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The influence of knowledge flow on sustainable innovation in a project-based industry: From demonstration to limited adoption of eco-innovations

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ABSTRACT

The effect of the flow of knowledge on sustainable innovation in project-based firms in project-based industries is the subject of in-depth research in this paper. It studies the simultaneous functioning and effects of knowledge flow mechanisms on sustainable innovation in project-based firms in project-based industries; industries like the construction-, film-, game-, consultancy-, and IT-industry. To this end, a retrospective case study, covering 20 years (1989–2008) of sustainable innovation in the Dutch house-building industry, is conducted. This study finds that bundles of knowledge flow mechanisms stimulate both sustainable innovation creation by small networks of innovative firms that cooperate in demonstration projects, as well as stimulates a limited adoption of some of these created sustainable innovations by networks of larger incumbent firms outside these demonstration projects. Based on this finding the paper proposes a model and related propositions. To scholars it can serve as a basis for future research that further explores and tests the effect of the flow of knowledge on the eco-innovativeness of industries that heavily rely on projects. The findings can also be of benefit for policy and business practitioners in and around project-based industries. To them it can provide a route for getting sustainable innovations applied on a larger scale, from demonstration projects to regular projects.

1. Introduction

Various industries are of a project-based nature, like for example the construction industry (Barrett and Sexton, 2006); film industry (DeFillippi and Arthur, 1998; Davenport, 2006); professional services industry (Sydow et al., 2004); and information technology industry (Blindenbach-Driessen and Van den Ende, 2010; Hodgson, 2002). The processes and products of project-based firms in these industries are often more unique, small-scale and design-driven, with fewer options for achieving managerial control and economies of scale (Gann, 2000; Hobday, 1998, 2000; Hobday et al., 2000; Hayes and Wheelwright, 1984; Turner and Keegan, 1999, 2001), compared to organizations that accommodate mass- and continuous flow production (Hill, 1983; Whitley, 2006; Woodward, 1965). To develop a specific theoretical approach for project-based firms and industries, Gann (2000) and Gann and Salter (1998, 2000) proposed a theory of innovation in project-based firms. Following in their wake, a growing number of researchers used this as a starting point for further research on knowledge flow mechanisms as enablers of innovation in, and between project-based firms (Koskinen, 2010; Pemsel et al., 2016; Wei and Miraglia, 2017). But to date no research has been conducted to specifically study the effect of knowledge flow mechanisms on sustainable innovation in project-based firms and industries. The study in this paper aims to be a first attempt to address this topic. This paper studies the simultaneous functioning and effects of combinations of knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry, and concentrates on the research question:

How do combinations of knowledge flow mechanisms influence sustainable innovation in project-based firms, in a project-based industry?

The contribution of the research in this paper to science and scholars is that it models, identifies and specifies the effects of combinations of knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry. The contribution of this paper to policy and practice is that it provides insights to policymakers and business practitioners in how, where and when to invest in various knowledge flow mechanisms in order

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to stimulate the sustainable innovativeness of project-based firms and -industries.

This paper is in five sections, of which this first section is introductory. The second section elaborates on previous theoretical work, and builds a framework that guides the inductive process of theory building in the addressed area. The third section describes the case study research methodology and methods that are applied to retrospectively study an eco-innovative period in the Dutch house-building industry. The fourth section presents the outcomes of this empirical study. Finally, the fifth section proposes and discusses a model of eco-innovation development in demonstration projects and limited eco-innovation adoption in regular projects, influenced by knowledge flow mechanisms.

2. Innovation and knowledge flow in project-based firms and industries

This section reviews the literature of innovation in project-based firms (Section 2.1), and develops a theoretical framework of the proposed influence of knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry (Section 2.2).

2.1. Innovation in project-based firms

The project organization facilitates the production of products and services that are often highly diverse, one-off, and based on articulated demands of a specific and known customer. The project-based organization is oftentimes used to cope with new developments, and many project-based organizations promote themselves as flexible specialists and providers of tailor-made solutions (Hill, 1983; Hobday, 1998, 2000; Hobday et al., 2000; Lundin and Söderholm, 1995; Packendorff, 1995; Turner and Keegan, 1999, 2001; Volberda, 1998; Whitley, 2006; Woodward, 1965).

According to Gann (2000) and Gann and Salter (1998, 2000) project-based firms combine technical expertise from other firms in order to deliver their own technical capabilities, usually in unique projects. Project-based firms need to integrate both project- and business processes within the firm to be able to harness and reproduce their innovative capabilities. Gann and Salter's emerging theory for innovation in project-based firms conceptualizes this linking of project- and business processes in project-based firms and consists of five elements that function as a system. The elements are: project-based firms, project supply networks, projects, a technical support infrastructure, and a regulatory and institutional framework (see Fig. 1).

Of these elements, the three elements 'project-based firms', 'projects', and 'project supply networks' represent the entities that innovate in a certain direction. The two elements 'technical support infrastructure' and 'regulatory and institutional framework' function as enabler of the innovation processes.

Project-based firms organize their design and production processes around projects. They mostly produce one-off and operate in coalitions of companies along the supplier-customer chain. Actors who for example function in project-based firms, are consultants, designers, engineers, project managers, constructors, specialist contractors, lawyers and financiers. These professionals focus for instance on the planning, design, engineering, procuring, integration, services, and assembly activities in the project. *Projects* are defined as the commissioning and use of the products that are produced by the project-based firms, by actors like clients, owners and users. *Project supply networks* consist of the continuous flow-, mass- and batch production firms delivering the materials, components and equipment that project-based firms need. *The technical support infrastructure* stands for the long-term technical development and support of the project-based firms, supply network, and projects. Actors in the technical support infrastructure are for example the government, education and R&D institutes, industry and professional associations, libraries and databases. *The regulatory and institutional framework* comprises the

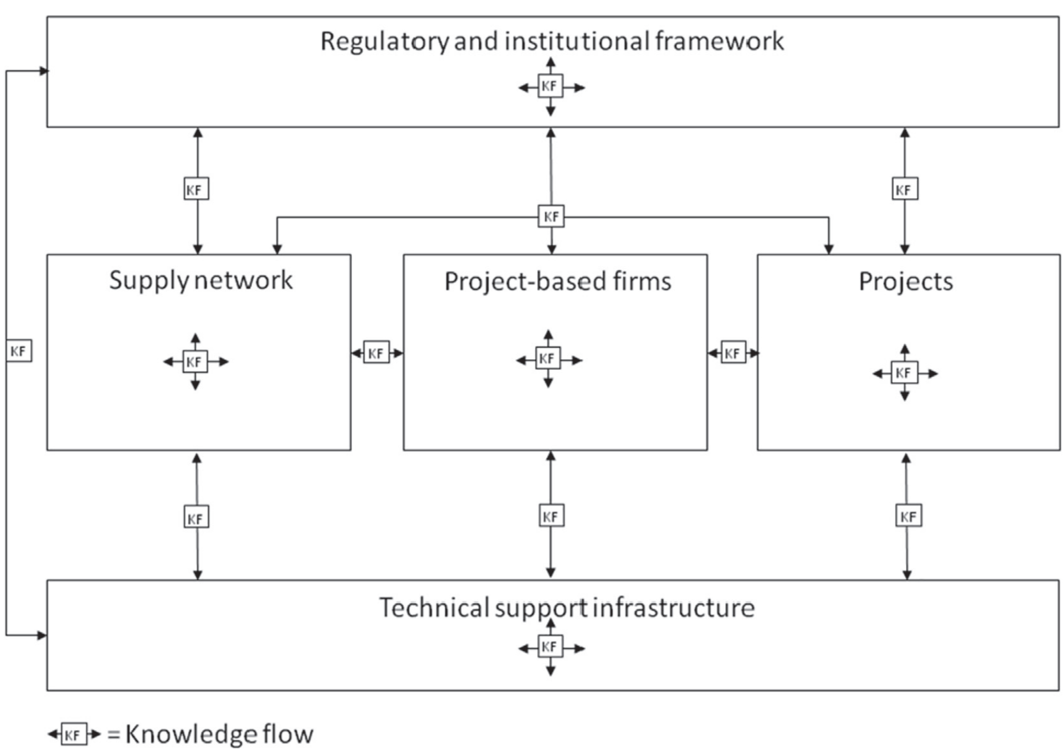

Fig. 1. Innovation and knowledge flow in project-based firms (Gann and Salter, 2000).

technical-, economic-, environmental- and social regulation of the project-based firms, the supply networks and the projects. The regulatory and institutional framework consists of actors like the government, local authorities, firms, industry associations, pressure groups, financiers and insurance firms.

2.2. Knowledge flow in project-based firms in a project-based industry

Building on the insights of Gann (2000) and Gann and Salter (1998, 2000), follow-up studies by different researchers covered the influence of knowledge flow mechanisms on innovation in project-based firms and industries (Sydow et al., 2004). In this research stream a relatively large number of studies is dedicated to the influence of distinctive knowledge flow mechanisms on the functioning and innovativeness of project-based firms (e.g. Pemsel et al., 2014; Sydow et al., 2004; Wei and Miraglia, 2017). These distinctive knowledge flow mechanisms have structural, cultural and learning characteristics. Firstly, the structural characteristic represents the physical systems and formal procedures project-based firms operate to produce, store, exchange, use, develop and transfer knowledge (Ajmal et al., 2010; Fong and Choi, 2009; Hanisch et al., 2009; Pemsel and Müller, 2012). Secondly, knowledge flow mechanisms also have a cultural characteristic, which means that project-based firms' knowledge flow is driven by these firms' socially accepted habits, routines and beliefs (Ajmal and Helo, 2010; Fong and Choi, 2009; Hanisch et al., 2009; Mueller, 2014; Pemsel and Müller, 2012; Pemsel et al., 2016; Solli-Sæther et al., 2015). A third characteristic of knowledge flow is learning. Knowledge flow in the project-based firm is often motivated by a drive to acquire, transform, apply and capture knowledge through individual and organizational learning (Almeida and Soares, 2014; Eriksson and Leiringer, 2015; Pemsel et al., 2014; Pemsel and Wiewiora, 2013; Solli-Sæther et al., 2015). The literature review led to the identification of six different knowledge flow mechanisms, each having its own unique structural, cultural and learning characteristics, that influence innovation in project-based firms (see Table 1).

Creating meta-routines. Acha et al. (2005) introduced the concept of meta-routines and define it as "*the patterns of behavior that form the organizational procedural 'mind' and these are retained in the project-based firm, despite the change in content and structure of activities*" (p. 260). Meta-routines "*are required to bind the firm together and offer the possibility of integrating the lessons of projects into the future capabilities of the firm*" (p. 276). They form the memory of the project-based organization (Koskinen, 2010) and enable project-based firms to capture the innovation lessons learnt from previous projects (Akhavan et al., 2014).

Building communities of reflective practitioners. According to Ayas and Zeniuk (2001) project-based learning can be realized by building 'insider-outsider communities' consisting of reflective practitioners, the so-called insiders, and relevance seeking academics, the outsiders. Cooperation between the insiders and outsiders stimulates the development of learning capabilities that transcend the boundaries of the specific project. Ayas and Zeniuk (2001) substantiate that "*cultivating habits of reflective practice in the fast-paced project, requires deliberate attention to learning and seeing beyond the task at hand*" (p. 74). People are at the center in this knowledge flow mechanism. Project-based firms need both inside business people who want to learn from their work by reflecting on it, as well as outside academics to stimulate this process of reflection and reflective learning.

Crossing learning boundaries. According to Scarbrough et al. (2004) learning boundaries, i.e. "*the boundaries to the transfer of learning between projects and other organizational units*" (p. 1580) constrain the exploitation of the benefits of project-led learning for the wider organization (see also Almeida and Soares, 2014). Scarbrough et al. (2004) substantiate that the difficulty of transferring what is learnt from a project to another organizational context is caused by the absence of organizational communities of people who appropriate the knowledge and practices of the project-based communities (see also Solli-Sæther et al., 2015). Most firms also do not have the right formal and informal organizational means, like procedures, norms and behavioral codes, to accumulate and appropriate project-based learning experience (Eriksson and Leiringer, 2015; Pemsel and Müller, 2012). Scarbrough et al. (2004, p. 1583) argue that "*most learning in projects is based on knowledge integration activities, which involve overcoming, rather than deepening, divisions of practice among project members*", while most "*mainstream and routinized work practices … …are conducive to … …specialization and evolving communities of practice*", and concentrate on a deepening of divisions of practice among organizational members. Scarbrough et al. (2004) emphasize this by stating that "*the corollary here is that the greater the degree of learning within the project, the greater the division between the new, shared practices of project members and the practices obtaining in other parts of the organization*" (p. 1585). Their major conclusion is that the crossing of learning boundaries is important to enable the exploitation of the benefits of project-based learning for the wider organization.

Business-led learning. Brady and Davies (2004) describe business-led learning in a project-based firm as the process of change of the organizational strategy that directs the learning processes in the firms' projects. They substantiate that in case a firm

Table 1
Knowledge flow mechanisms influencing innovation in project-based firms.

Knowledge flow mechanism	Definition	Proposed effect on innovation in project-based firms
Creating meta-routines	Capturing patterns of behavior that form the organizational procedural 'mind' for project-based innovation.	Contributes to the innovativeness of the firms' workers and to the firms' capability to innovate.
Building communities of reflective practitioners	Realization of project-based learning by building insider-outsider communities of reflective practitioners and relevance seeking academics.	Contributes to the innovativeness of the firms' workers and to the firms' innovative product development process.
Crossing learning boundaries	Overcoming the boundaries to the transfer of learning between projects and other organizational units.	Contributes to the wider exploitation of knowledge from projects.
Business-led learning	The change of the organizational strategy that directs the learning processes in the firms' projects.	Contributes to the firms' exploitation of new technologies or market bases that are developed in projects.
Integrating inside and outside human knowledge bases	Gaining access to the networks of specialists inside and outside the firm.	Contributes to the innovativeness of the firms' workers.
Visualizing and codifying knowledge	Making the outcomes of work and the interfaces between them visible, tangible and applicable.	Contributes to the innovativeness of the firms' workers and to the firms' exploration and exploitation of innovation.

applies business-led learning "*the project-led learning processes are embedded within the wider business organization and strategic context of the firm*" (p. 1608). It is a strategic process and culture that guides what has to be learnt in the projects of the firm. It also simultaneously develops routinized processes as well as it installs and coordinates renewed or completely new business processes in the firm that support this chosen strategic direction (Ajmal and Helo, 2010; Ajmal et al., 2010; Hanisch et al., 2009; Mueller, 2014; Pemsel et al., 2014, 2016; Pemsel and Wiewiora, 2013; Wei and Miraglia, 2017; Wen and Qiang, 2016).

Integrating inside and outside human knowledge bases. The cultural dimension is prominent in the maintenance and development of the knowledge base of the project-based firm (Bresnen et al., 2003). Bresnen et al. (2003) stress that knowledge is often "*tacit and embedded within particular social groups and situations*" (p. 157). This knowledge is difficult "*to capture in explicit forms, in ways that it can be understood and applied in new contexts*" (p. 163). In line with this, Bresnen et al. (2003) and Blindenbach-Driessen and Van den Ende (2006), Engwall (2003), Hobday (1998, 2000), Hobday et al. (2000), and Staber (2004) consider it important for firms to resolve this difficulty, and gain access to the inside and outside networks of specialists. It enables the appropriation of knowledge that is developed in realized projects, by others, and in other settings. In this respect Blindenbach-Driessen and Van den Ende (2006) consider the "*exchanged knowledge with colleagues and the captured knowledge for future reference*" (p. 551) to be important for a project-based organization. They mark the availability, commitment and inclusion of professionals with expertise, either as coworkers in projects or as sideline advisors of projects, as an important success factor.

Visualizing and codifying knowledge. Research also stresses the importance of using visualization (Cacciatori, 2008; Whyte et al., 2008) and codification (Boh, 2007; Cacciatori, 2008; Prencipe and Tell, 2001) practices to create and capture knowledge (Sokhanvar et al., 2014). It improves the tangibility, applicability and transferability of the knowledge that is developed and used in projects, and needs to be re-used in other contexts. According to Whyte et al. (2008) project-based firms can use visualization techniques to direct projects that explore new fields of interest and projects that aim to exploit new knowledge, techniques, products and processes for the firm. Visualization contributes to the "*effectiveness at sense-making by making the outcomes of … …work and the interfaces between them more visible and available for discussion among the team*" (Whyte et al., 2008, p. 87). In addition to a graphical representation of knowledge, this can also be codified in work procedures, product and process specifications, and databases (Boh, 2007; Cacciatori, 2008; Prencipe and Tell, 2001). Information technology supports this codification and according to Boh (2007, p. 30) information "*is carefully codified and stored in databases and documents, where it can be accessed and used easily by employees in the company*".

3. Methodology and methods

Although the literature indicates that there is a supportive effect of these six knowledge flow mechanisms on innovation in project-based firms, to date no study has empirically researched whether and how these knowledge flow mechanisms can stimulate sustainable innovation in project-based firms in a project-based industry. Thus, an empirical research project is conducted to study the effects of the six knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry (see Table 2).

This section presents the methodological structure of the research (Section 3.1), the data collection methods used (Section 3.2), a description of the method for data analysis (Section 3.3), and ends with an explanation of how the findings are synthesized into a model and propositions (Section 3.4).

3.1. Step 1: selection of empirical setting

In the qualitative research methodology, as introduced by Eisenhardt (1989) and Eisenhardt and Graebner (2007), an empirical setting is selected to be the subject of an inductive case study. To serve this purpose the case of innovation in environmental sustainability, or: eco-innovation, in the Dutch house building industry is chosen as the subject of study. This case is studied in retrospect from 1989 until 2008, and covers a period of 20 years of practice. The Dutch house building industry serves as a theoretical sample (Eisenhardt and Graebner, 2007) because of its project-based nature (Barrett and Sexton, 2006; DeFillippi and Arthur, 1998; Gann and Salter, 1998, 2000; Wei and Miraglia, 2017), and its nationwide initiative to innovate in environmental sustainability in that specific time frame (Bossink, 2011; Priemus, 2005; Van Bueren and Priemus, 2002). The choice for a single case study that covers a long time-period enables a rich, grounded and revelatory description of the effects of combinations of knowledge flow mechanisms on sustainable innovation during a long time period, securing that various effects can be observed, mutually compared and analyzed in terms of influence and importance (Siggelkow, 2007; Yin, 2009).

3.2. Step 2: data collection

Multiple methods of data collection, i.e.: document studies and project studies, are selected (see Table 3).

Documents study. The documents study covers 21 strategic

Table 2
Research steps.

Step	A) Choice in this step B) Logics behind this choice
1. Selection of empirical setting	A) Dutch house-building sector, from 1989 to 2008. B) This sector is project-based and dedicated to sustainable innovation in this time frame.
2. Data collection	A) Document studies and project studies. B) Chosen documents cover the whole time frame and cover the main events and circumstances; Chosen projects are exemplary projects that are analytically valid for sustainably innovative demonstration projects in this industry sector and time frame.
3. Data analysis	A) Open and axial coding of data. B) Gathered data is first labeled (open coding), then grouped into second-order categories and distributed among theoretical constructs from the theory of innovation in project-based firms (axial coding).
4. Synthesis into model and propositions	A) Development of a case study narrative, model and propositions. B) The case is narrated in terms of the constructs that are central in the theory of innovation in project-based firms, and from this case study narrative a model and propositions are derived.

Table 3
Data collection.

Research method	Data source
Documents study	21 Strategic documents: • 5 national environmental policy plans (NEPP, 1989, 1990; 1993, 1998; 2001); • 3 national sustainable building policy plans (ASSB, 1995, 1997; RSB, 1990); • 2 reports on the national demonstration program (Buis et al., 2000; SEV, 1997); • 4 dissertations on sustainability in the Dutch building industry (Bossink, 1998; De Jonge, 2005; Silvester, 1996; Van Hal, 2000); • 7 scientific peer reviewed papers/books on sustainability in Dutch building (Beerepoot and Sunikka, 2005; Bossink, 2011; Buijs and Silvester, 1996; Boonstra and Knapen, 2000; Priemus, 2005; Reijnders and Huijbregts, 2000; Van Bueren and Priemus, 2002).
Projects study	14 Green demonstration projects: • Interviews with at least three key project managers or specialists in each project; • Collection of at least five strategic project documents in each project; • Observation of at least three design meetings with all cooperating participants.

documents. It aims at developing a general overview of the Dutch situation in eco-innovative house building. The portfolio of gathered and analyzed strategic documents consists of five national environmental policy plans, three national sustainable building policy plans, two reports of 33 national eco-demonstration projects, four dissertations on Dutch eco-building, and seven scientific peer reviewed international papers or books on Dutch eco-innovative house building.

House building projects study. The house building projects study comprises 14 eco-innovative demonstration projects and aims at developing an in-depth insight into the sustainable innovation processes in, around, and between eco-innovative project-based firms. The projects had in common that these are officially labeled by a government-related institution as 'national eco-demonstration project'. All projects developed sustainably innovative house building plans for residential areas, varying from 10 to 200 dwellings each. The combined market value of the plans is approximately 300 million €. In all projects the primary project documents are collected, like the project plans, requirement schedules, drafts, designs, building specifications and meeting minutes. Also, in each project at least three design meetings in which all project participants were present, i.e. the sketch meeting, preliminary design meeting, and final design meeting, are attended and observed. In all projects the main project participants are interviewed, like the building project managers and building specialists of the municipalities, the clients, and the commercial architects and contractors. The interviewees are asked to reflect on the background and characteristics of their eco-innovation project.

3.3. Step 3: data analysis

The empirical material is analyzed by means of a comparison with the proposed effects of the six knowledge flow mechanisms on sustainable innovation in project-based firms. For this a process of open and axial coding is applied. The open coding process consists of labeling the gathered and recorded data. The subsequent axial coding process consists of a search for similarities between the labels to group these into second-order categories (Miles and Huberman, 1994; Strauss and Corbin, 1990). The second-order categories are compared with, and distributed among the six knowledge flow mechanisms and proposed effects on sustainable innovation in project-based firms. The outcomes of this process of labeling, grouping of labels into second-order categories, and distribution of second-order categories among the six knowledge flow mechanisms and their proposed effects are visualized in Fig. 2.

3.4. Step 4: synthesis into a model and propositions

The analysis is narrated into a case study report wherein the major findings are synthesized (Langley, 1999), with the structure in Fig. 2 as a guideline, and concentrating on the research question how combinations of knowledge flow mechanisms affect sustainable innovation in and between project-based firms (see Section 4). This all is synthesized into a model and related propositions, which constitute a theory-based, empirically grounded, testable initial theory of the effect of combinations of knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry (see Section 5), which is the final step in Eisenhardt (1989) and Eisenhardt and Graebner (2007) methodology for theory development from case study research.

4. Sustainable innovation and knowledge flow in Dutch eco-house building

This section narrates the empirical findings into a case study report. First, it examines the eco-innovation creation and adoption processes in Dutch house building (Section 4.1), and then proceeds with the found influence of combinations of knowledge flow mechanisms on these sustainable innovation processes (Section 4.2).

4.1. Sustainable innovation in project-based firms in Dutch eco-house building

4.1.1. How it started

In the late eighties the Dutch government initiated a sustainability strategy for its national building industry. The Dutch government considered the improvement of the environmental performance of the building industry as one of the spearheads of its environmental sustainability policy (ASSB, 1995, 1997; NEPP, 1989, 1990, 1993, 1998, 2001). With its plans the government developed more than 200 significant green building initiatives from 1989 to 2008.

4.1.2. Project-based firms

Most of these initiatives are concentrated around 33 demonstration projects for sustainable house building that are highly specialized (ASSB, 1995, 1997; Buis et al., 2000; SEV, 1997):

A small network created the eco-innovations. 133 Firms, representing 0.15% of the at that time 86,000 firms in the construction industry, participated in 33 nationally acknowledged innovation projects for eco-house building, the 'national demonstration projects' (Buis et al., 2000; SEV, 1997). The demonstration projects acted as high-profile examples in a provincial and municipal area. Most of the large and medium-sized municipalities in the Netherlands developed a demonstration project with remarkable results. All dwellings in these projects had high application rates, varying from 50 to 100% for 20 key eco-innovative building options (varying from water-efficient toilets, showers and taps, to energy-efficient window panes, to passive solar energy by means of

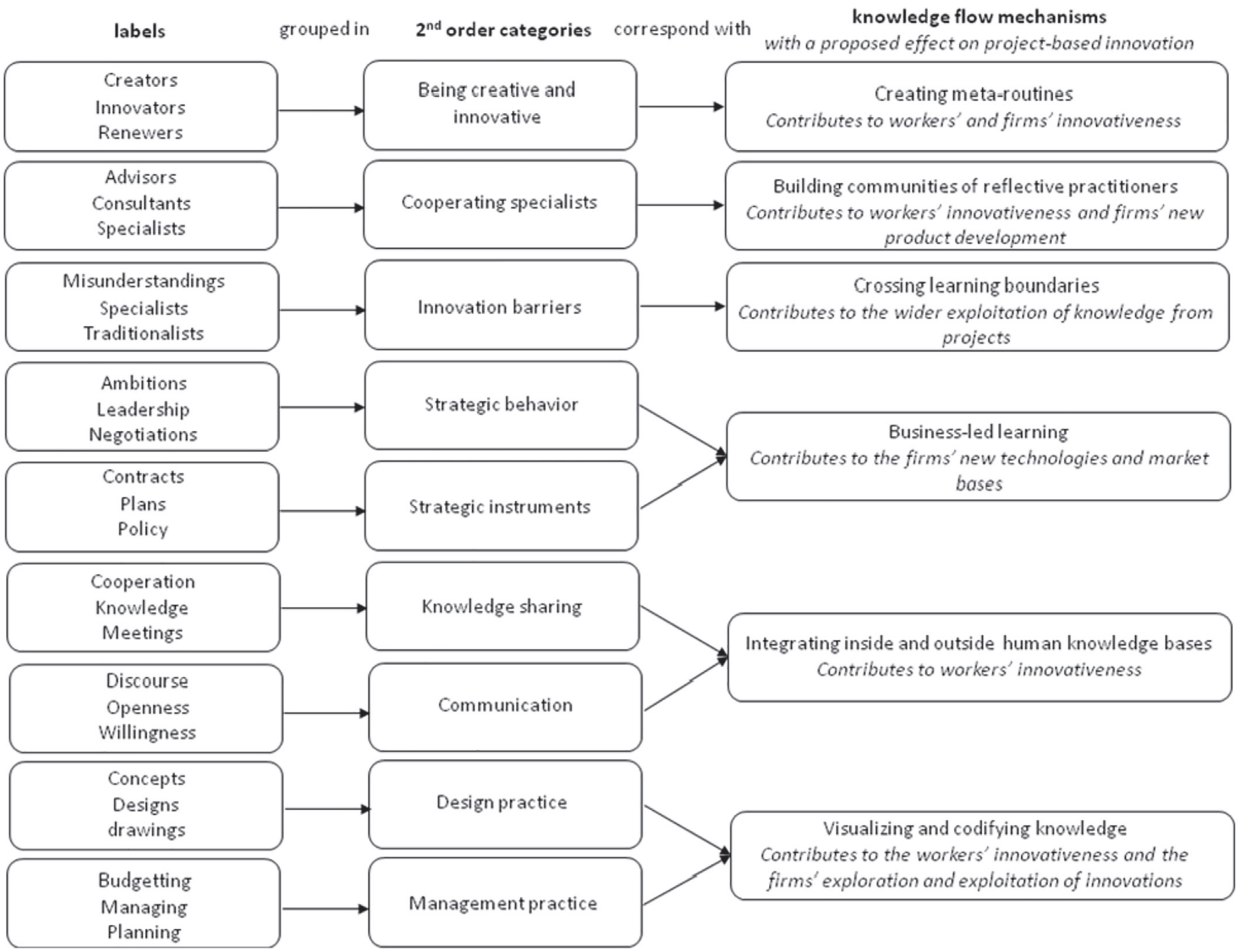

Fig. 2. Coding structure.

situating living rooms on the sunny side of the houses). The demonstrations are considered successful in the sense that these comprised real-world field experiments delivering valuable and demonstrable insights into the possibilities of eco-innovative building (Boonstra and Knapen, 2000; Bossink, 1998, 2011; Buijs and Silvester, 1996; Silvester, 1996; Van Hal, 2000).

Specialized architects led this eco-innovation process and supervised all 33 demonstration projects. It appeared that these specialists were members of a small national network of green architectural firms. Earlier, in the mid-seventies this movement of green building designers emerged. Three architectural professors, associated with Dutch Universities of Technology, symbolically represented this network. In the beginning it consisted of approximately 15–20 architectural firms that concentrated solely on green design, based on a strong sense of passion (Bossink, 1998). The small network of ambitious and passionate architects became highly critical to realizing the government's political ambitions. From 1989 to 1993 policy development and deployment risked running rampant, with ambitious national environmental policy plans and political statements, but just a few concrete projects in the field (NEPP, 1989, 1990, 1993). The need to show tangible results drove the authorities into the arms of the eco-architects, and they cooperated intensively between 1993 and 1999, the period in which most of the demonstration projects took place (Bossink, 1998, 2011; Buis et al., 2000; SEV, 1997).

4.1.3. Supply network

The architects saw the repeated and exclusive participation in the demonstration projects as an important way to sustain and further strengthen their business. Two of the dominant architectural firms developed and continuously refined their own sustainable, trademarked eco-design tools (Bossink, 1998; De Jonge, 2005; Ravesloot, 2005; Silvester, 1996; Van Hal, 2000).

All 33 demonstrations are built and evaluated with one of these eco-design tools, and the supply network had to meet the demands of these tools. The tools are based on the architects' experiential knowledge and on life cycle analyses. All real estate developers, clients and financiers who wanted 'to go green' in the demonstrations hired architects who used these tools.

4.1.4. Projects

The small network's ambitious eco-innovations scored high in terms of eco-innovation quality but low in terms of application scale.

The 33 demonstration projects realized 'good' to 'very good' eco-innovation scores. The green material scores of 24 demonstration projects, representing 3,217 dwellings, were measured and calculated, and overall, the building designs scored a weighted average of 93.2 on a scale of 0-to-100. The dwelling with the lowest score scored 76.5, and the dwelling with the best score scored 98.5 (Bossink, 1998; Buis et al., 2000). The energy-efficiency scores of 3,886 buildings in the 33 demonstration projects were also measured and calculated. The dwellings had to score equal to, or less than a 1.4 standard. Overall, the buildings scored a weighted average of 1.11 per dwelling; 0.29 better than the set 1.4 target (Bossink, 1998; Buis et al., 2000).

Yet, the demonstration projects employed a small fraction of firms in the industry and built a rather small percentage of the nation's houses. Altogether the demonstration projects involved 133 firms (Buis et al., 2000; SEV, 1997), representing a percentage of 0.15 of the approximately 86,000 commercial firms in the industry. The demonstrations built approximately 4,000 environmentally sustainable dwellings (Buis et al., 2000; SEV, 1997), which accounts for 0.2% of the total number of 1.75 million houses that are built from 1989 to 2008.

The government persistently declared that the building industry had to learn from the demonstration projects. The First National Action Plan for Sustainable Building for example stated that "*given the dynamics between experimental demonstrations and traditional applications, it is important to continue with demonstration projects*" (ASSB, 1995, p. 41). And the Second National Action Plan for Sustainable Building declared that "*experiments are needed to further develop environmentally sustainable measures that are immature today, but will become useful and applicable on a large scale tomorrow*" (ASSB, 1997, p. 73). Nevertheless the innovations from the demonstration projects were seldom implemented in other projects nor applied by incumbent firms.

4.1.5. Regulatory and institutional framework & Technical support infrastructure

Still, some energy-efficiency innovations that were applied successfully in the demonstration projects diffused to the industry on a large scale.

The Dutch government aimed at assuring a certain minimum level of sustainability in the building industry with prescriptive laws, acts, regulations and subsidies. Article 21 of the Dutch Constitution obliges the government to ensure the habitability of the country and to protect and improve the environment. As a large-scale diffusion of eco-innovations from demonstration projects to regular projects in the industry did not get started, the Dutch government decided to adopt a more coercive approach to fulfill its obligations. In 1996 it introduced the *Energy Efficiency Standard*, prescribed it by law, and made it part of the so-called *Building Decree*. From that moment all dwellings in the Netherlands had to be developed in accordance with this standard, which the government developed with the knowledge, insights and results obtained from the demonstration projects. The *Energy Efficiency Standard* was raised three times, in 1998, 2000 and 2006, and was successfully imposed on all 86,000 project-based firms, suppliers and projects in the industry from 1996 to 2008 (Beerepoot and Sunikka, 2005; Bossink, 1998).

Unlike the energy efficiency innovations, none of the eco-material innovations diffused from the demonstration projects to the industry on a significant scale.

Several provincial authorities established regional knowledge centers for sustainable residential building, and in 1996 the government even established a national knowledge center named 'the National DuBo-center'. (DuBo is a contraction of 'Duurzaam Bouwen', which is Dutch for 'Sustainable Building'). In the years that followed, various large and medium-sized cities established similar municipal centers with similar names (Bossink, 1998). The national center stimulated sustainable building on a nationwide scale, and the regional and civic centers functioned as information and subsidy desks for architects, contractors and consultants in the provinces and municipalities. Every year the National DuBo-center organized a national conference on sustainable building for representatives of governmental and commercial organizations (Bossink, 1998). In 1996, on this annual meeting, the Secretary of State introduced the first nationally acknowledged green building tool: the *National Package for Sustainable Building* (Jansen, 1996). The tool was developed in consultation with branch associations of 15 key interest groups in the industry. This instrument, which like the *Energy Efficiency Standard* is based on the experiences and results of the demonstration projects, enabled firms from outside the demonstration projects to select and apply some green material and design options. The package was, like the *Energy Efficiency Standard*, planned to become an integral part of the law. Yet, this plan was not realized. The package was not prescribed by law and not integrated in the *Building Decree* and remained an optional instrument. Although the government and all 15 key industry stakeholder groups encouraged the application of the *National Package for Sustainable Building*, the large majority of the incumbent firms in the industry decided to ignore it.

4.1.6. Synopsis

Table 4 summarizes the above findings.

Fig. 3 provides a visual summary of the sustainable innovation creation and adoption processes.

It shows that a small and specialized network in demonstration projects that receives regulatory, institutional and technical support, creates the reservoir of eco-innovations. With force from the regulatory and institutional framework and support from the technical infrastructure, a limited selection of options from this reservoir (i.e. the options included in the *Energy Efficiency Standard*) is adopted by the network of incumbent firms outside the demonstration projects; yet, a large number of options from the reservoir (i.e. the options included in the *National Package for Sustainable Building*) is not adopted by the network of incumbent firms outside the demonstrations. This creation of eco-innovations in demonstration projects and limited adoption of eco-innovations by incumbent firms in regular projects, contributes to the regulatory and institutional framework and the technical support infrastructure; it is the basis for laws, regulation and codes of conduct (regulatory and institutional framework), and for a growing general reservoir of eco-innovation knowledge and know-how (technical support infrastructure).

4.2. Knowledge flow mechanisms' effect on eco-innovation

A deeper analysis reveals that combinations of knowledge flow mechanisms had a stimulating effect on this creation of eco-innovations in demonstration projects and the limited adoption of some of these eco-innovations in regular projects.

4.2.1. Creating meta-routines

The firms in the demonstration projects relied on the meta-routines of a group of highly creative and innovative architects. In addition to this, the government marked the 33 demonstrations as 'learning projects', and these learning projects were supported by professionals from 133 firms who committed themselves fully to environmental sustainability. These participants saw the demonstration projects as a challenge, where people with different backgrounds could share and develop experience and competence. A dominant reason for companies to work on the basis of, and invest in a further development of green meta-routines in demonstration projects was that they saw eco-building as a dominant market, not so much for today, but for the future. It would be good to have a first-to-market advantage.

Table 4
Sustainable innovation in project-based firms in Dutch eco-house building.

Project-based entity	Innovation result	Empirical evidence
Project-based firms	A small network of project-based firms creates eco-innovations.	0.15% of the 86,000 project-based firms in the construction industry participated in 33 nationally acknowledged innovation projects for eco-house building.
	Specialized architects led this eco-innovation creation process.	One or more specialized architectural consultants supervise 100% of the 33 nationally acknowledged innovation projects for eco-house building.
Supply network	The specialized architects' eco-design tools prescribed which eco-innovations had to be ordered from and supplied by the supply network.	100% of the 33 nationally acknowledged innovation projects for eco-house building is built and evaluated with the architectural consultants' eco-design tools.
Projects	The small network's ambitious eco-innovations are applied on a small scale.	The 33 nationally acknowledged innovation projects for eco-house building received a top average eco-innovation score (93.2 on a top 100 scale) and a good energy-efficiency score (0.29 better than the 1.4 target). These projects represented 0.2% of all houses that are erected by the construction industry.
Regulatory and institutional framework&Technical support infrastructure	Various energy efficiency innovations of the small network diffused to the industry on a large scale.	100% of the industry's 86,000 firms had to meet the *Energy Efficiency Standard*, which is based on the results of the 33 nationally acknowledged innovation projects for eco-house building, and are enforced by law since 1996.
	None of the small network's material efficiency innovations diffused to industry on a significant scale.	0% of the industry's 86,000 firms met the norms of the *National Package for Sustainable Building*, which is based on the results of the 33 nationally acknowledged innovation projects for eco-house building, and is launched in 1996.

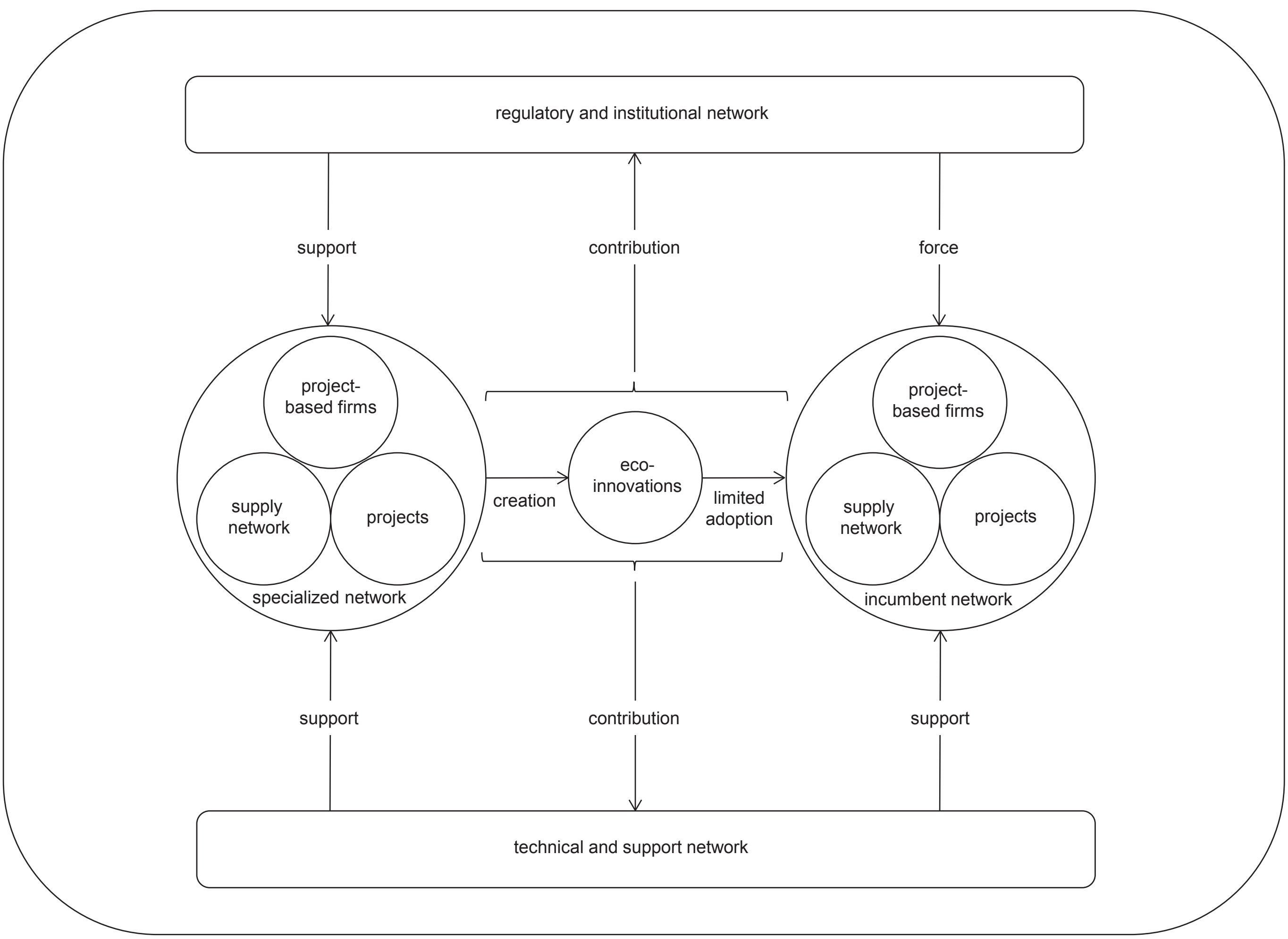

Fig. 3. Sustainable innovation creation and adoption in the Dutch building industry.

4.2.2. Building communities of reflective practitioners

The firms of the small network that cooperated in the demonstration projects relied on the academic ties of the specialized architects they hired. One or more, and sometimes even a team of specialized academic architects supported all 133 firms in the 33 demonstrations. Together the small group of architectural firms with academic ties and the commercial building firms in the demonstrations formed a community of reflective practitioners, of which participants met frequently, both in their own demonstration project, and in the overarching national demonstration program of 33 projects. All demonstration projects received lots of extra attention, additional funding and subsidized assistance of several scientific specialists from the green architects' network. This provided some of the also participating, and relatively ignorant real estate agents, contractors and municipal officials, the opportunity to learn. They got direct access to state-of-the-art green design methods, Life Cycle Analysis (LCA) -information, and the latest experiential knowledge.

4.2.3. Crossing learning boundaries

Participants of the demonstration projects did not cross learning boundaries. Most knowledge was locked in the demonstration projects and hidden in the tacit knowledge bases of the participants. All 133 firms in the 33 demonstrations worked in isolation from the industry's mainstream building projects. Demonstration projects were both physically and mentally isolated from other building projects in the country and were heavily dependent on the specialized participants. Designers, builders and real estate agents were specialized respectively in green design, -building operations, and -marketing, with relatively less knowledge of each other's specializations. Most contractors worked with the green architects to compensate for this lack of understanding, and vice versa.

4.2.4. Business-led learning

Business-led learning had a significant influence on the firms' ability to innovate in both demonstration projects and the regular projects in the country:

The small network prioritizes eco-innovation. To be admitted to the national demonstration program all 133 firms that participated had to show a sustainability strategy, by means of their past performance, a signed contract or a statement of intent. It led to a national demonstration program with eco-building projects that are situated in the larger cities of the country, and with participants with a demonstrable green strategy and/or commitment to eco-innovation. Most participants in the demonstration projects got their position because they were recommended and praised, and put a lot of effort in promoting their eco-capabilities and ambitions.

Incumbents put energy efficiency on their agenda. To also stimulate incumbent firms to design and build sustainably the government decided to introduce the *Energy Efficiency Standard*, and by this enforced that energy efficiency became on the strategic agenda of all 86,000 firms in the industry. From 1996 to 1997, 170,000 new dwellings had to score less than, or equal to a norm of 1.4; from 1998 to 2000, 240,000 new houses to a 1.2-norm; from 2000 to 2006, 400,000 new houses to a 1.0-norm; and from 2006 to 2008, 160,000 new houses to a 0.8-norm.

4.2.5. Integrating inside and outside human knowledge bases

Firms in both demonstration projects and regular projects benefited from inside and outside human knowledge bases:

The small network gets access to eco-knowledge. All firms in the demonstration projects organized weekly and monthly meetings to share information and align processes. Additionally, participants of the demonstration projects also gained access to networks of specialists outside their firm and demonstration project by attending regular meetings that were organized by the governmental officials of the national demonstration program. These meetings were organized to share eco-ideas, -design possibilities and -inventions, but also for the more standard issues, like planning, problem solving, and mutual adjustment of activities.

Specialists help the incumbents. While most incumbent firms in house-building struggled with the *Energy Efficiency Standard* in regular projects a new market for eco-innovative building consultancy emerged. Architects and consultants who learnt how to work with this standard in the 33 demonstrations started to offer their paid support to the large market of 86,000 firms in the industry that had to meet the *Energy Efficiency Standard*. It led to a considerable flow of knowledge about energy efficiency from the demonstration projects to the industry's regular projects.

4.2.6. Visualizing and codifying knowledge

Visualized and codified knowledge played an essential role in knowledge capture and transfer processes in demonstration- and traditional projects, but did not always have the desired effect:

The small network develops eco-innovations. Visualization and codification of knowledge had a high impact on the house building demonstration projects and the rest of the industry. The two dominant codified eco-design tools, the 'DCBA-list' and 'NIBE-classification', enabled all participants in all demonstration projects to translate their ambitions into tangible results. All 133 firms in the 33 demonstration projects built, evaluated and got their houses approved with a nation-wide acknowledged evaluation method that was derived from these two codified eco-design tools.

The incumbents apply energy-efficiency innovations. The *Energy Efficiency Standard*, a procedure with visualizations and codifications for calculating the energy-efficiency of a design, highly influenced the energy-efficiency of the whole industry, and was applied on an industry-wide scale, by all 86,000 firms.

The industry does not develop eco-material innovations. But, none of the 86,000 project-based firms in the industry applied the *National Package for Sustainable Building*, which did not become part of the law. The Package was not used. Actually, firms pushed it aside immediately after they approved it.

4.2.7. Synopsis

Table 5 summarizes the above findings.

Fig. 4 provides a visual summary of the described influence of combinations of knowledge flow mechanisms on the sustainable innovation creation and adoption processes in Dutch house building. It visualizes that combinations of respectively five and three knowledge flow mechanisms had a supporting effect on respectively sustainable innovation creation by the specialized network in demonstration projects, and on limited sustainable innovation adoption by the incumbent network in regular projects. A condition for this supporting effect is respectively regulatory, institutional and technical support; and regulatory and institutional force, and technical support.

5. Discussion and conclusion

This section proposes a theory of the influence of knowledge flow mechanisms on sustainable innovation in project-based firms in a project-based industry by means of introducing a model and propositions. It discusses the theoretical implications of this research, and its implications for policy and practice.

5.1. Model and propositions

Based on the literature, a supporting effect of all six knowledge flow mechanisms on sustainable innovation in project-based firms is expected. Table 5 shows that creation of meta-routines (Acha et al., 2005), building of communities of reflective practitioners (Ayas and Zeniuk, 2001), business-led learning (Brady and Davies, 2004), integrating inside and outside human knowledge bases

Table 5
Knowledge flow mechanisms' effect on sustainable innovation in project-based firms.

Knowledge flow mechanism	Found effect on sustainable innovation in project-based firms	Empirical evidence
Creating meta-routines	Supporting effect: the project-based firms of the small network relied on the meta-routines of the specialized architects.	One or more academic architectural consultants supported all 133 project-based firms in the 33 demonstration projects.
Building communities of reflective practitioners	Supporting effect: the project-based firms of the small network relied on the academic ties of the architects they hired.	One or more academic architectural consultants supported all 133 project-based firms in the 33 demonstration projects.
Crossing learning boundaries	Not applied: the project-based firms of the small network did not cross learning boundaries.	All 133 project-based firms in the 33 demonstration projects worked isolated from the mainstream building projects in the industry.
Business-led learning	Supporting effect: the project-based firms of the small network prioritized eco-innovation as a strategic goal.	All 133 project-based firms that participated in the 33 demonstration projects needed a demonstrable sustainability strategy to be admitted.
	Supporting effect: all project-based firms in the industry set innovative energy-efficiency goals.	All 86,000 project-based firms in the industry had to comply with the government's *National Energy Efficiency Standard*, which was enforced by law.
Integrating inside and outside human knowledge bases	Supporting effect: the project-based firms of the small network got access to and developed eco-knowledge themselves.	All 133 project-based firms in the 33 demonstration projects organized various information exchange meetings.
	Supporting effect: knowledge of energy-efficiency innovations flowed from the project-based firms of the small network to the industry's project-based firms.	The academic architectural consultants who helped the 133 project-based firms from the small network also offered their paid support to the other 86,000 firms that had to meet the *Energy Efficiency Standard*.
Visualizing and codifying knowledge	Supporting effect: the project-based firms of the small network methodically developed eco-innovations.	All 133 project-based firms in the 33 demonstration projects built, evaluated and got their houses approved with a nation-wide acknowledged eco-design tool.
	Supporting effect: all project-based firms in the industry methodically applied energy-efficiency innovations.	All 86,000 project-based firms in the industry had to comply with the government's *Energy Efficiency Standard*, enforced by law.
	No effect: the project-based firms in the industry did not develop eco-material innovations.	None of the 86,000 project-based firms in the industry was forced or applied the *National Package for Sustainable Building*, which did not become part of the law.

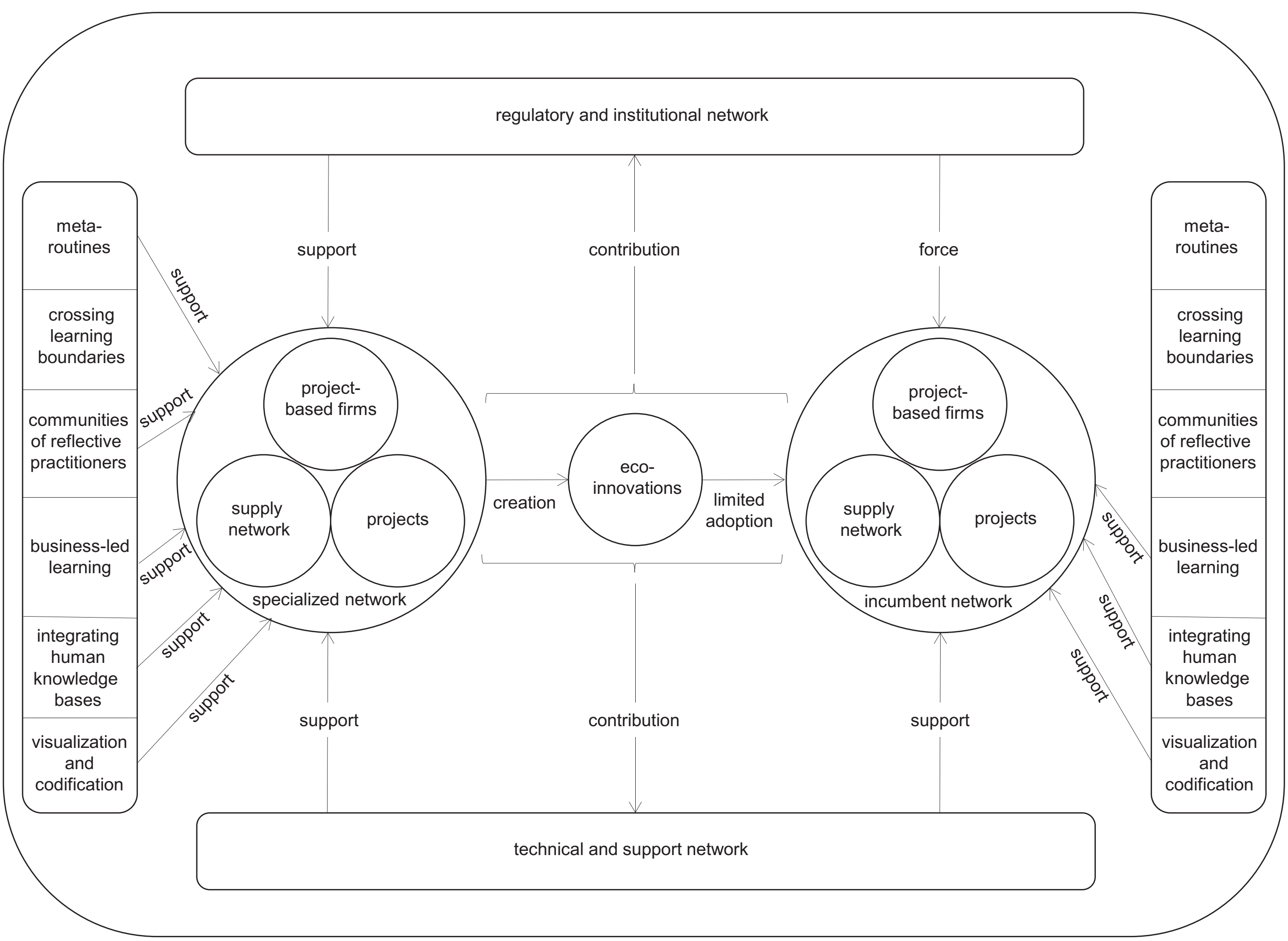

Fig. 4. Knowledge flow mechanisms' effect on sustainable innovation in the Dutch building industry.

(Bresnen et al., 2003), and visualizing and codifying knowledge (Cacciatori, 2008) have a proposed supporting effect, as well as a found empirical supporting effect on sustainable innovation in project-based firms in a project-based industry. One knowledge flow mechanism, i.e. the crossing of learning boundaries (Scarbrough et al., 2004), was not applied in practice and no empirical evidence is found in this empirical study that confirms a supporting effect of this knowledge flow mechanism on sustainable innovation in project-based firms in a project-based industry. In general, and based on these findings it can be proposed that bundles of knowledge flow mechanisms have a supporting effect on both sustainable innovation creation by demonstration projects as well as large scale adoption of a limited number of the created sustainable innovations by regular projects. The proposed model for sustainable innovation in a project-based industry that results from this is depicted in Fig. 5.

Fig. 5 visualizes that under the circumstance of regulatory, institutional and technical support, a small network of specialized project-based firms and suppliers creates a reservoir of sustainable innovations in demonstration projects. It also visualizes that under the circumstance of regulatory and institutional pressure and technical support, a large network of incumbent project-based firms and suppliers adopts a limited selection of the sustainable innovations from this reservoir in regular projects. In addition to this, it visualizes that combinations of knowledge flow mechanisms have a stimulating effect on both these sustainable innovation creation and limited innovation adoption processes. Based on this, the following two propositions are postulated:

Proposition 1. In a project-based industry, under the condition of the presence of regulatory, institutional and technical support, combinations of knowledge flow mechanisms have a supportive effect on sustainable innovation creation by a small network of specialized project-based firms and suppliers in demonstration projects.

Proposition 2. In a project-based industry, under the condition of the presence of regulatory and institutional force, and of technical support, combinations of knowledge flow mechanisms have a supportive effect on a limited sustainable innovation adoption by a large network of incumbent project-based firms and suppliers in regular projects.

The empirical findings indicate that practical experience with creating eco-innovations in demonstration projects and a limited adoption of some of these eco-innovations in regular projects enables:

i) the regulatory and institutional framework to develop and implement laws, rules and codes of conduct that gradually heighten the eco-innovation adoption level of the project-based industry as a whole; and
ii) the technical support infrastructure to develop and capture knowledge and know-how of developing, applying and integrating eco-innovations in demonstration and regular projects. This leads to the next two propositions:

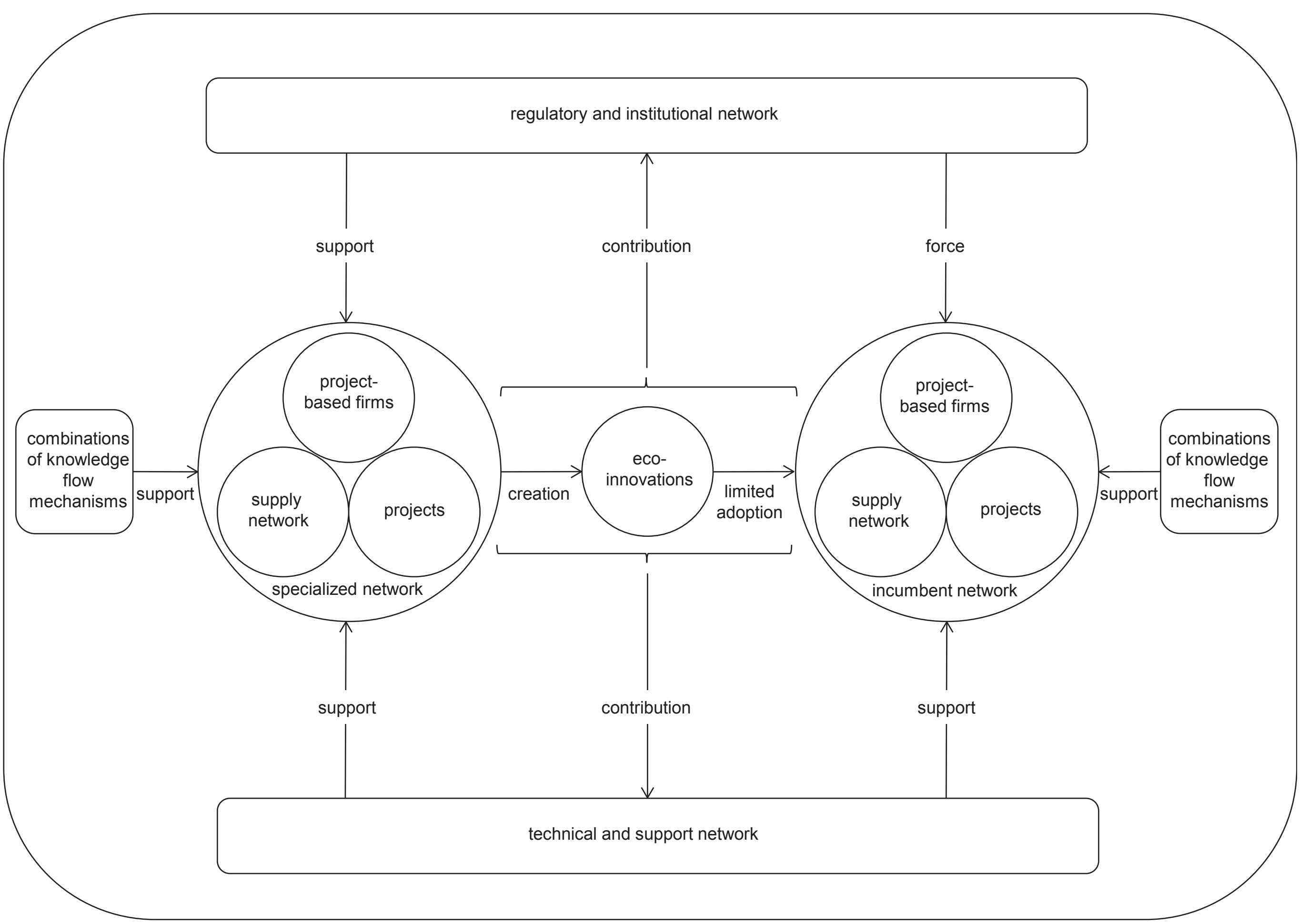

Fig. 5. Sustainable innovation in a project-based industry.

Proposition 3. Creation of eco-innovations in demonstration projects and limited adoption of eco-innovations in regular projects contributes to the development and implementation of eco-innovation prescribing regulation by the regulatory and institutional framework, which heightens the eco-innovation creation and adoption level of a project-based industry as a whole.

Proposition 4. Creation of eco-innovations in demonstration projects and limited adoption of eco-innovations in regular projects contributes to the development and capture of eco-innovative knowledge and know-how by the technical support infrastructure, which heightens the eco-innovation creation and adoption level of a project-based industry as a whole.

5.2. Further research

This is a first study on this subject matter. Its findings and the propositions derived from it can be put to the test in various ways and settings in future research. First, future research can be of a qualitative nature, with multiple case study research designs in sort-like or other project-based industries. These studies can be carried out to test the robustness of this research's findings, and the model and propositions derived from it. Next to this, also research of a more quantitative nature can be carried out. These studies can be situated in the same, and in other project-based industries, and test the propositions that are postulated in this study by means of questionnaires. Furthermore, a promising avenue for future research can be to study the moderators of sustainable innovation in project-based firms and industries that are closely related to knowledge flow mechanisms, like learning, training and education (Ajmal and Helo, 2010; Almeida and Soares, 2014; Eriksson and Leiringer, 2015).

The empirical research indicates that although combinations of knowledge flow mechanisms have a stimulating influence on sustainable innovation, these mechanisms are not a panacea for instant sustainable innovation success. This is in line with research of Harborne and Hendry (2009), and Hendry et al. (2010) that shows that innovative knowledge in sustainability that is developed in demonstration projects tends to exclusively flow to its participating firms and their future specialized projects, barely advances to incumbent firms and standard projects, and does not become general business or 'business as usual'. A question that can be asked in future research is to what degree networks of innovators and traditionalists protect themselves in demonstration projects by keeping others out and letting well-known partners in, and to what degree this impedes large-scale sustainable innovation adoption by, and diffusion to regular projects and business. It opens a direction for further research into the effects of the tendency to either form closed and self-protective networks, so-called 'small worlds' or 'cliques' (Granovetter, 1973; Uzzi and Spiro, 2005; Uzzi et al., 2007), or form open inter-organizational networks and clusters of firms that focus on cooperation, and are using open sustainable innovation strategies to sustainably innovate (Chesbrough, 2003).

5.2.1. Limitations

This study provides new insights but also has several limitations. The paper just presents one single case study in a major, but specific project-based context. The Dutch house-building case contains various idiosyncratic attributes since it represents a fairly closed network, which may reduce the applicability of the findings for, for example, more open networks in which innovating firms behave differently and may seduce or force incumbents to engage in joint sustainably innovative initiatives. In addition, firms in more open networks could exhibit a stronger emphasis on the large-scale exploitation of innovations. This is often the case for example in project-based settings as films, mobile communications and computer games, where many firms tend to cooperate with the aim to produce the next generation of box-office hits, killer applications and best-selling games. It is thus important to assess whether the model and propositions hold or can be refined in alternative sustainably innovative project-based settings, before setting up research to statistically test the proposed positive effect of combinations of knowledge flow mechanisms on project-based sustainable innovation creation and adoption processes.

Another limitation of the research approach adopted in this article is that it concentrates on the influence of six knowledge flow mechanisms on sustainable innovation in a project-based industry. This scope does not really focus on other factors that also have a significant and proven stimulating influence on sustainable innovation adoption and diffusion in project-based industries. It does for example not explicitly consider the possible positive influence of product reliability and quality improvement (Femenías et al., 2018; Haavik et al., 2012; Hagbert and Femenías, 2016; Mlecnik et al., 2010; Van Hal, 2000), cost reductions (Femenías et al., 2018; Hagbert and Femenías, 2016), and increasing opportunities to generate turnover and profit (Hagbert and Femenías, 2016; Van der Heijden, 2013) on the adoption and diffusion of sustainable innovations in the building industry. This implies that to study/stimulate sustainable innovation in building, or in another project-based industry, it is not sufficient to just study/manage knowledge and knowledge flow. Attention to lowering costs, improving and standardizing quality, creating business opportunities, and other aspects are also important.

5.2.2. Contribution to theory

This research's contribution to the emerging theory of innovation in project-based firms (Gann, 2000; Gann and Salter, 1998, 2000), and within this stream the innovation stimulating effect of knowledge flow mechanisms, is that it identifies and specifies the supporting effects of bundles of knowledge flow mechanisms on sustainable innovation creation in specialized demonstration projects, and on limited sustainable innovation adoption in regular projects where incumbent organizations work. It confirms that the knowledge management practices that are needed to support sustainable innovation in project-based firms are not just made of, and driven by a structural component, i.e. physical knowledge storage and distribution systems (e.g. Fong and Choi, 2009; Hanisch et al., 2009; Pemsel and Müller, 2012), but are also based on, and driven by a cultural component, i.e. firms' culture in favor of knowledge development, capture and sharing (e.g. Mueller, 2014; Pemsel et al., 2016; Solli-Sæther et al., 2015), and a learning component, i.e. firms' drive to be a learning organization, for the sake of the organization itself as well for its individual employees (e.g. Almeida and Soares, 2014; Eriksson and Leiringer, 2015; Solli-Sæther et al., 2015).

Another contribution of the research to the development of theory for sustainable innovation in project-based firms and industries is that it found a 'bulkhead' between sustainable innovation creation- and sustainable innovation adoption processes. This bulkhead was difficult to move by the participants in the studied case. Sustainable innovation creation had a small-scale, specialized character, and was open for a select group of front-running firms in demonstration projects. Sustainable innovation adoption had a large-scale, more universal character, and aimed at the major group of incumbent project-based firms in the industry. The small network of specialists worked *hard* for the demonstration projects but *hardly* for the dissemination of the results to the large majority in regular projects, and in the meantime the incumbent firms remained focused on their own proven, traditional practices, without putting extra efforts in sustainable innovation. This resulted in a relatively large reservoir of barely applied sustainable innovations. The case study showed that regulatory force was needed to induce a large-scale application of a relatively small fraction of options from the sustainable innovation reservoir. This corresponds with research by Beerepoot and Beerepoot (2007) in the Dutch construction industry, who also found regulatory force to be a necessary condition for large-scale adoption of energy efficiency innovations.

5.2.3. Contribution to practice

With regard to practice, several lessons can be learnt from the retrospectively studied Dutch case. The empirical findings confirm that a systematic innovation approach produces results. The results show that a systematic approach, concentrating on all elements and relationships in a project-based industry, and supported by various knowledge flow mechanisms, can at the same time create the newest sustainable innovations in demonstration projects, as well as adopt several of these to be applied on a large scale in regular projects. Today's house-building policy and business can invest in such a systematic approach. For other project-based industries, these lessons can be of value too, and worthwhile to take into consideration.

In general, the contribution of this research to practice, i.e. policy and business, is that it clarifies how and why sustainable innovations that are developed in demonstration projects are (not) adopted by incumbent project-based firms in regular projects. In practical terms the research implies that governments, policy makers and firm managers not only need to work on, in, and for sustainable innovation creating demonstration projects, but also need to set up initiatives and programs that aim at a large-scale adoption of options from the sustainable innovation reservoir in day-to-day projects. Alternatively, to support a widespread application of newly developed sustainable innovations and thus stimulate sustainable innovation adoption and diffusion, policy officials could decide to put large incumbent commercial organizations instead of small niche players in the driver's seat when stimulating sustainable demonstration projects, and by working with firms with more magnitude, aim directly at the development and exploitation of sustainable innovations on a larger, more industry-wide scale. Another main lesson that can be learnt is that practitioners could intensify the management of knowledge flow in and around projects and the project-based constellation. Knowledge, and the flow of it between all participants stimulate sustainable innovation creation as well as sustainable innovation adoption. Practitioners in policy and business can thus decide to:

- Create meta-routines by attracting and retaining professionals who have proven experience with sustainable innovation.
- Build communities of reflective practitioners by establishing and sustaining contacts and working relationships with academic consultants and researchers to further discuss, experience, articulate, and feel what can be learnt from sustainably innovative projects.
- Cross learning boundaries by means of letting their specialists, who work in the sustainably innovative demonstration projects, to also take part in other, less sustainably specialized demonstration projects and work settings, and with colleagues with less knowledge about sustainability.
- Stimulate business-led learning and integrate inside and outside human knowledge bases by developing a strategy with procedures, norms and cultural components that describe what is expected of their employees in terms of learning to sustainably innovate and contributing to organizational learning with regard to this.
- Visualize and codify knowledge by means of developing and maintaining databases, practical examples, documents and other knowledge capturing instruments to build a tangible reservoir of artifacts that represent their knowledge, which can be used, re-used, and combined in the projects to come.

6. Conclusion

In conclusion, this research studied the effect of knowledge flow mechanisms on sustainable innovation in a project-based industry. Based on a retrospective study of 20 years of sustainable innovation in the Dutch house-building industry (1989–2008) it finds that combinations of knowledge flow mechanisms support sustainable innovation creation as well as a limited adoption of these sustainable innovations. Sustainable innovations are created, tested and improved in small-scale demonstration projects; and just a small fraction of these sustainable innovations is adopted by large incumbent firms and their clients in regular projects. Considering a growing and worldwide call for more standardization of sustainable innovations developed in demonstration projects, it is worthwhile to both scientifically study the (im)perfections of this process further, as well as to increase, improve and intensify its effective use in practice.

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