a.
Foster knowledge exchange on the grain legume between the VC stakeholders	4	4	4	3	3	3	2	3	4	n.a.	2	n.a.	4	4	4	4	n.a.
Engage the VC stakeholders on a medium term collaboration by increasing common legibility	2	4	4	n.a.	3	3	3	3	4	n.a.	3	n.a.	4	4	4	3	n.a.
Engage the VC stakeholders in a progress curve (i.e. a learning curve)	3	4	4	3	3	4	3	3	4	n.a.	3	n.a.	4	4	4	3	n.a.

Each system builder: F-farmer, S-storage organization, P-processor, answered the questions concerning their level of agreement to those statements, based on the following Likert scale: 4 means strongly agree, 3 means somewhat agree, 2 means somewhat disagree, 1 means strongly disagree, n.a. means the respondent did not answer the question.

network resources themselves being a basis for further TIS building.

Moreover, our study contributes to the opening of the black box of "system building modes" (Musiolik et al., 2020), to reveal the organizational structures used by the actors within these modes. More precisely, we show that PC is a tool that is used both in the partner mode and in the intermediary mode of system building. In the first case, the PC will mainly secure the links between the different contracting parties, while in the second case the PC will secure a network of actors that can in addition formalize their commitment in a separate and dedicated entity.

5.2. Practical implications

Understanding system building processes is crucial in order to define sound policies for developing alternative technologies. Our results are interesting for practitioners and policy makers in the agricultural sector, as part of the EU strategy to foster the development of grain legumes, given the previous failure in developing those crops. So far, Europe granted millions of subsidies to farmers to increase legume cultivation, but their acreage is still only 2%. This failure results from lock-in effects, previously discussed by Magrini et al. (2016), and is an appeal for public policy instruments targeting value chains structuration and the reinforcement of the technological innovation system. By allocating part of agricultural subsidies to the establishment of PC between value chain actors, particularly for emerging and sustainable crops, policy makers could create more leverage on sustainable agrifood development. Furthermore, these value chains under PC could be a basis for system building.

5.3. Limitations and future research

This study opens a research agenda to analyze how contracting for goods brings the stakeholders into a collective progress curve favoring system building. This enables us to consider the potential of contractualization in value chains to foster knowledge dynamics and innovation. These findings allow us to go beyond the analysis of R&D partnerships/contracts, too often considered by public policies as the major tool to foster the creation of knowledge.

However, our study presents several limitations.

First, knowledge development is measured on the basis of the perception of the actors under PC before and after the implementation of PC. This method represents some bias. Combining it with an analysis of the sociotechnical mechanisms by which PC enable the transfer and development of knowledge on a long-term basis will strenghten the validity of the results. Using a longer time span could show how those PC value chains are the roots of a transformative pathway for new TIS building at regional, national or even European level (when contractual links exists between stakeholders from different countries). One possible next line of research would be to reveal the mechanisms by which the developed knowledge in those formal networks (i.e., by initial system builders) extends to outside network actors, thus strengthening a whole sector. Compiling the recent literature on transition intermediaries would then be relevant. Further studies could analyze the role of extension services (Labarthe and Laurent, 2013) and knowledge brokers (Klerkx, and Leeuwis, 2009; Kivimaa et al., 2019) in the diffusion of the knowledge developed by the value chain formal network to other value chains. The survey we conducted did not reveal the existence of such intermediaries who could accelerate knowledge development. This aspect, however, could be addressed by in-depth analysis of the PC governance with regard to its intermediation role in knowledge brokering (Grin et al., 2010).

Second, even though our study concerns four different European countries, we assumed the institutional context to be the same under the European Union. This seems to make sense given that the political choices for grain legumes development have operated within the Common Agricultural Policy for the last decades. Still, we recognize that the national context could also influence the way value chain actors strategically organize themselves. Indeed, it is well acknowledged that the institutional context shapes the development of technologies (e.g., Lundvall, 2007). The current analysis could therefore be extended by a study of national institutional specificities and their relation to the network building strategy of actors. In particular, the development of formal contracts to support value chain structuration, may depend on the politico-cultural inheritance of the European countries, and differ particularly between Western and Eastern Europe. "*One of the dominant findings in the literature documents the pervasiveness of informality among economic agents throughout the post-communist countries*" in agrifood chains, says Varga (2017: 59). This context could hinder adoption of formal agreement mechanisms. Thus, these historical and cultural differences could justify an adaptation of European structural public policies on contractualization instead of a one-size-fits-all approach; specially to accompany and define the best conditions of implementation of such contractual schemes.

Third, our paper focuses on the knowledge and competences built by actors throughout the use of PC in the value chain. By reinforcing interactions and defining common expectations on the characteristics of the product – here the quantity and quality of the grain legumes – the PC may also reinforce a common vision of the future between the actors of the value chains. Future study could therefore disentangle the specific dynamics leading to a congruence of visioning, in line with recent work showing the co-influence of trust, learning, and interactive visioning in protein transition (Koole, 2022). Going a step further, the use of PC in the value chain may enable the actors to modify the institutional environment due to coalition, lobbying and legitimization of their action as a group. This political perspective of the TIS constitutes a very promising research avenue (Kern, 2015). Although some preliminary evidence has been found on the role of PC in shaping the institutions in the emerging grain legumes sector, this aspect was beyond the scope of the study and would benefit from further investigation.

Fourth, our main perspective of sustainability was relative to the nutritional and environmental benefits of grain legumes, as acknowledged in the literature (Magrini et al., 2016). However, we did not question the contribution of the grain legumes to other sustainable goals (Eckert, 2022). Recent works questioned the ways networks facilitate and give support to other sustainable goals, leading to consider them as mission-oriented networks (e.g., Hekkert et al., 2020). We could enlarge our study with more sustainable goals by considering on the one hand how stakeholders engaged through PC improve the ethics of their relations, particularly as regards added value sharing; and on the other hand, their ability to co-solve problems on other sustainability issues such as energy, water use and transport choices, etc.

Finally, in this study we analyzed a specific formal network based on PC, in a specific TIS: the emerging field of grain legumes in Europe. Similar studies could be conducted in other countries where PC are used for value chains strongly concerned with sustainability transition. Also, while the term 'production contract' is particularly used in the agrifood sector, similar contractual forms, such as procurement contracts or sub-contracting are also used in other sectors such as energy or transports. A similar research design could therefore be applied to other sectorial TIS to reinforce the generic validity of our findings.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Survey available at: https://data.inrae.fr/dataset.xhtml?persistentId=doi:10.15454/KLHNVA. Data will be made available on request.

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Supplementary materials

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