Exploring Complementarities of Productive IT use through Methodological Complementarism

Natallia Pashkevich[1] and Darek Haftor[2]
[1]Department of Informatics, Linnaeus University, Växjö, Sweden
[2]Department of Informatics and Media, Uppsala University, Sweden
natallia.pashkevich@lnu.se
darek.haftor@im.uu.se

Abstract: Factors affecting productivity and particularly IT-enabled productivity increase have been and still remain the major concern for many business sectors. While previously researchers investigated what factors and their complementary relationships affect organizational productivity, organizational economists came to the conclusion that an organization cannot be regarded anymore as a black box since it is not an organization per se that conducts the very work but its resources with the basic elements being a single worker and a single IT system. Currently, it is proposed that we understand organizational internal mechanisms and their functioning for productivity through the lens of complementarity theory and maintain that when factors are synchronized correctly they can bring significant productivity increase. Identification of the complementarity factors and their synchronization bring, however, a major challenge for research methodology. Unlike conventional studies where a few variables independent of each other cause a reaction to dependent variables, in the context of complementarities, the assumption is closer to the real-world experiences where a set of factors interact with each other to affect one or several dependent variables. The present paper addresses this difficulty of researching complementary factors for an individual knowledge worker and their productivity. The approach taken here is to use multiple and different research methods in a complementary manner, so that the results from each study of the same kind of phenomenon uncover new insights that cannot be derived from any such single study. The results from this multi-method approach demonstrate new insights into the interplay between the studied factors that condition the productivity of knowledge workers and show the importance of analysing a complex phenomenon with complementary research methods.

Keywords: complementarity systems approach, individual IT-enabled productivity, knowledge worker, methodological complementarism, online experiment, quasi-randomized field experiment

1. Introduction

Today's modern organizations prioritize the challenge of improving productivity and researchers continuously searching for new factors, their combinations and methods that may lead organizations to productivity improvement (Bender et al., 2018; Singh, Burgess and Heap, 2016). The more IT systems become available to support a specific kind of work process; the more challenges emerge for how these technologies can be used in a more efficient way. While researchers previously studied productivity of organization in its market, currently a number of attempts are being made to unpack the black box of an organization and understand its mechanisms (Gibbons and Roberts, 2013). The main argument for this exploration is that it is not an organization that conducts operations but a knowledge worker and an IT system that are basic elements of an organizational workstream (Palvalin, Lönnqvist and Vuolle, 2013; Pyöriä, 2005).

Productivity of a knowledge worker and IT use is currently discussed in line with the debates about the productivity paradox (Aral, Brynjolfsson and van Alstyne, 2012; Jain and Kanungo, 2013; 2016) originally described by Robert Solow (Solow, 1987). The exploration of this paradox led to the conclusion that when certain complementary factors are matched correctly they can create a synergy and thus increase productivity significantly (Brynjolfsson and Milgrom, 2013; Cardona, Kretschmer and Strobel, 2013; Sabherwal and Jeyaraj, 2015; Schryen, 2013). For an individual knowledge worker two pioneering studies concluded that productivity increase from IT use may require complementarities such as a work process (Athey and Stern, 2002; Autor, Levy and Murnane, 2003), while a more recent study demonstrates that these complementary factors may have a contingent relationship (Aral, Brynjolfsson and van Alstyne, 2012).

The limited insights into individual knowledge worker productivity are explained by difficulties in demonstrating productivity gains from a narrow system of complementary factors and difficulties in IT complementarities' management (Ennen and Richter, 2010). In contrast, we study the effect of a set of complementarities on individual productivity in a particular situation when an IT system that is aligned with

Reference this paper: Pashkevich, N., and Haftor, D., 2018. Exploring Complementarities of Productive IT use through Methodological Complementarism. *The Electronic Journal of Business Research Methods,* 16(3), pp. 128-138, available online at www.ejbrm.com

the work process is used and we compare productivity data with a situation where a not aligned IT system is used. This is investigated empirically here by applying an experimental approach when an artificially created situation involves a manipulation of certain conditions relevant to the outcome (Mingers, 2003). Moreover, the use of such an experimental approach in studying IT and complementarity impacts is strongly supported by recent researchers (Camerer and Weber, 2013; Gupta, 2014; Gupta, Kannan and Sanyal, 2018). Studying complementarities is challenging as, unlike conventional studies with few variables, where independent variables are assumed independent of each other and offering a linear cause-effect relation to the dependent variables, the complementarity approach recognises the complexity of reality where a set of factors interact with each other to generate effects on dependent variables. These challenges demand specific requirements in the research approach for studying complementary mechanisms. To overcome these limitations the approach taken here is to use a systems approach of the complementarity theory (Ennen and Richter, 2010) and a multiple and different research method (a longitudinal quasi-randomized field experiment and a web-based online experiment) in a complementary manner. In this way, the research results from each study of the same kind of phenomenon bring several insights that cannot be derived from any single study (Bazeley, 2015; Bentahar and Cameron, 2015). As a result, complementary factors that condition knowledge worker productivity are investigated here with several research methods that complement each other.

This paper presents methodological insights from two parallel and differently designed experimental studies. These studies were conducted independently to investigate configurations of complementary factors that influence individual IT-enabled productivity of knowledge workers both before and after the introduction and use of aligned IT systems. We stress, however, that we do not discuss the detailed settings and findings of each study although we provide some background and results for each study. Rather our main focus is on the key methodological insights obtained from two studies. Taken together, the two studies demonstrate (i) the support for the complementarity theory and its systems approach for IT-enabled productivity for an individual knowledge worker, (ii) that further research is needed to understand the effect of a worker's cognitive style interactions with complementary factors investigated here on individual productivity, (iii) that granularity and learning effects are central to the understanding of productivity. Thus, the design of future experiments should explore in more detail a learning curve before and after an aligned IT system is used, (iv) that a mandatory context of IT use might provide better access to individuals with both adaptive and innovative cognitive styles than a voluntary working environment. Therefore, this paper seeks to show the complementary effect gained from two different research methods used to study the same kind of phenomenon. By comparing the results obtained from both studies, new insights are gained that are not provided by individual studies on their own.

The rest of this paper is structured as follows: The first sections present the theoretical background underlying formulated complementarity set-ups. Following that, a description of the research methodology and the obtained results are presented. Finally, a summary of the methodological insights, key contributions and future research directions concludes the paper.

2. Theoretical background

In an organization, factors can have an independent, substitutive or complementary relationship (Parmigiani and Mitchell, 2009). An independent relationship occurs when a change in one factor does not affect the value of another factor. A substitution relationship exists when a change in one factor diminishes the value of another factor. A complementarity relationship emerges when a change in one factor increases the value of another factor. In this study, we use the complementarity theory (Milgrom and Roberts, 1990; 1995) which states that, in order to increase productivity, there is a need to allocate a number of factors in a system in a particular manner so that each factor enlarges the value of another factor.

The complementarity theory has two investigative approaches (Ennen and Richter, 2010). The main distinctive feature between these two approaches is that while the interactive approach studies the nature of the factors which potentially are complementary, the systems approach explores effects of the entire system of multiple factors on productivity. In our research, we take the systems approach of the complementarity theory and study the impact of complementarity set-ups on individual productivity in a situation where a more aligned with the work process IT system is introduced and used in a company. An aligned IT system is defined as that which offers information and information-processing functionality that is adjusted and tuned to support specific work activities within a specific kind of work process.

While the systems approach allows the investigation of a system of factors that together can significantly increase productivity, this approach imposes some methodological difficulties. For example, it is unclear how to design studies to explore complementary factors for an individual so as to increase IT-enabled productivity and what design is most appropriate. By applying the systems approach it is also difficult to isolate what complementarities are critically important. This would require multiple runs with many configurations, which is often impossible in real life settings. This also imposes a need for longitudinal studies to demonstrate causality directions, rather than only correlations. Our approach in dealing with these uncertainties is to combine different yet complementary methodological approaches since it has been emphasized that: *"The complementarity among the methods permits researchers to clarify, explicate and to apprehend some levels of analysis different from the object of research. Thus, the objective is not to corroborate the results, but to apprehend a supplementary facet of reality"* (Bentahar and Cameron, 2015, p. 7). Studying the same phenomenon using two different experimental methods not only helps us to uncover new configurations of complementary factors but also provides us with new methodological insights that neither of these two approaches could offer alone.

3. Formulated complementarity set-ups

To overcome limitations from previous individual level studies (Aral, Brynjolfsson and van Alstyne, 2012; Athey and Stern, 2002; Autor, Levy and Murnane, 2003), we applied the systems approach of the complementarity theory. This assumes that studying the interaction between multiple complementary factors may demonstrate a superior productivity increase rather than exploring only a limited number of factors (Ennen and Richter, 2010). In this study, we developed two complementarity set-ups aligned with adaptive-innovative cognitive style, including training and education, incentive and decision-making modes and tested individual productivity both before and after the introduction and use of a more aligned work process IT system. The development of complementarity set-ups is presented below in more detail.

In general, individual productivity of a knowledge worker is conceived as a function of a single worker, IT tool used by the worker, a task conducted and contextual settings of the worker, i.e. processes that govern the interactions among the individual, task and IT tool in order to complete tasks (Hopp, Iravani and Liu, 2009). Therefore, based on these premises and the systems approach of complementarity theory, we formulated two complementarity set-ups in which the following factors fit each other in a particular manner: adaptive/innovative cognitive style (as human cognition is the main act of information processing by a knowledge worker) (Kirton, 1976; 2003), the structural complexity of the operational process (MacCormack, Verganti and Iansiti, 2001; Weber and Wild, 2005), training activities, incentives, and decision-making structure (Amabile, 1996; Baer, Oldham and Cummings, 2003; Bloom and van Reenen, 2011; Ryan and Deci, 2000; Sense, 2007). These factors were linked together into one greater system of factors that complemented each other, in which each factor was assumed to hold a binary value set. This provided a foundation for the formulation of the two key complementarity set-ups that were subjected to empirical tests (Table 1).

Table 1: Summary of predicting complementarity factors and their value range

Predicting complementarity set-ups and factors	Value range	
Complementarity set-up	**Stable**	**Dynamic**
Cognitive style	Adaptive	Innovative
Work process	Stiff	Flexible
Training mode	Push	Pull
Motivation mode	Exogenous	Endogenous
Decision-making mode	High centralization	High decentralization

Therefore, we expect that (i) individuals with adaptive cognitive style generate higher productivity when matched with a 'stable' complementarity set-up that includes a stiff operating process, push mode training in work technology, exogenous incentives, and centralized decision-making compared to other configurations of these factors when a more aligned IT system is used. In contrast, we expect that (ii) individuals with innovative cognitive style generate higher productivity when matched with a 'dynamic' complementarity set-up that includes a flexible operating process, a combination of minor upfront mandatory training with optional on-demand training in work technology, endogenous incentives, and decentralized decision-making compared to other configurations of these factors when a more aligned IT system is used. Our contribution to the complementarity literature is that, by applying the systems approach of complementarity theory, we propose new configurations of complementary factors that have been established and explored independently by other studies mentioned in this section.

4. Methodology

Although recent studies gathered some knowledge on potential complementary factors that can affect individual productivity, we still do not know how to study these complementary factors for an individual. For example, previous studies on the relationships between IT complementarities and individual worker productivity applied the survey approach (Aral, Brynjolfsson and van Alstyne, 2012; Athey and Stern, 2002; Autor, Levy and Murnane, 2003) and demonstrated mixed results. These heterogeneous results can be explained by challenges in studying complementarities and their effect. For example, in conventional studies independent variables are assumed independent of each other and offer a linear cause-effect relation to the dependent variables. The complementarity approach recognises the complexity of reality where a set of factors interact with each other to generate effects on dependent variables. These challenges demand specific requirements for a research approach in studying complementary mechanisms.

Studying the effect of complementarities on outcome variable requires identification of causation rather than correlation, and thus calls for longitudinal experimental studies (Hassett and Paavilainen-Msntymski, 2013). Field experimental approach is also proposed by organizational economic literature to clearly quantify the effect of complementarities on performance indicators (Camerer and Weber, 2013). Although longitudinal experimental studies are preferable to identify a causal effect of treatment on outcome variables, they can imply low temporal resolution and thus changes in such patterns as learning effect (Womer, 1984) may not be visible. Moreover, since we investigate complementary factors of an individual's cognitive style, where one of the styles is innovative which implies a great need of autonomy and voluntary behaviour rather than imposed norms, the research method must be able to recognize such needs. Therefore, there is a need to use experimental methods that can address these requirements in a more detailed manner (Camerer and Weber, 2013; Gupta, 2014; Gupta, Kannan and Sanyal, 2018). In general, two requirements (causality and granularity) clearly demonstrate that the use of a multi-method research approach can be beneficial in order to demonstrate the effect of complementarities on outcome variables. Studying the effect of the system of complementarities requires different empirical contexts to demonstrate whether the system is contextually dependent. This means that the same system has to be tested in different empirical contexts, in our case in different information-intensive occupations, in order to claim that the complementarity system may be generalised and thus can be used to increase individual productivity of knowledge workers.

In this paper, the research strategy was based on two independent studies: a longitudinal quasi-randomized field experiment (Study A) in which we investigated the operational productivity of sales representatives and an online experiment of software programmer productivity (Study B). The choice of research methodology and its rationale is as follows: Firstly, since we needed to study whether changes in operational set-ups cause productivity differences owing to different configurations of complementary factors, the experimental design was appropriate for testing the formulated complementarity set-ups. Secondly, in order to study the impact of IT use on individual productivity it was necessary to capture productivity data over a period of time and to take into account the time-lag effect on productivity gains from IT use (Brynjolfsson, 1993; Devaraj and Kohli, 2003). Therefore, a longitudinal research approach is important when studying complementarities of productive IT use to demonstrate their effect over time. These two premises form a foundation for the longitudinal field experiment. This type of experiment enables analysis of a targeted phenomenon in its natural setting without artificially introducing confounding variables as well as capturing the effect of intervention over time (Hassett and Paavilainen-Msntymski, 2013). Thirdly, in addition to the time-lag effect, we needed to provide better control over complementarities and their impact on IT-enabled productivity that could be achieved by conducting well-controlled laboratory experiments. However, recent online experiments have become even more popular than laboratory experiments, since they reduce the influence of experimenters' expectations on participants' behaviour, provide access to wider populations, and increase the uniformity of the experimental procedure across participants (Reips, 2002; Wolfe, 2017). Therefore, both a longitudinal field experiment and a well-controlled online experiment responded to the complementarity set-ups tested in this research. Finally, we chose two information-intensive professions – sales representatives and software programmers – as appropriate examples of knowledge workers (North and Gueldenberg, 2011). These workers require cognitive skills to process information which is an input and output of the production process and use expressly designed IT systems as their main production tool. Thus, two independent studies are appropriate for in-depth exploration of complementarity configurations, because we can identify whether the emerged patterns in one study are confirmed in the other, and as a result, can expect stable results. The set-up characterization of Study A and Study B is presented in Table 2.

Table 2: Set-up characterization of Study A and Study B

Key characteristics	Study A	Study B
Type of study	Longitudinal quasi-randomized field experiment	Web-based online experiment
Focus	Productivity of sales representatives	Productivity of software programmers
Data collected	Data were collected over a period of 5.5 years: January 2012 – June 2017 (9 quarters pre-change and 13 quarters post-change)	The online experiment was available online for 4 months (October 2015 – January 2016)
Context	Nordic affiliate of a global pharmaceutical corporation	Dedicated website for experiment; subjects recruited globally through online staffing firms
Metric	Number of sales calls and products sold in relation to the duration of time worked by an individual	Programming time and quality (completeness and correctness) of the product developed
Subject participation	Mandatory participation as part of regular work tasks	Voluntary participation incentivized with minor payment
No. of subjects investigated	91 of which 31 were innovators and 60 are adaptors	113, of which 110 were innovators and 3 were adaptors
Study design	4-factor configurations distributed over 16 business units (4 products; 4 counties): Design 1: no change; control group Design 2: an aligned IT system only Design 3: an aligned IT system, new sales process Design 4: all factors; an aligned IT system, new process, training and education mode, incentives, and decision-making authority	3 sessions/assignments for software programming for each subject. Session 1: simple IT-tool support Session 2: advanced IT-tool support and all factors Session 3: advanced IT-tool support and all factors Each session lasted between 20 minutes and 1 hour
Subjects' context allocation	Adaptors in a 'stable' complementarity set-up Innovators in a 'dynamic' complementarity set-up	Innovators in 'stable' and 'dynamic' complementarity set-ups
Data analysis method	Difference-in-difference	Repeated measures analysis of variance
Study deviation	Subjects' allocation did not allow us to identify productivity of adaptors in 'dynamic' and innovators in 'stable' complementarity set-ups	The study succeeded in attracting mostly innovators

Study A was conducted in a Nordic affiliate of a global pharmaceutical company that is among the top 50 largest life-science corporations in the world. The affiliate received a new sales-support IT system that was designed to facilitate sales representatives' daily work at the end of April 2014. This IT system was installed in the company with four different designs (operational–organizational configurations of complementary factors) to study their impact on individual productivity of sales representatives. These four designs were allocated to a four-by-four operational structure (with four different products, A, B, C, and D, and four different markets, Denmark, Finland, Norway, and Sweden) to neutralize the influence of the product as well as the market over sales performance. Participants in the first group (Design 1) acted as a control group and operated in a way the whole company operated prior to the introduction of the aligned IT system. Participants in the second group (Design 2) received the aligned IT system, yet remained in the same operational set-up as prior to the change. Participants in the third group (Design 3) received the aligned IT system together with a new and specific type of sales process (sales representatives were not obliged to follow all operational steps in the new process). In the fourth group (Design 4), the 'full' or comprehensive set of IT complementarities was assumed, based on the developed complementarity set-ups. Productivity data (the number of sales calls and products sold relative to the length of time worked by an individual) were collected for every quarter over a period of 5.5 years (9 quarters before and 13 quarters after the introduction of the aligned IT system).

In Study B, we used a dedicated website to test whether a set of matched complementary factors can actually affect productivity in relation to adaptive-innovative cognitive style when a more aligned IT system was implemented and used. We expected that adaptors rather than innovators would have productivity advantages when a more aligned IT system is used together with a 'stable' complementarity set-up. In contrast to adaptors, we expected that innovators would gain productivity advantages when a more aligned IT system is used together with a 'dynamic' complementarity set-up. The experiment consisted of three sessions/assignments. In the first session, in order to establish a benchmark, participants developed a software application using a text editor, which represents an existing IT system in a company. In the second session, an advanced IT system, Cloud9, an online integrated development environment that provides comprehensive facilities for software development introduced in a synchronized manner with both cognitive styles and complementarity set-ups. The third session was designed to consider a learning-curve effect (McLeod et al., 2008; Womer, 1984). This session also included the advanced IT tool and complementarities of the second session. Each session had identical time frames (approximately 20 minutes to 1 hour) and a slight variation of assignments, yet with an equal level of complexity. The time taken by the subjects to complete each session was used to characterize a quantitative dimension of the productivity metric. In addition, as a measure of productivity, we used completeness (how many of the functional requirements were completed) and correctness (how well the functional requirements were implemented) of the application developed to evaluate the quality of the developed product.

5. Results

Table 3 summarizes the characterization of the key results from both studies that together offer insights into the methodology of the investigated phenomenon about complementarities and IT-enabled productivity.

Table 3: Results characterization of Study A and Study B

Key characteristics	Study A	Study B
Study results	Design 1: no productivity change Design 2: decreased productivity Design 3: decreased productivity Design 4: increased productivity	Session 1: Innovators in a 'dynamic' context worked faster yet generated lower quality of the product developed, while innovators in a 'stable' context worked slower yet generated higher quality of the product. Session 2: Innovators involved in a 'dynamic' context had a greater change in completion time when they learned an aligned IT system. Session 3: Innovators involved in a 'dynamic' context set-up learned an aligned IT system faster than those innovators involved in a 'stable' context
Key conclusions	Synchronization of complementarities conditions productivity of knowledge workers. There is a learning effect from the changes made for productivity gains that takes no longer than 3 months	In the first and third sessions, innovators involved in a 'dynamic' context worked faster, yet with significantly lower quality than those innovators involved in a 'stable' context. A learning effect is achieved in the second and third sessions. However, the study suggests that the learning effect has just started
Key methodological insights	Complementarity set-ups might have both positive and negative productivity impacts. With productivity data provided on a quarterly basis, it is difficult to identify the learning effects of the adoption of an aligned IT system and work practices. Further research is needed to understand how the productivity of individuals with different cognitive styles is affected by non-matched complementarity set-ups	Future research has to consider whether a work environment is mandatory or voluntary to collect data on individuals with both cognitive styles. More sessions of the experiment are needed to achieve saturation in productivity scores before and after use of a more aligned IT system is stabilized. Both performance metrics (time and quality) have to be monitored closely to understand the impact of complementarity set-ups

In Study A, the final sample for the analysis comprised 91 participants located almost equally in each design. The average age was 39 years old and most participants had a Master's (52%) and Bachelor's degree (42%). On average, participants had 5 years' experience in the company, 7 years' experience in sales and 10 years' experience in the sales industry. By using Kirton's inventory of adoption-innovation (Kirton, 1976), we identified that of 91 subjects 31 were innovators and 60 were adaptors and in particular in Design 4, of 27 subjects 7 were innovators and 20 adaptors. In this study, we expected that sales representatives involved in Design 4 with a full set of complementarities would generate greater productivity than sales representatives involved in Design 1 without operational change, Design 2 with structured partial change, and Design 3 with semi-structured partial change. Consistent with our expectation, the obtained results in Study A showed a positive and statistically significant effect of complementarities on individual IT-enabled productivity of sales representatives. In particular, the results indicated that the productivity of sales representatives involved in the design with the full complementarity set-up increased significantly after the implementation of changes compared to the productivity of sales representatives involved in designs with no or only partial complementarity set-ups. In addition, our results showed that when the more aligned IT system was used without complementarities, the opposite (negative) effect could occur. Moreover, the results showed that limited or incorrectly assumed complementarity factors might negatively affect individual IT-enabled productivity. These results are in line with those of previous studies (Poon, Davis and Choi, 2009; Roberts,

2007) which demonstrated that some configurations of factors might generate positive performance while others might generate negative performance. Moreover, the study demonstrated that the learning effect from the changes made for productivity gains is not more than 3 months.

In Study B, we were able to collect data only for software programmers with innovative cognitive style. Of 113 participants that completed the experiment, only 3 have had an adaptive cognitive style and were excluded from the analysis. The majority of participants were from Europe (47%), Asia (23%) and North America (14%). Most of the participants (80%) were of male gender with an average age of 28 years old. The largest number of participants had a Bachelor's degree (39.8%), up to five (34.1%) and ten years of programming experience (30.7%). In Study B, the results showed that when completing the first session with a less aligned IT system, time scores were significantly different for innovators who were involved in 'stable' and 'dynamic' complementarity set-ups (42 minutes vs. 33 minutes, p = 0.009). Quality scores were significantly different for innovators involved in 'stable' and 'dynamic' complementarity set-ups (77% vs. 63%, p = 0.006). When completing the second session with a more aligned IT system, time scores increased for both groups. However, average session completion time increased by 7 minutes (16%) for innovators involved in a 'stable' complementarity set-up and by 18 (54%) minutes for innovators involved in a 'dynamic' complementarity set-up compared to the baseline. Nonetheless, the difference between time scores for both groups of participants became insignificant. Quality scores remained similar to the first session and the difference between these scores was statistically significant (75% vs. 62%, p = 0.002 respectively). The results demonstrate that, in comparison to the second session, time scores in the third session decreased for the participants involved in both complementarity set-ups. The average session completion time decreased by 2 minutes (4%) for innovators involved in a 'stable' complementarity set-up and by 6 minutes (12%) for innovators involved in a 'dynamic' complementarity set-up. Quality scores did not change significantly in comparison to the second assignment (73% vs. 61%, respectively, p = 0.032). Overall, besides the results that demonstrate how individual productivity of innovators differs in relation to complementarities, the study offers several insights into the design of similar experiments.

6. Methodological insights

In order to generate insights into the same target phenomenon, in our case complementarities of productive IT use, two very different research approaches have been applied. Below, we summarize the key methodological insights from both studies taken together, which may be considered by future research in the field of complementarities and individual IT-enabled productivity (Table 4).

Table 4: Key methodological insights

Insights	Description	Future research
Complementarity systems approach and complementary multiple experimental studies	Both studies demonstrate strong support for the systems approach of the complementarity theory by studying the same phenomenon with multiple complementary experimental studies	Further research could address the challenge of studying complementarities by applying multiple and complementary research methods
Productivity of individuals involved in complementarity set-ups matched with inappropriate cognitive style	While in a longitudinal field experiment, we were not able to test productivity of adaptors and innovators involved in inappropriate complementarity set-up due to practical reasons, online experiment demonstrates that innovators involved in 'stable' and 'dynamic' set-ups demonstrate different productivity	More research is needed to investigate how complementarity set-ups that are matched with inappropriate cognitive style affect individual productivity
Granularity and learning effect	The longitudinal study has low resolution while a long-time span and the opposite is for the online experiment. Therefore, these two methods produce different granularity of knowledge of the complementarity mechanisms	Future research should extend the experimental design to multiple runs before and after a more aligned IT system is used and consider granularity of knowledge when designing studies to understand learning patterns and times required to reach stabilization of IT system use
Cognitive style and mandatory/voluntary work environment	Voluntary work environment attracted individuals mostly with innovative cognitive style	Future research should take into consideration that mandatory context of IT use might provide better access to individuals with both adaptive and innovative cognitive

Firstly, the results obtained from Study A showed that complementarities introduced together with a more aligned IT system positively affected the productivity of employees. The results from Study B demonstrated that individuals with innovative cognitive style performed differently in different complementarity set-ups (stable vs. dynamic). These results provide strong support for the systems approach of complementarity theory (Ennen and Richter, 2010) which investigates the impact of a system of multiple factors on performance outcomes. In addition, these results add new and unique configurations of complementary factors for individual IT-enabled productivity studies (Athey and Stern, 2002; Autor, Levy and Murnane, 2003). Thus, two complementary experimental methods are shown to be an appropriate strategy to validate the results and the same strategy can be used in further research to address the challenge of studying the impact of complementarity set-ups on individual productivity.

Secondly, Study A showed that the productivity of a particular cognitive style increased in a particular complementarity set-up, that is, adaptors in a 'stable' complementarity set-up and innovators in a 'dynamic' complementarity set-up. However, Study A did not show whether a cognitive style could perform differently in the non-matched complementarity set-up, all else being equal. In Study B, innovators involved in a 'dynamic' complementarity set-up spent, on average, much less time performing the first assignment. However, on average, the quality was higher for applications developed by innovators involved in a 'stable' complementarity set-up. The manner in which both groups of participants learned a more aligned IT system was also quite different. Innovators involved in a 'dynamic' complementarity set-up had a greater change in completion time when learning to use the more aligned IT system first. However, the learning pattern was lower than that of innovators involved in a 'stable' complementarity set-up. These results demonstrate that more research is needed to understand how complementarity set-ups that are matched with inappropriate cognitive style affect individual productivity. The proposed complementarity set-ups in this study can further be validated in studying different groups of knowledge worker by combining complementary experimental studies.

Thirdly, both studies demonstrate that granularity of the data of the studied phenomenon can play a significant role in the obtained results. In Study A, the granularity of the data was low since individual productivity data was collected every quarter. This low granularity did not show where learning effects take place. In Study B, the granularity of the data was high and thus we can only demonstrate that the learning effect has just started. Thus, a research design that is in between the two studies may be appropriate. For example, although the data in Study A showed that it took around 3 months for individuals to learn the aligned IT system, this study did not show exactly how individuals with different cognitive styles learned and mastered this IT system. At the same time, Study B demonstrated that a learning effect was achieved from two sessions using the aligned IT system. However, the study demonstrated that the learning effect had only just emerged. Therefore, the results from both studies taken jointly showed that the learning effect of the aligned IT system requires more than two sessions, but less than 3 months daily use. Overall, future experimental research should consider the granularity of the obtained data to understand how the learning effect is achieved.

Fourthly, the two studies show jointly that there seems to be an important interaction factor that the initial research model does not take into account, namely the interaction between the cognitive style of knowledge worker and the work environment. Our results demonstrate that the work environment that is more dynamic and voluntary manifests a higher association with an innovative cognitive style than with an adaptive one. For example, Study A was conducted in real work settings, meaning that knowledge workers had to partake in the study, as it was part of their conventional work and employment. On the other hand, in Study B, participation in the experiment was voluntary. This voluntary-based approach merely attracted individuals with innovative cognitive style. One plausible conclusion is that, in order to study both cognitive styles in the same context, a mandatory context has to be used, as voluntary participation might fail to attract both cognitive styles. On the other hand, an online environment as a working environment could mostly attract individuals with innovative cognitive style, rather than individuals with adaptive cognitive style. For example, internet-based jobs are characterized as temporary and rapidly changing (Sadler, Robertson and Kan, 2009), which is more suitable for innovative individuals. This association between cognitive style and working environment seems to match findings from previous studies (Chilton, Hardgrave and Armstrong, 2005; Kirton, 2003), suggesting that a rapidly changing environment requires individuals with an innovative cognitive style. Nonetheless, more research is needed, since online work environments have not been researched extensively. All this shows the value of methodological complementarity used here. Clearly employing any single methodological approach, like the two mentioned here, would not provide these insights.

In summary, our empirical investigation demonstrated that, in order to explore complementarities and their effect on IT-enabled productivity, complementary multiple research designs are required to address the limitations of each design alone. For example, although we were able to take into account the effect of complementarities on IT-enabled productivity over time in the first study, data collected quarterly did not allow us to identify the learning effects of adopting and using the aligned IT system. On the other hand, in the second study we collected data from only three sessions (two of which were related to use of an aligned IT system), which was not enough to identify the learning effect. Therefore, since more tests are required to establish saturation with less aligned IT systems as well as more aligned IT systems, a time-series design of the experiment would be appropriate. This design would enable the assessment of productivity before and after the introduction of an aligned IT system and would lead to the identification of the existence of complementarity effects on IT-enabled productivity within a temporal sequence of events.

7. Discussion and conclusion

While researchers in IS discipline report significant advances in economic experiments due to the widespread use of recent technologies and information-intensive organizations (Gupta, 2014; Gupta, Kannan and Sanyal, 2018), researchers in organizational economics call for organizational experiments to understand what factors affect economic performance (Camerer and Weber, 2013). Recently the idea that a set of complementary factors when synchronized correctly can reinforce each other and significantly increase IT-enabled productivity received special attention, yet it is less certain how to study these complementary factors for an individual. The research of complementary factors and their effect on productivity is challenging because, unlike conventional studies where independent variables are assumed independent of each other and have a linear cause-effect relation to the dependent variables, the complementarity approach recognises that a set of factors interact with each other to generate effects on dependent variables. Although simple experiments have obvious advantages and a high value of control, field experiments are considered as powerful complements in considering organizational reality and establishing the generalisation of the results. The complementarity between multiple methods allows researchers to understand an additional and different facet of reality rather than a simple comparison of results (Bentahar and Cameron, 2015). All this demonstrates that multiple experimental studies to investigate the same phenomenon have the power to provide new theoretical and methodological insights rather than a single experiment.

By conducting two complementary studies (a longitudinal quasi-randomized field experiment and online experiment) we not only provide important theoretical implications into the studied phenomenon but also gained additional and unique methodological insights that can be used by researchers who plan to conduct similar studies that no other experimental study could provide alone. Firstly, together our two studies have important implications for the systems approach of the complementarity theory (Ennen and Richter, 2010) by confirming that when a work process, training and education, incentive, and decision-making modes are matched with appropriate adaptive-innovative cognitive style, productivity of an individual can be increased significantly. Secondly, a longitudinal study has a low resolution yet a long-time span while the opposite is true for the online experiment and thus, these two studies provide different granularity of knowledge of the complementarity mechanisms. This confirms a need to use multiple methods to address the challenge of investigating complementarities. This different granularity helped us to demonstrate that future experimental studies should be designed in a way to analyse the differences between adaptors and innovators with regard to complementarity set-ups in learning patterns (McLeod et al., 2008) and times required to reach stabilization of IT system use. Thirdly, the results from both studies jointly demonstrate that a mandatory context of IT use might provide better access to individuals with both adaptive and innovative cognitive styles than a voluntary working environment. Finally, both studies demonstrate that more detailed research is needed to understand how the productivity of individuals differs when inappropriate cognitive styles are included in complementarity set-ups. Overall, our findings show the importance of analysing complex phenomenon with multiple, different, and complementary research designs, as each design has inherent conditions with opportunities and limitations to reveal characteristics about the phenomenon being investigated.

Despite the contribution we have made, this research is subject to certain inherent limitations that may be addressed by future research. For example, we used only one instrument for measuring individual cognitive style (adaptive-innovative), because it is a well-explored, elaborated and well-tested categorization of human cognitive styles that provides a good fit with the remaining factors and responds to current organizational needs to adapt and innovate in order to remain successful. Future research may use other instruments for assessing cognitive style and formulate other complementarity set-ups. Although we used a longitudinal quasi-randomized field experiment and an online experiment, a laboratory experiment with multiple runs may provide high control over circumstances and greater internal validity. Finally, in order to increase generalisation, the formulated complementarity set-ups may be tested with other information-intensive occupations such as journalists, architects, recruiters or accountants.

References

Amabile, T.M. (1996) Creativity in Context: Update to the Social Psychology of Creativity, Boulder, CO: Westview Press, US.

Aral, S., Brynjolfsson, E. and van Alstyne, M. (2012) "Information, Technology and Information Worker Productivity", Information System Research, Vol 23, No. 3, pp 849–867.

Athey, S. and Stern, S. (2002) "The Impact of Information Technology on Emergency Health Care Outcomes", RAND Journal of Economics, Vol 33, pp 339–432.

Autor, D.H., Levy, F. and Murnane, R.J. (2003) "The Skill Content of Recent Technological Change: An Empirical Exploration", Quarterly Journal of Economics, Vol 118, No. 4, pp 1279–1333.

Baer, M., Oldham, G.R. and Cummings, A. (2003) "Rewarding Creativity: When Does It Really Matter?", Leadership Quarterly, Vol 14, pp 569–586.

Bazeley, P. (2015) "Mixed Methods in Management Research: Implications for the Field", Electronic Journal of Business Research Methods, Vol 13, No. 1, pp 27–35.

Bender, S., Bloom, N., Card, D., Van Reenen, J. and Wolter, S. (2018) "Management Practices, Workforce Selection, and Productivity", Journal of Labor Economics, Vol 36, No. S1, pp S371–S409.

Bentahar, O. and Cameron, R. (2015) "Design and Implementation of a Mixed Method Research Study in Project Management", Electronic Journal of Business Research Methods, Vol 13, No. 1, pp 3–15.

Bloom, N. and van Reenen, J. (2011) "Human Resource Management and Productivity", in Ashenfelter, O. and Card, D. (eds) New Developments and Research on Labour Markets: Handbook of Labour Economics, Elsevier, Vol 4b, pp 1697–1767.

Brynjolfsson, E. (1993) "The Productivity Paradox of Information Technology", Communication of the ACM, Vol 36, No. 12, pp 67–77.

Brynjolfsson, E. and Milgrom, P. (2013) "Complementarity in Organizations", in Gibbons, R. and Roberts, J. (eds) The Handbook of Organizational Economics, Princeton University Press, NJ, pp 11–55.

Camerer, C.F. and Weber, R.A. (2013) "Experimental Organizational Economics", in Gibbons, R. and Roberts, J. (eds) The Handbook of Organizational Economics, Princeton University Press, NJ, pp 213–262.

Cardona, M., Kretschmer, T. and Strobel, T. (2013) "ICT and Productivity: Conclusions from the Empirical Literature", Information Economics and Policy, Vol 25, No. 3, pp 109–125.

Chilton, M.A., Hardgrave, B.C. and Armstrong, D.J. (2005) "Person-Job Cognitive Style Fit for Software Developers: The Effect on Strain and Performance", Journal of Management Information Systems, Vol 22, No. 2, pp 193–226.

Devaraj, S. and Kohli, R. (2003) "Performance Impacts of Information Technology: Is Actual Usage the Missing Link?", Management Science, Vol 49, No. 3, pp 273–289.

Ennen, E. and Richter, A. (2010) "The Whole Is More Than the Sum of Its Parts – Or Is It? A Review of the Empirical Literature on Complementarities in Organizations", Journal of Management, Vol 36, No. 1, pp 207–233.

Gibbons, R. and Roberts, J. (2013), The Handbook of Organizational Economics (pp. 213–262). Princeton University Press.

Gupta, A., Kannan, K. and Sanyal, P. (2018) "Economic Experiments in Information Systems", MIS Quarterly, Vol 42, No. 2, pp 595–606.

Gupta, S. (2014) "SEM for Experimental Designs: An Information Systems Example", Electronic Journal of Business Research Methods, Vol 12, No. 1, pp 27–40.

Hassett, M.E. and Paavilainen-Msntymski, E. (2013) Handbook of Longitudinal Research Methods in Organisation and Business Studies, Edward Elgar Publishing, Cheltenham.

Hopp, W.J., Iravani, S.M.R. and Liu, F. (2009) "Managing White-Collar Work: An Operations-Oriented Survey", Production and Operations Management, Vol 18, No.1, pp 1–32.

Jain, V. and Kanungo, S. (2013) "Realizing IT Value: Post Adoptive IS Usage and Performance Impacts at Individual Level", International Journal of Business Information Systems, Vol 14, No. 2, pp 202–222.

Jain, V. and Kanungo, S. (2016) "Working Smarter or Working Harder? Complementary Relationship Between Extent of IS Use and Nature of IS Use", International Journal of Business Information Systems, Vol 21, No. 4, pp 512–540.

Kirton, M. (1976) "Adaptors and Innovators: A Description and Measure", Journal of Applied Psychology, Vol 61, No. 5, pp 622–629.

Kirton, M.J. (2003) Adaption-Innovation: In the Context of Diversity and Change, NY: Routledge, New York.

MacCormack, A., Verganti, R. and Iansiti, M. (2001) "Developing Products on "Internet Time": The Autonomy of a Flexible Development Process", Management Science, Vol 47, No. 1, pp 133–150.

McLeod, A., Clark, J., Warren, J. and Dietrich, G. (2008) "The Impact of Information Systems on End User Performance: Examining the Effects of Cognitive Style Using Learning Curves in an Electronic Medical Record Implementation", Communications of the Association for Information Systems, Vol 22, pp 165–184.

Milgrom, P. and Roberts, J. (1990) "The Economics of Modern Manufacturing: Technology, Strategy, and Organization", American Economic Review, Vol. 80, No.3, pp 511–528.

Milgrom, P. and Roberts, J. (1995) "Complementarities and Fit: Strategy, Structure, and Organizational Change in Manufacturing", Journal of Accounting and Economics, Vol 19, pp 179–208.

Mingers, J. (2003) "The Paucity of Multi-Method Research: A Review of The Information Systems Literature", Information Systems Journal, Vol 13, pp 233–249
North, K. and Gueldenberg, S. (2011) Effective Knowledge Work: Answers to the Management Challenges of the 21st Century, Emerald Group Publishing Limited, United Kingdom.
Palvalin, M., Lönnqvist, A. and Vuolle, M. (2013) "Analysing the Impacts of ICT on Knowledge Work Productivity", Journal of Knowledge Management, Vol 17, No. 4, pp 545–557.
Parmigiani, A. and Mitchell, W. (2009) "Complementarity, Capabilities, and the Boundaries of the Firm: The Impact of Within-Firm and Interfirm Expertise on Concurrent Sourcing of Complementary Components", Strategic Management Journal, Vol. 30, No. 10, pp 1065–1091.
Poon, S.K., Davis, J.G. and Choi, B. (2009) "Augmenting Productivity Analysis with Data Mining: An Application on IT Business Value", Expert Systems with Applications, Vol 36, No. 2, pp 2213–2224.
Pyöriä, P. (2005) "The Concept of Knowledge Work Revisited", Journal of Knowledge Management, Vol 9, No. 3, pp 116–127.
Reips, U.-D. (2002) "Standards for Internet-Based Experimenting", Experimental Psychology, Vol 49, pp 243–256.
Roberts, J. (2007) The Modern Firm: Organizational Design for Performance and Growth, Oxford University Press, Oxford.
Ryan, R. and Deci, E.L. (2000) "Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions", Contemporary Educational Psychology, Vol 25, No. 1, pp 54–67.
Sabherwal, R. and Jeyaraj, A. (2015) "Information Technology Impacts on Firm Performance: An Extension of Kohli and Devaraj (2003)", MIS Quarterly, Vol 39, No. 4, pp 809–836.
Sadler, K., Robertson, T. and Kan, M. (2009) "Exploring the Project Transitions and Everyday Mobile Practices of Freelancers: Emergent Concepts from Empirical Studies of Practice", Proceedings of the 21st Annual Conference of the Australian Computer-Human Interaction Special Interest Group: Design: Open 24/7, ACM, pp 81–88.
Schryen, G. (2013) "Revisiting IS business Value Research: What We Already Know, What We Still Need to Know, And How We Can Get There", European Journal of Information Systems, Vol 22, No. 2, pp 139–169.
Sense, A. (2007) "Structuring the Project Environment for Learning", International Journal of Project Management, Vol 25, No. 4, pp 405–412.
Singh, S.K., Burgess, T.F. and Heap, J. (2016) "Managing Performance and Productivity for Organizational Competitiveness", International Journal of Productivity and Performance Management, Vol 65, No. 6.
Solow, R. (1987) "We'd Better Watch Out", New York Times Book Review, July 12, 36.
Weber, B. and Wild, W. (2005) "Towards the Agile Management of Business Processes", in Althoff, K.D., Dengel, A., Bergmann, R., Nick M. and Roth-Berghofer, T. (eds) Professional Knowledge Management, Third Biennial Conference, WM. Berlin Heidelberg, Springer, Berlin, pp 409–419.
Wolfe, C.R. (2017) "Twenty Years of Internet-Based Research at SCiP: A Discussion of Surviving Concepts and New Methodologies", Behavior Research Methods, Vol 49, No. 5, pp 1615–1620.
Womer, N. (1984) "Estimating Learning Curves from Aggregate Monthly Data", Management Science, Vol 30, No. 8, pp 982–992.

