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## DUI mode learning and barriers to innovation—A case from Germany

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### ABSTRACT

This paper aims to provide a better understanding of informal modes of learning based on Doing, Using and Interacting (DUI). Innovating firms from Germany are grouped according to the degree to which they combine DUI mode competencies with formal learning of science and technology (i.e. the Science, Technology and Innovation – STI – mode). To more deeply assess the practical relevance of this grouping for innovation policy, it is subsequently examined how a firm's learning mode relates to the relevance of different sets of innovation barriers. According to the empirical results, DUI mode learning is generally important in the field of innovation, since it occurs either in its pure form or in combination with formal processes of research and development (R & D). Moreover, the more dominant that the DUI mode of learning is at the company level, the more likely that the corresponding firm is small. In such a less R & D-oriented knowledge environment, innovating firms can exploit certain competitive advantages when they concentrate on their experience-based DUI mode competencies. On the other hand, firms trying to compensate for limited in-house R & D capabilities through collaboration with external partners have to overcome a number of knowledge and market barriers to innovation. The paper concludes with implications for policy and research.

### 1. Introduction

An important feature of innovation is its heterogeneous nature across sectors and industries. Starting with the seminal work of Nelson and Winter (1982), several studies have pointed to the shaping role of specific knowledge bases on innovation activities in explaining the systematic differences arising from this variability (Malerba, 2002; Malerba and Orsenigo, 1997; for an overview, see Fagerberg, 2005). One implication of this evidence is that policy-makers should be aware that innovation can occur under various knowledge environments; otherwise, they might easily fail to meet the needs of certain firms and industries.

To take such differences into account when designing policies, information is needed on how ways of learning can differ in innovating firms. In a seminal paper, Jensen et al. (2007) contrasted two *ideal* modes of learning being integrated and combined at the company level to a greater or lesser degree by innovating firms. The first one – labelled the Science, Technology and Innovation (STI) mode – is dominated by scientific and technical knowledge, which is explicit and codified due to being embedded in formal processes of research and development (R & D). By contrast, the second one – labelled the Doing, Using and Interacting (DUI) mode – is described as being dominated by informal processes of learning and experience-based know-how. Here, the creation and use of tacit knowledge lies at the heart of the innovation process. In light of this, Jensen et al. (2007) argue for an ongoing bias

towards an orientation on STI indicators such as R & D data or patent grants and citations. As a result, policy-makers tend to overly focus on formal R & D activities that lead to product innovation in high-technology industries, prompting the authors' plea for “a realignment of policy objectives and priorities” (p. 690).

However, the other side of the coin is that at the level of scholarly research, relatively little is known about the DUI mode of learning. For example, this holds with respect to innovation in low- and medium-tech companies (see Tunzelmann and Acha, 2005; Hirsch-Kreinsen and Jacobson, 2008; Santamaría et al., 2009), the role of DUI mode learning for non-technological innovation (i.e. organisational and marketing innovations, see Parrilli and Alcalde Heras, 2016) or the general importance of experience-based learning in the context of innovation (see Lundvall and Borrás, 2005).

The dichotomy between the emphasis on STI indicators and the little known about the DUI mode of learning should be especially pronounced in the case of Germany. On the one hand, a core competitive strength of the German production and innovation model is seen as resulting from a special mix of academic and vocational qualifications (EFI, 2014). Innovation activities of German firms are strongly rooted in the interaction between graduates from tertiary education institutions (notably university graduates of natural sciences and engineering) and graduates from the dual system of vocational education and training (VET). The latter – comprising technicians, craftspeople and other skilled workers – form a major part of the German workforce. Dual

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training includes workplace learning to acquire experience-based, practical knowledge as well as the provision of theoretical expertise through accompanying school-based vocational instruction. On this basis, VET trained workers have the ability to engage in complex problem-solving. They also share a common professional language, which enables them to communicate and closely interact with a firm's scientific and engineering staff. Both aspects are especially important for incremental innovation (Toner, 2010, 2011). Thus, due to the significant role that the dual system of VET plays in the skill formation regime of Germany, one would expect the DUI mode of learning to be strongly embedded in the German innovation system.

On the other hand, German innovation and technology policy-making strongly relies on a linear R & D-based model of innovation (Lay and Som, 2015). The focus lies on high-tech manufacturing, while non-R & D-intensive firms and industries – with their stronger dependence on DUI mode learning – tend to be overlooked in terms of national competitiveness and innovativeness. For example, low-tech industries account for the majority of the industrial workforce in Germany. Compared to the total manufacturing sector, a relatively large share of personnel employed there are VET graduates (Frietsch and Gehrke, 2006; Frietsch and Neuhäusler, 2015). Recent company-level evidence also suggests that experience-based, practical knowledge and distinct customer-related competences are a key source of innovation for non-R & D-performing and non-R & D-intensive firms across all sectors of the German economy (Kirner and Som, 2015). However, the patterns of knowledge creation that underlie innovation activities in these firms can still be regarded as a “black box”, which is why policy-makers from Germany (as well as other countries) who aim to promote innovation in less-R & D-oriented knowledge environments require further insights into the functioning of the DUI mode of learning.

Previous research motivated by the paper of Jensen et al. (2007) has investigated different types of interaction typically associated with STI and DUI mode learning (see Fitjar and Rodríguez-Pose, 2013; González-Pernía et al., 2015; Parrilli and Alcalde Heras, 2016). The present analysis more directly draws upon Jensen et al. (2007). Based upon a broad survey of innovating firms from Germany, different modes of learning are identified. Accordingly, this paper aims to provide a better understanding of DUI-based innovation in less-R & D-oriented knowledge environments through a twofold contribution, as outlined below.

First, contrary to Jensen et al. (2007), who refer to the use of high-performance work practices, the organisational structure of firms and the extent of customer involvement as indicators to measure DUI mode learning, the present paper makes informal processes of learning and experience-based know-how more concrete by adopting a competence-based approach. For this purpose, answers to a question prompting respondents to assess the distinctiveness of several innovation competencies in their enterprise are evaluated, which are directly related to the build-up of tacit knowledge at the level of the firm (e.g. learning by trial-and-error, person-embodied creativity or the inclusion of external partners). Some additional profiling variables are also included in the present analysis to better illustrate some particularities of DUI mode learning in a less-R & D-oriented knowledge environment (e.g. the important role of the non-academic workforce and the relative neglect by policy-makers). Finally, the present paper provides a deeper understanding on DUI mode learning and its interrelationship to the STI mode by also considering non-technological innovation. Without directly referring to it, Jensen et al. (2007) already briefly touched upon this issue when stating that DUI mode learning can be either unintentionally triggered at the company level as a by-product of design, production and marketing activities or intentionally stimulated by changing organisational procedures that enhance and utilize learning by doing, using and interacting. Parrilli and Alcalde Heras (2016) provide recent evidence in this regard, with their results indicating that DUI mode learning is indeed closely related to marketing and organisational innovations, whereas technological innovations tend to primarily rely on the STI mode. This is supplemented by the finding of

Hervas-Oliver et al. (2015) that non-R & D technological innovators heavily rely on organisational and marketing activities to compensate for the lack of in-house R & D capacities. Hence, a consideration of non-technological innovation should be crucially important to achieve a better understanding of DUI mode learning in less-R & D-oriented knowledge environments.

Second, after identifying and profiling the different modes of learning, it is examined how they relate to the company-specific relevance of different sets of innovation barriers (i.e. cost barriers, knowledge barriers, market barriers and regulation barriers). This further ensures the practical significance of the derived modes from policy-makers' perspective. Moreover, it provides them with information about the factors that can hinder innovation in a less-R & D-oriented knowledge environment dominated by DUI mode learning: an issue not directly addressed by Jensen et al. (2007) or prior studies on barriers to innovation (e.g. Baldwin and Lin, 2002; Galia and Legros, 2004; Tourigny and Le, 2004; D'Este et al., 2012). To approach this theoretically, the present paper refers to the case of small firm innovation. It is important to keep in mind that analysing the informal processes of learning and experience-based know-how in less-R & D-oriented knowledge environments primarily implies thinking about small and medium-sized enterprises (SMEs), given that non-R & D-performing and non-R & D-intensive firms are predominantly found in the “Mittelstand”, the so-called backbone of the German economy (Kirner et al., 2009; Kirner and Som, 2015). In light of this, Hirsch-Kreinsen (2015) argues that the organisation and management of knowledge in non-R & D-intensive firms and industries is characterised by practices that are typically found in SMEs. According to him, this not only holds true for Germany, but also for Europe in general. In fact, the typical features associated with DUI mode learning (see Section 2) strongly resemble those discussed in the literature on the nature of small firm innovation (e.g. Baldwin and Gellatly, 2003; Mazzarol and Reboud, 2009; Thomä and Bizer, 2013). The relative importance of pure DUI mode learning in small innovating firms has already become evident in the empirical results of Jensen et al. (2007). In the case of Germany, a first indication in this direction is that vocational training in the dual system primarily takes place in companies with fewer than 249 employees (BIBB, 2015). As such, the typical strengths and weaknesses that small innovating firms have under the conditions of their less R & D-oriented knowledge environment may help to explain the role of certain innovation barriers in the context of DUI mode learning.

The remainder of this paper is structured as follows. In Section 2, the theoretical background is described, before Section 3 presents the data set. The empirical analysis is conducted in Section 4. In the first part, factor analysis and cluster analysis are combined to group and classify innovating firms according to their mode of learning. In the second part, by employing multivariate probit regression, it is investigated how the identified learning modes relate to the importance of different sets of innovation barriers. Finally, concluding remarks and implications for policy and research are provided in Section 5.

## 2. Theoretical background

### 2.1. Concepts of knowledge creation in innovating firms

With respect to the mode of learning of innovating firms, two closely-related concepts of the knowledge creation process hold relevance: the distinction between STI and DUI mode learning provided by Jensen et al. (2007), as well as the differentiation of industrial knowledge bases in terms of being either “analytical” (science-based) or “synthetic” (experienced-based), which was first proposed by Laestadius (1998) and subsequently developed in detail by Asheim and Gertler (2005). Both concepts contrast two opposing (ideal) types of knowledge environments under which innovation occurs, while their authors fully acknowledge that in practice innovating firms need to mix – at least to some degree – different forms of knowledge to be successful. While the

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