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Knowledge transfer across projects: Codification in creative, high-tech and engineering industries

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Abstract

The use of codification to support knowledge transfer across projects has been explored in several recent, and mostly qualitative, studies. Building on that research, this article puts forward hypotheses about the antecedents of knowledge codification, and tests them on a sample of 540 inter-organizational projects carried out in the creative, high-tech and engineering industries. We find that the presence of strong industry norms governing the division of labour discourages knowledge transfer through codification, as suggested by the existing qualitative studies. The presence of a system integrator plays an important role in driving the use of codification for knowledge transfer, to some extent embodying an organizational memory in volatile project environments. Finally, the level of use of administrative control in the project is a robust predictor of attempts to transfer knowledge via codification. When these antecedents are taken into account, the novelty of products and services plays a smaller role than previously found in determining the use of codification.

Keywords

codification, knowledge transfer, system integration, project-based organizing, networks

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Introduction

Forgetfulness is often seen as the hallmark of project operations. Because projects are temporary enterprises with specific objectives and are organizationally distinct from other projects and the organizations generating them, accumulating and sedimenting learning is more difficult than in organizations characterized by continuous operations (Gann and Salter, 1998; Scarbrough et al., 2004a, 2004b). The forgetfulness of projects is both a blessing and a curse (cf. Hobday, 2000). Many things are started anew for each project, liberating them from the 'shadow of the past' and facilitating adaptation to the specificities of changing clients, places and products. This forgetting makes projects the organizational device of choice for the pursuit of novelty and is a feature appreciated in creative industries, such as advertising or film making, in which the discontinuity of projects is valued as a means to respond to the creative imperative of 'freshness'. In these industries, firms intentionally and frequently change the composition of teams in order to ensure novelty in the product (e.g. Grabher, 2002). In other industries, such as those involved in the production of complex investment goods (e.g. construction or engineering design), the discontinuity of projects that is instead often seen as problematic (Gann and Salter, 1998; Scarbrough et al., 2004b). Many managers, particularly in industries that rely on complex technologies, believe that there is much to gain from improving the transfer of knowledge across projects (Williams, 2008).

Despite the different emphasis placed by industries on the benefits of and drawbacks to forgetting, balancing the need for creativity unconstrained by the past, with the benefits of learning from experience is paramount for project-based organizations in all industries. On the one hand, there is an extensive body of research in strategy and organization showing that experiential learning is of fundamental importance for the development of the organizational capabilities underpinning competitive advantage (e.g. Gavetti and Levinthal, 2000; Nelson and Winter, 1982; Pisano, 2000) and to provide a basis for adaptation to environmental changes (Levinthal, 1991; Levinthal and Rerup, 2006). Relying on projects may bring firms too far in escaping 'competency traps' (Levitt and March, 1988) and 'core rigidities' (Leonard-Barton, 1992), making it difficult for them to develop reliable competencies. For example, even in the advertising business, it is important for account holders to have a solid understanding of their clients, their clients' business and their ways of working, understanding that is developed through experience and needs to be preserved and maintained (cf. Grabher, 2002). In an attempt to deal with the problems caused by forgetting in projects, many firms have invested in organizational processes and information technology to support the transfer of learning across projects. On the other hand, even in industries, such as those involved in the production of investment goods, in which the cumulative nature of competencies is acknowledged as an important source of competitive advantage, firms need to innovate in order to remain competitive, and therefore need to preserve creativity by guaranteeing that projects are free of the 'shadow of the past' (Brady and Hobday, 2011; Engwall, 2003; Leonard-Barton, 1992).

For both theoretical and practical reasons, therefore, the topic of how learning can be transferred across projects without hindering adaptability and creativity is attracting considerable research attention. Most studies in this area are conceptual or qualitative and help to clarify the reasons why the transfer and accumulation of learning in project environments is so challenging (Gann and Salter, 1998; Hobday, 2000; Keegan and Turner, 2001; Scarbrough et al., 2004a, 2004b). Previous research has examined the encoding of learning into routines (Davies and Brady, 2000); the differences in learning practices across industries (Grabher, 2004); and the role played by social networks (Christopherson, 2002; DeFillippi and Arthur, 1998; Grabher and Ibert, 2005) and communities of reflective practitioners (Ayas and Zeniuk, 2001; Garrick and Clegg, 2001; Lindkvist, 2011). This article builds on the findings from this extensive body of qualitative research and develops a contingency view of forgetting in projects and how this can be rectified—in a way similar to what has already been attempted in relation to projects in general (Shenhar and Dvir, 1996; Söderlund, 2004). We do so by focusing on the extent to which the codification of knowledge is used to support knowledge transfer across projects in different industries. Knowledge codification, understood as the inscription of knowledge into text, drawings, templates, models and similar media, often plays a central role in the strategies devised by firms to preserve and transfer learning. Because of the vastly augmented scope of codification afforded by information technology (IT), and the relative lack of success of many IT-supported codification efforts, the issue of codification has been extensively investigated by scholars (e.g. Balcony et al., 2007; Hall, 2006; Swan et al., 1999). In the present study, we test the relevance of the antecedents to codification in a sample of successful inter-organizational projects in three project-based industries—creative, high-tech, engineering—shown by qualitative research to have different learning architectures. We find that strong industry norms dictating the division of labour, the presence of a system integrator, and firm specific factors such as the tendency to use formal administrative tools, influence the decision to transfer learning across projects via codification. In contrast to previous studies, we find that product novelty has little influence on the decision of firms to use codification, once these other factors are taken into account. The article is organized as follows. Section 'Knowledge transfer through codification in project environments' reviews the debate on the role of codification in the transfer of knowledge in project environments. Based on this, we develop hypotheses on the antecedents to the transfer of knowledge by codification. Section 'Data and method' presents the data and method used to test our model. Section 'Variables' presents the variables and Section 'Results' discusses the results. We close with conclusions in Section 'Conclusions' and an outlook on further research directions in Section 'Directions for further research'.

Knowledge transfer through codification in project environments

Knowledge codification is the inscription of knowledge in symbolic forms. At minimum, it includes the textual and mathematical representations needed to express knowledge in the form of declarative statements and consistent propositions (cf. Cowan et al., 2000), but can also include graphical modelling and newer forms of representation such as video (Foray and Steinmueller, 2003). The output of knowledge codification efforts can include 'lessons learnt' reports and databases, best practice portfolios, handbooks and design templates. The question of whether and how codification helps to transfer learning has been at the centre of a lively debate that developed out of the information technology revolution and the seemingly limitless opportunities offered by this technology to spread knowledge in codified form. The debate falls broadly within two schools of thought based on general positions on the effects of the 'contextuality' of knowledge (Cohendet and Steinmueller, 2000). Scholars of the first school argue that in most cases information about the appropriate context of use for the knowledge being transferred can also be codified, for instance in the form of conditional statements. This allows the incorporation of information about the context into the knowledge to be transferred. Specifying the context, however, incurs costs, which in turn influence the actual degree of codification: codification will be extensive in contexts that are easy to specify and less so in contexts that are difficult to specify. Scholars subscribing to the second school of thought, however, maintain that the meaning of codified knowledge is embedded in its social context and therefore cannot itself be codified (e.g. Amin and Cohendet, 2003; Styhre, 2009). In this case, in order for codification to be useful for transferring knowledge, there must be either some sort of continuity in the social contexts of senders and receivers, or these contexts must be reproducible to some extent. There is a similar divide in the related literature on knowledge management (Schultze and Leidner, 2002; Swan and Scarbrough, 2001). Investigations on the benefits of knowledge codification efforts, especially when supported by information and communication technology (ICT), generally find that, despite the significant investment, employees are reluctant to use them (Newell et al., 2006; Prencipe and Tell, 2001; Rajan et al., 1999; Swan et al., 2010). It is only recently that research has begun to uncover the cultural and organizational conditions that can make codification supported by information technology beneficial to the performance of firms (Vaccaro et al., 2010).

The polarization of the debate, in favour and against the usefulness of codification, has led to the view that codification (whether or not supported by ICT) is a substitute to knowledge transfer through personal interaction (e.g. Greiner et al., 2007; Hansen et al., 1999). Several studies investigate when a 'social' rather than a 'codified' approach to knowledge transfer is appropriate. Researchers have focused on the degree of innovativeness or customization of the project output. Increasing innovativeness or customization seems to reduce the scope for reusing knowledge due to substantial differences in the contexts of generation and use of this knowledge. The task of locating, assessing and adapting knowledge then becomes difficult (Carlile and Rebentisch, 2003). Codified knowledge typically is less malleable than knowledge exchanged through personal interactions in which the individuals involved have the opportunity to renegotiate meanings (Wenger, 1998) and jointly to modify the knowledge (e.g. Carlile, 2004). Therefore, in the case of more innovative or customized products, firms will find the transfer of knowledge based primarily on codification less useful. These findings are generally supported by research on project-based contexts, for example management accounting and consulting firms (Morris and Empson, 1998); firms engaged in the production of complex products and systems (Prencipe and Tell, 2001); biotechnology firms (Garcia-Muina et al., 2009); and consulting firms (Hansen et al., 1999). These studies find that firms providing more standardized products use comparatively more codified means of knowledge transfer, while customized and creative products emerge from multiple direct personal contacts. In terms of performance, Haas and Hansen's (2005) quantitative study of a management consultancy firm shows that the probability that a sales team will win a client contract increases with the team's use of codified material only in the case of standardized projects and inexperienced teams. In a follow-up study, Haas and Hansen (2007) found that use of codified knowledge enables sales teams to save time, but decreases quality of the proposal made to the client. On the basis of the findings in the literature, we posit that:

Hypothesis 1: The probability that codification is used to support the transfer of learning from project to project decreases with the innovativeness of product.

While the studies discussed above are consistent in their findings for different industries, the industry dimension warrants closer examination. Industries are characterized by significant variation in the sources and modes of their innovation, in the structure and stability of their knowledge bases, and in their institutional arrangements (Malerba, 2002; Nelson, 2003; Pavitt, 1984). These differences most likely impact on the extent to which firms use codified knowledge, especially vis-à-vis strategies based on personal interaction. A key aspect here is the presence of industry norms, understood as expected modes of behaviour that are considered socially acceptable, that clearly specify the division of labour among actors, thereby creating a stable structure of roles and predictable actions that facilitate coordination (Bechky, 2006; Grabher, 2002; Meyerson et al., 1996; Sydow and Staber, 2002). In this context of established norms, the codification of knowledge about how to perform a role and how to interface with others (that is procedural knowledge), is less necessary because people learn how to coordinate with others through socialization.[1] Relatively stable role structures are often associated with clear professional identities, which have an impact on the way knowledge about substantive technical issues, as opposed to knowledge about how to interface with other professionals, is managed. There is an extensive literature on how knowledge transfer related to substantive technical issues tends to take place through informal (and different types of) professional networks (e.g., Allen, 1977; Grabher, 2002, 2004; Smet, 1992). Emergent industries often exhibit patterns that are significantly different from the traditional 'managed project' (e.g. as usually practised in the construction industry). In a study of the organization of project work in the new media industry, Heydebrand and Miron (2002) find that projects are 'self-organized'. In self-organized projects, the project team's knowledge does not correspond to a preordained division of labour, and team coordination does not follow traditional managerial practice. Work phases are organized less sequentially than in more mature industries, and may overlap or occur simultaneously, in self-coordinated teams. The flexibility between project conception and execution corresponds to 'immediatism', and the renegotiation of means and ends during project performance (Girard and Stark, 2002). The use of codification to store and transfer knowledge across projects therefore is likely to depend on the extent to which industry norms about appropriate behaviour and role structure exist. Therefore, we can posit the following:

Hypothesis 2: The probability that codification is used to support the transfer of learning from project to project decreases with the strength of industry norms specifying the division of labour among actors.

Projects have proliferated in recent years because they are the organizational form of choice for new product development. As the breadth and depth of the knowledge bases involved in product development increase (Granstrand et al., 1997) firms are resorting more to inter-organizational collaboration, which that has given rise to innovation networks. These networks are based on contractual relationships and typically are characterized by low density and the presence of a high centrality 'hub'. These hub firms play leadership roles and orchestrate the activities within the network (Dhanaraj and Parkhe, 2006). In industries characterized by complex products consisting of highly interdependent components, such as computers, jet engines, or cars, central actors play the role of 'systems integrators'. Similarly, industries such as the construction business, traditionally based on a project organization, rely on inter-organizational networks built around a 'general contractor' who performs the role of system integrator (cf. Cacciatori and Jacobides, 2005). In addition to coordinating activities, systems integrators organize the integration of the knowledge that is distributed among network members (Chataway et al., 2007; Orsenigo et al., 2001; Powell et al., 2005) by maintaining in-house competencies in a wider range of areas than required by their productive activities (Brusoni et al., 2001). Research on system integrators and their knowledge integrating activities so far has focused on their competencies to manage substantive technological knowledge related to the product. However, integrators are also the locus of the development and accumulation of the complex organizational competency of coordination of the efforts of a wide range of diverse partners (cf. Dhanaraj and Parkhe, 2006). That is, system integrators or general contractors need to accumulate procedural knowledge, understood as knowledge about how to run large multi-projects effectively (project capabilities in the sense of Davies and Brady, 2000). Procedural knowledge about how to sustain multi-connectivity might contribute to 'cumulative advantage' making hubs increasingly attractive to other project collaborators (e.g. Powell et al., 2005). The procedural knowledge about how to orchestrate a large network ('learning by repetition' in the sense of Davies and Brady, 2000) might be more easily formalized in portfolios than the substantive knowledge generated in projects, particularly if the same process can be used to generate different individual project outcomes (see also Newell et al., 2006). For instance, in a creative industry such as feature film production, the movie production process is relatively well established and stable despite the diverse content of each film (Bechky, 2006). There are robust processes, supported by strong industry norms that regulate the division of labour and the interactions of different actors in such projects. In industries with less developed institutional regulation, the presence of a system integrator can facilitate the transfer of learning through similar mechanisms. System integrators typically have stronger contractual and technical authority than other project partners (Brusoni, 2005) and can maintain a certain stability in processes across projects. Therefore, we posit that:

> *Hypothesis 3: The presence of a system integrator increases the probability that codification will be employed in order to sustain the transfer of learning from project to project.*

So far we have discussed the antecedents to knowledge codification connected to industry features, and in particular the way that the division of labour is regulated. However, firms in the same industry may differ significantly in their organizational arrangements and culture. For instance, Swan et al. (2010) find that the type of matrix structures employed by project based organizations influence their ability to learn from project to project, with organizations employing more project-oriented structures performing better. Also the level of firms' administrative governance may differ, i.e. the extent to which the rules governing the behaviour of organizational members, including the behaviours associated with their roles, are prescribed explicitly—typically in written procedures, regulations and job descriptions (Pugh et al., 1963; Scott and Davis, 2007). Administrative regulation is associated with the rise of the modern 'rational' organization, and helps to decouple roles from the individuals occupying them, and by providing an abstract representation of the organization, aids its conscious manipulation (cf. Scott and Davis, 2007). This process of organizational modernization has recently gained additional momentum in performance-based organizations (PBOs) with the introduction of project management offices (Aubry et al., 2007; Dai and Wells, 2004; Hobbs et al., 2009). This organizational innovation helps to transform accumulated knowledge from past project experiences into project management routines and procedures (see, for example, Julian, 2008). The degree of administrative regulation has been shown to vary substantially across differently sized organizations and in similarly sized organizations it may depend on environmental stability (Donaldson, 2001) which can vary considerably among niches in the same industry. Finally, by making role expectations explicit, administrative regulation clarifies and helps to enforce accountability for incumbents. Thus organizations operating in high-risk environments such as nuclear power plants or aviation companies are characterized by higher levels of administrative regulation (Perrow, 1974). While it entails a form of codification, administrative regulation typically is developed with the intent of controlling the behaviour of organizational members. It is primarily normative and emphasizes conformity over learning. However, firms that are more bureaucratic and use codification as a way to control behaviour are more likely to favour knowledge codification to transfer learning from project to project. In particular, procedural knowledge

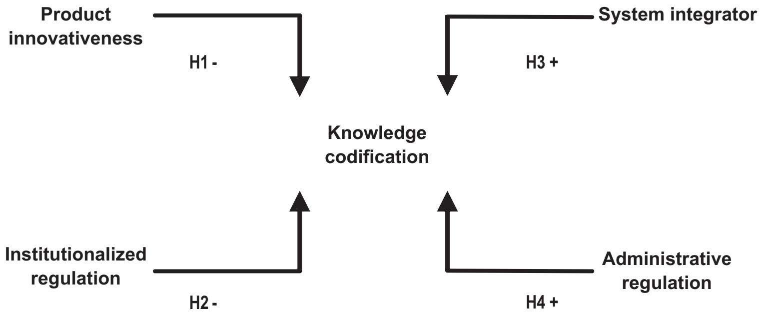

Figure 1. Antecedents to the use of codification in across-project knowledge transfer.

about how to run a project is likely to be incorporated into procedures and administrative tools. Therefore, we posit that:

> *Hypothesis 4: The probability that codification is used to support the transfer of learning from project to project increases with the use of administrative regulation.*

Our hypotheses are summarized in Figure 1.

Data and method

The data for this article are from a survey carried out within an international collaborative research project involving several European universities.[2] The project's database contains detailed information on 540 completed projects involving three or more partners. Data were gathered between February 2006 and January 2007 through a questionnaire survey that targeted projects in the engineering, creative and high-tech industries in Canada, Denmark, France, Germany, Italy and the US.

These industries were chosen because they are characterized by different institutional arrangements for sustaining learning and innovation, and by different levels of product innovativeness. For example, creative industries differ from engineering and high-tech industries because of their greater reliance on symbolic innovation, produced through a disruptive learning regime, rather than technological innovation produced through a cumulative regime (see e.g. Aage and Belussi, 2008; Cappetta et al., 2006; Grabher, 2004; Nelson, 2003). While engineering and high-tech industries both rely on technological knowledge that typically evolves cumulatively, engineering industries as defined in this article operate on the basis of mature technologies where technical change is incremental, while high-tech industries work with emerging technologies and therefore are subject to periods of technological upheaval and radical change. Engineering industries are involved in the production of investment goods, ranging from machine tools to industrial plants, and draw on more stable technologies than high-tech industries such as biotech, semiconductors and software. Further, the spatial complexity and the coordination needs of engineering projects are typically higher than in high-tech industries (Shenhar and Dvir, 1996).

As lists of projects are not publicly available, we surveyed firms that perform projects in the selected industries. Since projects can be accessed through any of their main partners, we used convenience sampling to select firms, based on national statistical office data (NACE industry

Table 1. Overview of the sample.

Location	Firms contacted	Projects	Response rate
Canada (Montreal)	500	50	10.0%
Denmark	443	101	22.8%
France (Sophia Antipolis)	114	18	15.8%
Germany	1328	228	17.2%
Italy	584	93	15.9%
USA (Silicon Valley)	155	50	32.3%
Total sample	**3.124**	**540**	**17.3%**

Table 2. Projects per industry and country.

	Creative industry	Engineering industry	High-tech industry	Total
Canada (Montreal)	3	3	44	50
Denmark	46	21	34	101
France (Sophia Antipolis)	0	2	16	18
Germany	74	135	19	228
Italy	1	85	7	93
USA (Silicon Valley)	0	0	50	50
Total	124	246	170	540

classification codes or national statistical office listings) and on industry listings when national statistical office data were insufficiently detailed or unavailable. Information from both national statistical office and industry association listings were used to select firms in the creative industries—which included firms operating in feature film production, advertising, book and magazine publishing, events, interior and fashion design, operation of arts facilities, music publishing and theatre presentations. Firms operating in the engineering industries were accessed through national industry associations. The engineering industries in our sample include machine tools, industrial and agricultural machinery, industrial and chemical plant and aerospace. Firms in the high-tech industries (software, semiconductors, biotech and telecommunication) were identified through industry listings of the high-tech clusters in Silicon Valley and Sophia Antipolis. We identified each industry in at least two countries in order to control for country-specific institutional settings. Table 1 provides a description of the sample in terms of location and response rate. Table 2 provides the industry distribution of the sample.

We enquired about up to three projects for each firm. Industry country was on the basis of the location of the firms contacted not the location of their headquarters. Firms were contacted by phone via their publicly available contact information. The purpose of the survey was explained and we then requested to be put through or given contacts of people directly involved in the management of projects. This process continued until we reached a person with in-depth knowledge of individual projects. Most interviewees were in managerial positions, which ensured a broad overview of the project and specific knowledge about its practices derived from direct involvement.

In order to limit recall bias, interviewees were asked to choose a project completed within the previous three years. We also asked interviewees to focus on projects that: (1) were successful; (2) involved different independent legal entities as partners (either organizations or individuals); and (3) in which the respondent organization was a 'key partner'.

Project success was defined in terms of (1) effectiveness (it produced a valuable output) and (2) economic viability. These criteria were very broad and include projects that did not meet their objectives in terms of expected output, cost and delivery date, but were of value for at least one of the organizations involved. This definition of project success strikes a balance between very short-term and limited measures of success, and too imprecise criteria. The problems involved in measuring project performance have been discussed extensively in the literature (Atkinson, 1999; Atkinson et al., 2006; Fincham, 2002; Flyvbjerg et al., 2003) and are among the main reasons for the small number of quantitative studies in this area. Traditional measures of performance, i.e. adherence to schedule and budget, impose several limitations. First, success in these measures might reflect the organization's ability or willingness to make reliable time and budget estimations, rather than measuring the intrinsic features of the project. Project bidders may deliberately underestimate budget and time in order to win the project, on the basis that they can renegotiate later. Second, such measures favour more predictable and routine projects. Third, they focus on short-term and direct results whereas a project that goes over budget and over time may produce profits in the long term and in indirect ways (e.g. by building reputation). This definition of performance also neglects the fact that firms typically manage portfolios, in which a certain share of projects may not yield immediate returns but will produce significant benefits in other areas (e.g. an unprofitable project may establish a valuable client relationship). Fourth, data on project performance in terms of cost and time are typically sensitive and difficult to collect. More qualitative measures of success, such as the generation of new knowledge or long-term profitability, tend to be too subjective and open to the maneuverings of organizational politics. Our choice of a broad and relatively undemanding definition of success provides us with an overview of the 'normal' practice related to codification in an industry, without the need to probe the issue of what is project success. It also does not delve into the extent to which codification influences project performance, which is beyond the scope of this article.

'Key partner' is defined as a participant organization that ranks high for the amount, quality and indispensable nature of the resources provided for the viability of the project.

In order to eliminate biases due to missing data, the database was imputed by latent class analysis (Van Ginkel, 2007; Vermunt et al., 2007) using Latent GOLD 4.0 (Vermunt and Magidson, 2005).[3]

Variables

Dependent variable

To measure *use of codification*, our dependent variable, interviewees were asked whether 'the project incorporated lessons learnt or solutions developed in previous projects which were formally stored in portfolios of best practice, databases, manuals and reports'. The dependent variable was coded as a dummy, with value 1 if the interviewee checked the box. In order to check the stability of knowledge transfer over time, we also asked interviewees, in a separate question, whether lessons learnt or solutions developed in the project were codified for use in later project. Correlation between the two answers is 0.543 with significance at the 0.01 level.

Independent variables

Degree of product innovativeness was measured on a five-point scale based on the question of whether 'the product or service developed in the projects was: a variation of an existing product or service; a new generation of an existing product or service line; a new product or service line for the partners; a new-to-the-industry product or service line; a new-to-the-world product or service line'. Since degree of product innovativeness is an ordinal level variable, in the regressions we used separate dummies for each level of innovativeness. We tracked the presence of a *system integrator* by asking whether the project was based on a set of contracts with one central contracting party, as opposed to multi-party contracts. *Degree of administrative regulation* was assessed by asking about the extent of use in the relationship between the three key partners, of extra-contractual but written regulation exemplified by the use of internal charts, procedures and job descriptions of the type used for internal organization. In order to include all aspects of the division of labour, and not just substantive tasks, interviewees were asked about the use of administrative regulation in relation to 'property rights over assets and outputs; decision and control rights; definition of tasks; definition of duration; separation procedures; warranties and indemnities; prices, fees and royalties' (cf. Young, 2008). Responses were scored on a four-point Likert scale: (1) no specification; (2) general principles; (3) extensive specification; (4) complete specification.

The degree of informal, *institutionalized regulation through norms, habits or practices of the industry* was measured by asking interviewees about the relative importance of industry norms, habits and practices vis-à-vis written contracts or administrative regulation, two alternatives for standardizing behaviour (see Scott and Davis, 2007). The same Likert scale and items were used for scoring degree of administrative regulation.

Responses relating to each of the seven types of objects for regulation are highly correlated in relation to both administrative and institutionalized regulation (see Tables in Appendices 2 and 3). We created an average degree of administrative regulation by aggregating the responses across the seven objects and normalizing the result. We did the same for institutionalized regulation.

Control variables

We introduced the following control variables.

Complexity of knowledge, in terms of the number of different disciplines involved in the project. A high level of knowledge complexity makes effective codification of project learning more difficult because it requires the integrated effort of a larger number of people. Also, the likelihood of solutions being easily reused across projects is small because different disciplines interact in complex ways. High levels of knowledge complexity discourage the use of codification to transfer learning. We gauged the degree of knowledge complexity through the following question: 'Projects often draw upon many distinct and complex bodies of knowledge. One way to measure the knowledge complexity of a project is to ask how many of the activities involved could be carried out by an individual. Assuming 100 to be the entire range of activities included in the project, what is the largest share of the full range of activities that a single person would have been fully qualified to carry out (irrespective of acceptable work-load)? (For instance, in the development of a new space shuttle, it is likely that the percentage of activities that a person would be fully qualified to carry out would be close to zero. Conversely, an architect is likely to be fully qualified to carry out 100 percent of the activities connected with the design of a small house)'. Knowledge complexity decreases as the percentage of activities that can be carried out by one individual increases.

Face-to-face communication was included to take into account that, in the case of numerous meetings for coordination purposes, knowledge and expertise will also be transferred. Face-to-face communication was measured through the question: 'How much of the time spent for communication among the three key partners was in face-to-face meetings?' indicated as a percentage.

Industry dummies were introduced to check for sector differences, with engineering as the reference industry. Industry dummies take account of differences in the institutional structure of industries not incorporated in our explanatory variables or other controls.

Table 3. Variables used in the analysis.

	Variable	Parameter value	Explanation
Dependent variable	knowledge codification (databases, portfolios, manuals & reports)	*1* *0*	*utilized* *not utilized*
Independent variables	*dummies* for product innovativeness		
	(1) new generation of existing product	*1* *0*	*yes* *no*
	(2) new-to-the-partners	*1* *0*	*yes* *no*
	(3) new-to-the-industry	*1* *0*	*yes* *no*
	(4) new-to-the-world	*1* *0*	*yes* *no*
	system integrator	*1* *0*	*central party contract* *multi party contract*
	administrative regulation (normalized)	*0 – 1*	*ranging from 0 = no specifications to 1 = complete specification*
	institutionalized regulation (normalized)	*0 – 1*	*ranging from 0 = no specifications to 1 = complete specification*
Control variables	knowledge complexity	*0 – 100*	*% of activities that could have been accomplished by a single person*
	face to face communication	*0 – 100*	*% of activities that required face-to-face communication*
	dummies for industry		
	(1) high-tech industries	*1* *0*	*high-tech project* *non high-tech project*
	(2) creative industries	*1* *0*	*creative project* *non creative project*

Results

Because the dependent variable is dichotomous, we use a binary logistic regression (see Agresti, 2002). The results of the analysis are presented in Table 4. The pseudo *r*-square of this model is 0.118 (see Nagelkerke, 1991). The classification table shows that the inclusion of the explanatory variables increases the proportion of the model's correctly predicted results by 9.9 percent. A Hosmer Lemeshow test provides a chi-square of 8.960 with a significance of 0.346 indicating the good quality of the model in terms of goodness of fit.

Among the explanatory variables, only product innovativeness does not contribute significantly. Hypothesis 1 is thus not supported. Hypotheses 2, 3 and 4 are supported, and especially the hypothesis that project regulation by institutionalized industry-wide norms, habits and practices is negatively related to knowledge transfer across inter-firm projects through codification (H2). The likelihood that codification is used to transfer learning across projects decreases by slightly

Table 4. Regression results[a].

		Descriptive statistics		Logistic regression		
		Mean	Standard deviation	Regression coefficient	Standard deviation	Odds ratio
Dependent variable	knowledge codification	.49	.50			
Included explanatory variables	*dummies for innovativeness*[b]					
	(1) new generation of existing product	.33	.47	–.288	.199	.750
	(2) new product for the partners	.19	.40	–.069	.238	.934
	(3) new to the industry	.16	.36	.010	.264	1.011
	(4) new to the world	.09	.28	–.183	.339	.833
	institutionalized regulation	.49	.21	–1.042	.464	.353***
	system integrator	.44	.50	.485	.190	1.625***
	administrative regulation	.56	.22	1.257	.445	3.514***
Control variables	knowledge complexity	31.54	24.90	–.009	.004	.991***
	face-to-face communication	27.87	22.63	–.010	.004	.990***
	dummies for industry[c]					
	(1) high-tech	.20	.40	.583	.222	1.792***
	(2) creative	.23	.42	–.497	.245	.609***
	constant			.178	.383	1.195
	N	515				
	pseudo r_2	.118				
	chi2	47.740***				

Note: Significances are flagged on a * .1 level, ** .05 level and on a *** .01 level.
[a]The modelling was performed with SPSS 17.0. Correlation tables for the explanatory variables can be found in the Appendix 1.
[b]*A variation of an existing product* serves as reference category.
[c]*Engineering Industries* serves as a reference category.

over 60 percent if the project is regulated by institutionalized means. Our hypothesis that the presence of a system integrator increases the probability of implementation of knowledge management strategy based on codification (H3) is supported, with the likelihood of using codification to support the transfer of knowledge across projects increasing by about 60 percent. Our hypothesis of a positive relationship between administrative regulation and the employment of codification is also strongly supported (H4). The likelihood of codification being used increases by 250 percent if internal charts and job descriptions (administrative regulation) are used.

Among the control variables, complexity of knowledge is significant but has a weak effect, showing a slight negative relation to the implementation of codification strategies. Face-to-face communication has weak negative effects on the implementation of knowledge transfer through codification, which confirms our assumption that when face to face meetings are involved in project coordination, some knowledge transfer takes place, which reduces the likelihood of reliance on codified knowledge transfer.

Among the industry dummies, differences are strong and significant. High-tech projects tend to use codification more frequently than creative projects.

We also conducted some further checks. Level of innovation does not correlate significantly with the use of administrative tools or industry norms. Uncertainty, measured by the availability of feedback on performance during the projects and the extent of revisions to activities during the project, does not significantly influence the knowledge transfer strategy. Geographical dispersion of the project (see Shenhar and Dvir, 1996), and length (years of cooperation among the key partners) or depth of the relationship (number of projects performed in collaboration with key partners) (cf. Argote et al., 2003; Uzzi and Lancaster, 2003) exert significant influence on the type of knowledge transfer mechanism employed in inter-firm projects. We controlled also for project size effects because the use of formalized administrative control has been associated with size and geographical scope (Shenhar and Dvir, 1996). The number of partners, number of people involved, and project duration and budget have no significant influence on the knowledge transfer strategy. We can conclude therefore that the model is robust to uncertainty, geography and size, and to various dimensions of the relationships among project partners. We also introduced dummies for the location of firms to control for the influence of geography but the robustness checks using location dummies show that geography does not impact systematically on knowledge codification practices.

Differences across industries

Our analysis of the knowledge transfer mechanisms across industries shows that engineering and high-tech industries use codification as a means to transfer learning across projects more frequently than creative industries. Only 36.4 percent of creative projects incorporated learning transferred through codification, compared to 59.0 percent of high-tech and 49.0 percent of engineering projects. We ran separate logistic regressions for each industry to explore the differences in the use of codification to support knowledge transfer across industries in more depth. The results in Table 5 indicate that the antecedents identified in the literature are more accurate predictors of the use of codification strategies in technologically complex settings (high-tech or not) than in creative industries, where the choice to use codification seems to be linked exclusively to the propensity for administrative regulation, measured by the extent of use of internal charts, procedures and job descriptions.

Table 5. Logistic regressions for individual industries.

		Descriptive statistics for complete database		Logistic regression at industry level		
		Mean	Standard deviation	Creative Odds ratio[a]	Engineering Odds ratio	High-tech Odds ratio
Dependent variable	knowledge codification	.52	.50			
Included explanatory variables	*dummies for innovativeness*[b]					
	(1) new generation of existing product	.33	.47		(–) .483**	
	(2) new product for the partners	.19	.40			
	(3) new to the industry	.16	.36			
	(4) new to the world	.09	.28			
	institutionalized regulation	.49	.21			
	system integrator	.44	.50		(+) 1.761**	(+) 2.461**
	administrative regulation	.56	.22	(+) 5.708*		(+) 14.756***
Control variables	knowledge complexity	31.54	24.90		(–) .983***	
	face-to-face communication	27.87	22.63		(–) .982***	
	constant			(–) .414	(+) 3.514**	(–) .457
	N	515		118	241	156
	pseudo r_2			.069	.177	.124
	chi2			6.098	34.362***	15.056*

[a](+) and (–) specify the direction of influence as indicated by the regression coefficient.
[b]*A variation of an existing product* serves as reference category.

The model works well for engineering industries, explaining almost 18 percent of use of codification to support knowledge transfer. Engineering is the only industry where there is limited support for Hypothesis 1, i.e. that product innovativeness reduces the chance of knowledge transfer via codification. The complexity of the knowledge being transferred also limits the use of codification. Interestingly, use of codification is driven by the presence of a system integrator, but industry norms and administrative regulation are not significant.

For high-tech industries, the model shows a pseudo *r*-square of 12.4 percent, with the administrative regulation level being the strongest driver of codification, followed by presence of a system integrator. These results can be explained by the different knowledge accumulation regimes in high-tech industries. Industries based on technically complex bodies of knowledge tend to operate within a regime of cumulative learning in which significant overall progress and improvement are derived from the cumulative effect of relatively incremental innovations. For instance, in software projects, the reuse of code modules is an effective way to transfer knowledge across projects, and is used as a basis for subsequent innovation and customization. Creative industries tend to operate within a more disruptive learning regime, in which change and freshness are paramount (Grabher, 2004; Sapsed et al., 2005). In other words, the endemic amnesia of projects seems to be particularly problematic for industries producing technologically complex goods that rely on cumulative learning. Most studies on project-to-project learning are based on technologically complex industries such as engineering design and aerospace.

All three of the industry models were checked for size (persons, partners, budget, duration), geographical dispersion of the project partners and relationship (length of relationship and number of projects carried out by project partners) variables: none was significant.

Conclusions

This article has investigated the factors determining the use of codification to support the transfer of knowledge across projects. In contrast to a widely held assumption, the innovativeness of the product may not be the most important determinant of the choice to use codification to support knowledge transfer across projects. The results support the findings from qualitative studies (e.g. Grabher, 2002, 2004) on the importance of institutionalized governance. Industry conventions, norms and regulations establish more or less stable expectations about roles, practices and procedures, and constitute channels facilitating the accumulation and consolidation of knowledge (Sydow and Staber, 2002).

The presence of a system integrator, as revealed by a contractual hub firm, is important for supporting deliberate knowledge transfer strategies based on codification. Previous studies show that system integrators maintain in-house knowledge about the technologies used by their partners (Brusoni et al., 2001) and play pivotal roles in the management of projects, acting as 'linchpins' for the development of trust in the absence of personal relations and familiarity (Meyerson et al., 1996: 171). Our research shows that, in volatile environments, the system integrator can embody some degree of organizational memory which favours the systematic transfer of knowledge across projects in industries characterized by technologically complex products.

Finally, our study provides an empirical exploration of the role of different industry contexts and knowledge bases in shaping knowledge management strategies. On the one hand, the relative importance of codification in engineering and high technology industries reflects their cumulative learning regimes. Knowledge is built up in continuous step-by-step processes, and sedimented in modules and methods that can be recombined for different purposes. In creative industries, the learning trajectory is discontinuous and deliberately disruptive. While cumulative learning helps to avoid 'reinventing of the wheel' through deliberate knowledge management, and the achievement of often significant progress over time through the accumulation of incremental innovation, discontinuous learning is driven by the creative imperative of 'freshness.' On the other hand, norms, roles and professions in emerging high-tech fields are more fluid and shifting than in established creative or engineering contexts, making the 'silos' and channels through which knowledge traditionally was accumulated only partially available. In other words, more traditional formalized means of knowledge management might be important in emerging new fields that have yet to develop the organizational registers that make possible the consolidation of knowledge.

Directions for further research

This study is primarily concerned with the factors that influence the choice of firms to use codification in order to support the transfer of experiential learning across projects. The costs, challenges and impacts of codification on performance are beyond its scope.

As suggested by the literature on knowledge management, codification cannot be reduced to the cognitive process of transforming tacit knowledge into codebooks or manuals. Rather, the effectiveness of the process of codification and also de-codification and adaptation to diverse local circumstances (D'Adderio, 2003; Hall, 2006) relies heavily on a robust social infrastructure of networks and communities in which these processes are embedded (Amin and Roberts, 2008; Bosua and Scheepers, 2007; Swan et al., 1999). Future research could explore to what extent cumulative knowledge regimes draw relatively more benefits from codebooks while disruptive knowledge regimes rely relatively more on networks and communities. Additionally, the quality of the processes that make possible de-contextualizing and re-contextualizing knowledge to different context may depend significantly more on how knowledge is codified, rather than on the extent of codification (Adler and Borys, 1996; Cacciatori, 2008; Carlile and Rebentisch, 2003). Further research investigating the effects of different types of knowledge codification is therefore warranted.

The existing body of research on the performance benefits of codification (e.g. Haas and Hansen, 2005, 2007) also raises a number of questions. On the one hand, it is important to understand whether the *direct* impacts of codification on traditional performance parameters, such as time, costs and quality, differ for different knowledge regimes and industries. Research is needed into the effects of knowledge codification on innovative performance, how they vary between process and product innovation, and whether such differential effects are stable across industries. For instance, creative industries might have a higher propensity to rely on personal relationships and networks for product innovation than technology intensive industries and the reverse could be true for process innovation, whose tacit nature is a source of competitive advantage for manufacturing (Winter, 1987). Beyond the impacts on traditional performance indicators and innovation, codification might also enhance the stability of client relations. Codification entails increasing transparency of the project completion process, improves the (long-term) accountability of the project partners, and corroborates the legitimacy of the various steps taken in the course of the project. Codification in this sense signifies the 'rationality' of project performance which in turn might help to convert a single project into a lasting client relationship.

On the other hand, there is also a range of *indirect* or non-intended effects on performance that would benefit from further research. Regardless of whether the outputs of knowledge codification such as codebooks are used or not, the process of codification might increase organizational reflexivity (see Prencipe and Tell, 2001; Zollo and Winter, 2002). The organizational practice of codification forces actors to discursively reflect on established practices and procedures thereby enhancing the quality of their learning. Also, discursive reflection in the course of the knowledge codification process might induce interrelating activities that trigger moments of collective creativity (see Hargadon and Bechky, 2006): search for and provision of help, reflective reframing (in which each actor in turn attends to and builds upon the comments and actions of others), and reinforcing (e.g. through organizational values that support individuals' seeking and providing help and reflective reframing). In this sense, codification could induce 'heedful interrelating' (Weick and Roberts, 1993) within the organization that connects individual ideas and experiences in ways that can help to redefine and resolve the demands of emerging situations.

Finally, further research should examine whether and to what extent codification for the purposes of knowledge transfer, ultimately is used in a normative sense, to increase conformity. Increased conformity might have positive impacts on traditional performance indicators, but at the same time might reduce the propensity to 'think outside the box' and to explore novel approaches.

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Notes

1. The term procedural knowledge in this context is different from its use in psychology and decision-sciences where it is defined as knowledge about how to perform an act as opposed to declarative knowledge, which is defined as knowledge about facts (Anderson, 1983; D'Adderio, 2003; Kogut and Zander, 1992; Lynn and Akgun, 2000).
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Appendix 1

Correlation table for explanatory variables

	Knowledge complexity	Product variation	New generation of existing product	New product for the partners	New to the industry	New to the world	System integrator	Administrative regulation	Institutionalized regulation	Face–to–face communication
Knowledge complexity	1									
Product variation	.022	1								
New generation of existing product	–.025	–.319**	1							
New product for the partners	.010	–.201**	–.086	1						
New to the industry	.047	–.251**	–.089*	.031	1				.	.
New to the world	–.005	–.140**	–.053	.026	.097*	1		.		.
System integrator	–.093*	.027	.038	.013	–.131**	–.051	1			
Administrative regulation	–.098*	–.039	–.041	–.032	.009	.022	.026	1		.
Institutionalized regulation	.052	–.059	–.012	.005	.034	.018	.020	.232**	1	
Face-to-face communication	–.074	–.028	–.001	.083	.004	.073	–.024	.097*	.102*	1

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Appendix 2

Correlations in administrative regulation

	Property rights	Decision and control rights	Tasks	Duration	Separation procedures	Warranties and indemnities	prices, fees and royalties
Property rights	1						
Decision and control rights	,574**	1					
Tasks	,348**	,496**	1				
Duration	,422**	,436**	,676**	1			
Separation procedures	,517**	,519**	,465**	,525**	1		
Warranties and indemnities	,493**	,500**	,543**	,644**	,650**	1	
Prices, fees and royalties	,460**	,441**	,552**	,665**	,586**	,737**	1

**Correlation is significant at the 0.01 level (2-tailed).

Appendix 3

Correlations in institutionalized regulation

	Property rights	Decision and control rights	Tasks	Duration	Separation procedures	Warranties and indemnities	prices, fees and royalties
Property rights	1						
Decision and control rights	,521**	1					
Tasks	,431**	,558**	1				
Duration	,490**	,415**	,625**	1			
Separation procedures	,591**	,450**	,458**	,567**	1		
Warranties and indemnities	,538**	,384**	,514**	,625**	,680**	1	
Prices, fees and royalties	,549**	,421**	,555**	,663**	,619**	,727**	1

**Correlation is significant at the 0.01 level (2-tailed).