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Resource Complementarity and IT Economies of Scale: Mechanisms and Empirical Evidence

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ABSTRACT
In this study, we explore economies of scale for IT infrastructure and application services. An in-depth appreciation of economies of scale is imperative for an adequate understanding of the impact of IT investments. Our findings indicate that even low IT spending organizations can make a difference by devoting at least 60% of their total IT budget on IT infrastructure in order to foster economies of scale and extract strategic benefits.

KEYWORDS
Business productivity; economies of scale; IT productivity; IT value; resource complementarity; shared IT services

Introduction

Information technology (IT) has become increasingly "commoditized" (Carr, 2003). Yet, even as technology matures, debates continue to persevere over its benefits (Aral & Weill, 2007). While organizations have devoted substantial resources to IT investments in hope of generating comparable economic returns, past studies reported mixed results regarding the benefits to be gleaned from such investments, thereby culminating in a productivity paradox (Brynjolfsson & Hitt, 1998; Mithas, Tafti, Bardhan, & Goh, 2012). In light of prior evidence that alludes to the effective and efficient deployment of IT as a prime determinant of successful organizations (Bharadwaj, 2000; Mithas et al., 2012), it calls into question the strategic value of technology since the commoditization of IT equalizes competition among organizations. If all organizations have homogeneous access to the same technology, is it possible to enact management strategies to outperform competitors? To answer this question, Barron (1992) and Kitchenham (2002) appealed for a closer inspection of IT economies of scale as a probable source of competitive advantage for organizations.

As acknowledged by Melville, Kraemer, and Gurbaxani (2004), approaches grounded in the *resource-based view* (RBV) are most appropriate for explaining disaggregated effects of value drivers through IT usage. In addition, the suitability of RBV as a theoretical lens for exploring the impact of IT-enabled value drivers has also been verified in a number of parallel studies in the likes of Clemons and Row (1991) and Mithas and colleagues (2012). RBV holds that organizational performance is tied to firm-specific resources and capabilities, which are inimitable, rare, and non-substitutable (Barney, 1991). Despite its merits, the RBV tends to neglect the fact that resources rarely act alone in creating and/or sustaining competitive advantages within organizations. This is especially true for IT resources. In almost all cases, IT resources need to be combined with other organizational resources to produce strategic benefits (Ravichandran & Lertwongsatien, 2002). Indeed, there is an abundance of empirical evidence that testifies to the complementary role of IT in organizations' resource configurations. Powell and Dent-Micallef (1997) observed that the complementary deployment of IT and human resources leads to superior organizational performance. Similar conclusions were reached by Benjamin and Levinson (1993), who surmised that organizational performance is dependent on the integration of IT with other business-related resources. Arguably, *resource complementarity* is a significant moderator mitigating the impact of IT on organizational performance (Wade & Hulland, 2004). Yet, the process by which IT resources interact with other organization resources is poorly understood, as is the nature of such resources (Ravichandran & Lertwongsatien, 2002). Resource complementarity thus persists as an elusive and understudied area of research within extant literature

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uism.

on IT-driven organizational performance (Wade & Hulland, 2004).

This study distinguishes between infrastructural and application resources as focal sources of IT-driven resource complementarity within organizations. Though there is no direct evidence to validate our claim thus far, allusions to the pivotal role of infrastructural and application resource configurations in bolstering organizational performance can be found in previous studies. Zhu (2004) discovered that both front-end and back-end capabilities contribute to e-business value. The same sentiments were echoed by Aral and Weill (2007), who noted that organizations with superior corporate performance are often those that align investments in IT infrastructure and applications with business practices and competencies. They further observed that complementarity between business and IT resources enable these top performers to spend 10% less on technological investments than the industrial average (Aral & Weill, 2007). Conceivably, the presence of complementarities within infrastructural and application resource configurations would affect organizations' ability to generate economies of scale and, in turn, improve organizational performance for both the IT conversion process and business conversion process (Soh & Markus, 1995). Integrating the research streams of economies of scale and resource complementarity, we contend competitive advantage is derived from investing in complementary infrastructural and application resources and manifest in the form of economies of scale within organizations. To this end, this study endeavours to answer the following two research questions:

(1) To what extent do IT infrastructure services foster economies of scale in the IT conversion process?
(2) To what extent do IT application services foster economies of scale in the business processes?

We subject these research questions to empirical validation based on analyzing the IT investment portfolios of housing corporations situated in the Netherlands. In doing so, this study contributes to theory in four ways: (1) augments the RBV of IT by exploring the impact of resource complementarity on the effectiveness of the IT conversion process and the productivity of business processes within organizations; (2) synthesizes extant literature in positing economies of scale as a prominent outcome of resource complementarity; (3) advances a theoretical model together with testable hypotheses on how IT investments relate to organizational performance, and; (4) verifies the veracity of hypothesized relationships espoused in our theoretical model.

This article is organized as follows. First, we offer a brief overview of extant literature on the RBV of IT as well as economies of scale in business and IT. Next, we construct our theoretical framework together with testable hypotheses. This is then followed by a description of the data and methodology. Our dataset for this study consists of 109 organizations for which data were available from 2002 to 2011. We then present the results from our data analysis. Our results suggest a significant effect of IT infrastructural resource configurations in generating economies of scale within the IT conversion process. Finally, we discuss these findings and address their implications in a concluding section.

Theory, constructs, and hypotheses

RBV

Barney (1991) alleged that organizations acquire competitive advantage from leveraging firm-specific resources difficult to imitate and not strategically substitutable by other resources. In this sense, IT assets can hardly be construed as a source of sustained competitive advantage due to their commodity-like nature (Mata, Fuerst, & Barney, 1995; Ray, Muhanna, & Barney, 2005). Instead of relying on independent IT resources as basic units of competitiveness within organizations, Grant (1991) and Makadok (2001) countered that sustainable competitive advantage can only be derived from assembling these resources to yield unique capabilities, which are inaccessible to competitors. Likewise, Santhanam and Hartono (2003) also advocated a capability view of IT resources by arguing that the ease with which competitors may be able to duplicate organizations' investments in IT resources erodes the competitive value of such resources. Rather, it is the manner by which organizations leverage their IT resources to create unique capabilities that impact their eventual performance (Clemons & Row, 1991; Mata et al., 1995). Even if independent resources can be readily copied across organizations, it remains much harder to replicate firm-specific resource configurations comprising a blend of business processes, technological architectures, and the related *synergies* among them (Barua & Whinston, 1998; Collis & Montgomery, 1995). For this reason, several scholars promoted a complementarity view of IT resources in order to glean insights into how technological investments can translate into sustainable competitive advantages for organizations (Bharadwaj, 2000; Wade & Hulland, 2004; Zhu, 2004).

Zhu (2004) defined resource complementarity as the configuration of technological, infrastructural, and business resources to create synergies and generate greater returns in one another's presence. Resource complementarity hence captures the scenario whereby the value of a resource is significantly enhanced through producing greater returns in the presence of another resource than by itself (Milgrom, Qian, & Roberts, 1991). Conceivably, the notion of complementarity implies a more complex role for IT resources within the organization (Alavi & Leidner, 2001; Henderson & Venkatraman, 1994; Wade & Hulland, 2004). In the same way that software applications are rendered useless without accompanying technological hardware (and vice versa), IT resources play a complementary role in conjunction with other organization resources (Keen, 1993; Walton, 1989). Yet, the nature of this role remains largely unexplored. Kettinger, Grover, Guha, and Segars (1994) conceded that IT-driven performance rests on organizations' solid technological infrastructure but offer little guidance on how this might be realized. Similarly, Jarvenpaa and Leidner (1998) acknowledged that IT assets can generate competitive value only if deployed in ways that coexist with and complement preexisting business functions and human resource management practices within organizations. Despite resource complementarity being well-recognized as a benefit of IT (Aral & Weill, 2007; Zhu, 2004), there is a paucity of studies that seek to unravel the intricate relationship between resource complementarity and organizational performance.

In this study, we distinguish between resource complementarity on the IT infrastructural level and the IT application level. McKay and Brockway (1989) were among the first to define *IT infrastructure* as an integrated set of reliable IT services that support existing applications and new initiatives. IT infrastructure, in their view, is composed of three distinct resources: (1) IT components resources; (2) human IT infrastructure, and; (3) shared IT services or general IT capabilities. IT components resources are commodities like computers, printers, routers, database software, and operating systems. The human IT infrastructure includes the knowledge, skills, policies, standards, and experience required for binding IT components to the underlying supportive services. Shared IT services include supportive services such as the management of operating and database systems as well as desktop services (Nyrhinen, 2006). These shared IT services lay the foundation for communication exchange across the organization—a prerequisite for the successful implementation and deployment of present and future business applications (Allen & Boynton, 1991; McKay & Brockway, 1989; Weill, 1993). Resource complementarity at the IT infrastructural level has been investigated in the form of "IT infrastructure flexibility" (Duncan, 1995). IT infrastructure flexibility refers to the degree to which a firm's technical and human resources are shareable and reusable (Duncan, 1995). This, in turn, drives the speed and cost with which the firm can respond to changes in the marketplace (Broadbent, Weill, & St. Clair, 1999; Byrd & Turner, 2000; Kumar, 2004; Peppard & Ward, 2004). Failure to invest in flexible IT infrastructure, which is essential for integrating newly installed business applications, may reduce the benefits of technological investments (Davern & Kaufman, 2000). Aral and Weill (2007) noted that while top performers in financial services spend 10% less on IT than the average financial organization, they spend much more in flexible IT infrastructures. In this research, we investigate how flexible IT infrastructure services will lead to economies of scale in the IT conversion process.

Despite a large body of literature on the business value of IT, the impact of specific types of *IT applications* remains unclear (Melville et al., 2004). Prior research observed that the successful application of IT is often accompanied by complementary capabilities, including organizational structure, decision-making processes, and other firm-specific business practices (Banker, Bardhan, Lin, & Chang, 2006). The appropriate use of IT applications is not well-comprehended, particularly in areas such as defining what constitutes suitable and beneficial use, and how the use of IT actually shapes varying aspects of business performance (Peppard & Ward, 2004). Though there is an abundance of literature about evaluations of IT investments (see for example Bharadwaj, 2000; Karimi, Somers, & Bhattacherjee, 2007; Kim, 2004), there is a dearth of research that examines how value is actually unlocked by complementary applications. A recent study by Mithas and colleagues (2012) attributed business revenue growth to the capabilities of IT in: (1) delivering novel value propositions; (2) establishing new marketing and sales channels; as well as (3) improving the management of the customer life cycle. The study, however, fails to offer evidence for the positive impact of IT in reducing operational costs (Mithas et al., 2012). Findings suggest that firms have had greater success in achieving higher profitability through IT-enabled revenue growth than through IT-enabled cost reduction (Mithas et al., 2012). In this study, we explore whether IT applications services will lead to cost reduction by economies of scale in business processes.

A number of studies espoused a "process-oriented" view that draws attention to the effects of IT resources on intermediate business processes (Barua & Whinston, 1998; Bharadwaj, 2000; Soh & Markus, 1995). For our study, we draw on Soh and Markus's (1995) IT Value Creation Model (ITVCM) to draw a distinction in resource complementarity between the IT infrastructural level and the IT application level. According to the ITVCM, IT expenditures lead to IT assets (i.e., IT conversion process), IT assets lead to IT impacts (i.e., IT use process), and IT impacts lead to organizational performance (i.e., competitive process). Extending these basic ideas, we present a conceptual framework of IT value creation in which the IT use process and the competitive process are merged to form the business conversion process. Consequently, the scale of IT assets depends on economies of scale derived from: (1) the agile application of: flexible IT infrastructures and well-intended application services; as well as (2) skillful implementation through knowledgeable users (Soh & Markus, 1995). This conceptual framework is illustrated in Figure 1. As stated above, we investigate how the IT conversion process can benefit from flexible IT infrastructure services due to the implementation and deployment of new application services in an efficient and rapid manner. In addition, we also investigate whether the business conversion process will benefit from IT application services due to resource complementarity between application services and knowledgeable users.

Economies of scale in business and IT

A central premise of economies of scale is that specialization coupled with congruent work volumes increase productivity (Canback, Samouel, & Price, 2006; Silberston, 1972; Smith, 1776). An example of economies of scales in the IT conversion process could be the outsourcing of technologically-stable systems to large scale application service providers (Lacity & Willcocks, 2001). Economies of scale in industry have been investigated by McConnell (1945) and Stigler (1958). The relationship between average cost and scale is depicted in Figure 2, where the average unit cost (AUC) vary with the amount of output (S) produced. The AUC for scale (S) depend on the total cost (TC) divided by quantity (S). The formula is (Besanko, Dranove, Shanley, & Schaefer, 2010):

$$AUC(S) = \frac{\mathrm{TC(S)}}{S}$$

Furthermore, the cost per unit decrease until effort level S_1 is reached. In between S_1 and S_2, there is an *inert area* without scale effects. Beyond this inert area, unit costs will rise again (S_2) and diseconomies of scale materialize as a consequence. Example of such diseconomies of scale are increasing requirements for organizational controls (Williamson, 1967). The notion of economies of scale, conceptualized in terms of the two effort levels S_1 and S_2 and the inert area in between S_1 and S_2, is depicted in Figure 2.

Studies on economies of scale in *software development* confirmed the model in Figure 2 with $S_1 = S_2$ (Banker & Kemerer, 1989; Banker et al., 1984). Prior research on economies of scale effects in *IT management* demonstrate a counter-intuitive absence of economies of scale due to constant returns to scale for IT, be it increasing or decreasing (Barron, 1992; Kang, 1989; Mendelson, 1987). Extant literature on IT and *business productivity* differentiates between labor productivity resulting from the simple substitution of labor by IT and the advantages to be gained from fundamental improvements made to managerial practices, business processes, and strategies (Bresnahan, Brynjolfsson, & Hitt, 2002; Brynjolfsson & Hitt, 2003; Davenport & Short, 1990). The former is labeled as capital deepening, whereas the latter is referred to as multi-factor productivity or total factor productivity. Input-driven productivity may involve the substitution of certain types of capital or labor inputs by IT. That is, capital deepening may be associated with economies of scale effects when the production function demonstrates decreased returns to scale.

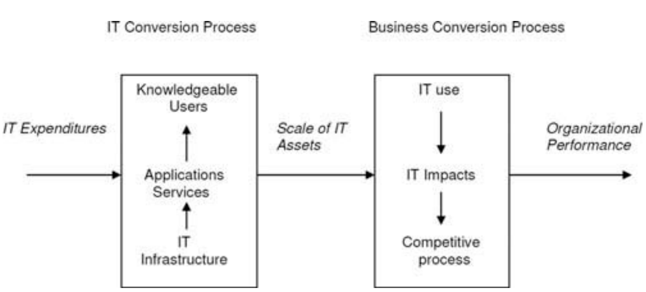

Figure 1. Conceptual framework of ITVCM (adapted from Soh and Markus [1995]).

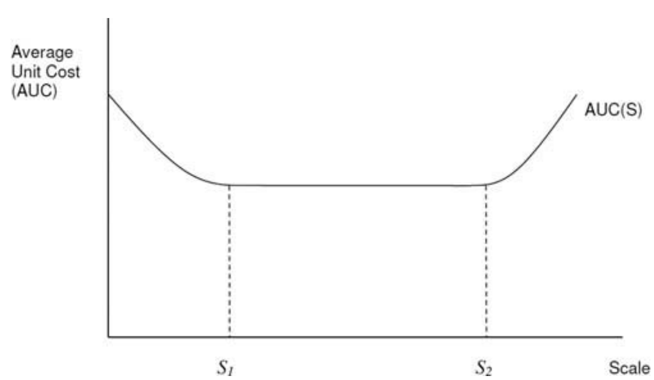

Figure 2. McDonnell/Stigler relationship between unit cost and scale (McConnell, 1945; Stigler, 1958).

To our knowledge, this study is the first of its kind to concurrently scrutinize the impact of resource complementarity on economies of scale in the IT conversion and business processes. We investigate whether: (1) shared IT infrastructure services will lead to economies of scale in the IT conversion process; and (2) IT applications services will lead to economies of scale in business processes.

Formulation of hypotheses

The applied concepts in this study have been introduced in the preceding sections. In our study, we are typically interested in organizations able to exploit lower IT expenditures to attain comparatively better or similar business outputs. By focusing on efficient organizations with more proficient conversion processes, we eliminate competitive effects and can channel our efforts toward deciphering the relationship between IT investments and organizational performance. The elementary model regarding productivity is (Chew, 1988):

$$Productivity = Output/Input$$

Consequently, the productivity of the IT conversion process, converting IT expenditures (input) into scale of IT assets (output; see Figure 1) equals:

$$Scale\ of\ IT\ assets/ITexpenditures$$

The productivity of the IT conversion process will benefit from a flexible IT infrastructure (Aral & Weill, 2007; IDC, 2007). In a way, the *degree of shared IT services* (shared infrastructure versus application-specific infrastructure services) can be construed as a consequence of the degree of complementarity between infrastructure resources and applications. As highlighted in the above discussion, shared IT services play a deterministic role in the productivity of the operational IT conversion process (see scale < S_1 in Figure 2). We therefore hypothesize:

(H1a) A high degree of ("many") shared IT services coincides with economies of scale in the IT conversion process.

And vice versa:

(H1b) A low degree of ("few") shared IT services coincides with diseconomies of scale in the IT conversion process.

Next, we define the business conversion process as the conversion from IT assets (input) into organization performance (output; see Figure 1). The productivity of the business conversion process (see Figure 1) is defined as the quotient:

Organizational performance /Scale of IT assets

The productivity of the business conversion process will benefit from adequate IT applications (Bharadwaj, 2000; Mithas et al., 2012). Likewise, the adequacy of applications can be conceived as a function of the degree of complementarity between IT applications and the business conversion process. With respect to the business conversion process, we assume its complexity would grow by the square of the scale, thus causing diseconomies of scale and leading to lower than average organizational performance at a higher scale (see scale > S_2 in Figure 2). However, if these processes would be structured and supported by application services, economies of scale could be attained from application resource complementarity (see scale < S_1 in Figure 2). We therefore hypothesize:

(H2a) A high degree of ("many") application services coincides with economies of scale in the business conversion process.

And vice versa,

(H2b) A low degree of ("few") application services coincides with diseconomies of scale in the business conversion process.

Melville and colleagues (2004) stressed the importance of external effects on organizational performance. In other words, the profitability of the market may also affect the performance of the organization. We will therefore control for these effects by analyzing data from a single industry: housing corporations.

Method and data

Empirical datasets

For this research, we draw on housing corporations' data from the period 2002 to 2011. Housing corporations build, manage, and rent out affordable houses. In the Netherlands, these organizations act independently and on a nonprofit basis. Housing corporations are particularly suited for comparison because these organizations share similar business processes even though they differ in size and management processes. The primary data were made available through the consultancy company, M&I/Partners, which has ample experience in this industry (Eekeren et al., 2006).

The IT costs of 35 housing corporations, which are included in our sample for data analysis, for the year 2015, are depicted in Figure 3. IT costs have been subdivided into *application cost* and *infrastructure cost*, which were subsequently divided by total number of workstations. Infrastructure cost include hardware,

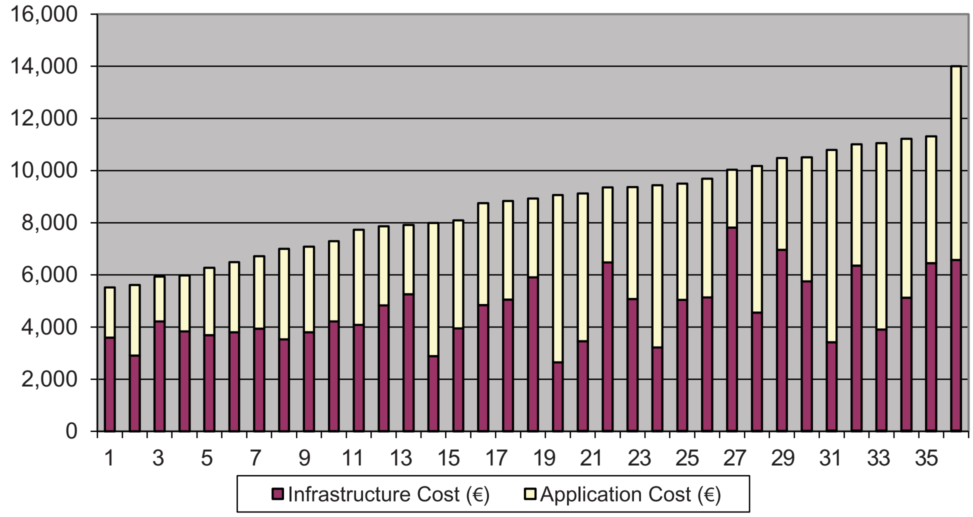

Figure 3. Housing corporations' IT costs per workstation (€) for 2015.

software, and personnel cost categories. Applications cost includes software and personnel cost categories. Data were gathered in accordance with well-accepted definitions of the aforementioned cost categories and in consultation with the financial departments of the housing corporations. All source data have been validated by housing corporations' management. The total number of data points is 338 and includes data from 109 organizations for the period 2002 to 2011. Of these 109 organizations, 32 organizations appear only once, 27 appear twice, 16 appear three times, 10 appear four times, eight appear five times, five appear six times, four appear seven times, one appears eight times, four appear nine times, and the remaining two appear 10 times. The average IT spending of the 338 organizations on an annual basis was 2.1% of total cost and amounts to €7800 per workstation per year; the average number of workstations is 270 per organization.

Construct operationalization

Scale of the IT assets is measured by the number of workstations, a commonly used representation (Gartner, 2007; IDC, 2007). The annual IT expenditures of the organizations in the dataset are computed based on Maanen and Berghout's (2002) total cost of ownership (TCO) model. This model discerns hardware, software, and human costs per TCO-entity. In accordance with our TCO model, we differentiate between infrastructure components (i.e., hardware and software) and application components (i.e., software). IT expenditure was measured by the total annual IT costs of the organization (i.e., summed costs of hardware, software, and human resources). The *degree of shared IT services* was measured by the infrastructure part of the total IT cost. This measure is called the *infrastructure factor* (IF):

Infrastructure factor (IF) = (Costs of infrastructure components and infrastructure human resources) /(Total IT cost)

Furthermore, *average IF cost* was calculated based on the years that precede a particular year, including that year. For example, if organization data were available for the years 2002 to 2011, the average IF for 2011 would be the average of the IF values for the years 2002 to 2011. Conversely, if organizational data for specific years is missing, then only data from the available years contribute to the average IF value. The *degree of application services* was measured by the applications part of the total IT cost (i.e., costs of application components and application human resources). Since total IT cost is the sum of infrastructure cost (including human resources) and application cost (including human resources), the degree of application services equals *1–IF*. For the measurement of the *organizational performance* of the housing corporations, the dataset provides the annual revenue in Euro, which was divided by the number of workstations to arrive at the business productivity for each organization.

Methodology

Our research methodology comprises three steps to identify high and low infrastructure organizations. These three steps are described below.

(1) First, the following variables are identified for each organization for each of the 10 years:

a. The average infrastructure factor (IF);
b. The total IT cost (x);
c. The number of workstations (y); and
d. The IT productivity value (y/x).

(2) For each year (1, 2, until 10), the IT productivity value of each organization was computed. To verify H1 (IF values have a significant and positive correlation with IT productivity values), the group of organizations with the highest IF values were compared to a group (of the same size) with the lowest IF values in terms of productivity values (the middle group was excluded). If both ANOVA and Mann-Whitney tests were statistically significant (i.e., $p < 0.05$), it implies a substantial difference between the IT productivity values of the two groups for a particular year. In year 1, the high (and low) IF group consists of m_1 organizations. The value of m_1 was determined as follows. The initial sample size is $m_1 = n_1$ /2–1. In the event when there was no substantial difference, the group size was, subsequently, decreased until the two groups were significantly different. We refer to these groups as m_1 organizations in year 1, m_2 organizations in year 2, until m_{10} organizations in year 10. If, for a certain year, no substantial difference could be found for any group size, then the data of that year was excluded from the next step (three).

(3) Regression analysis was performed on the total of the m_1+m_2+…+ m_{10} organizations with high IF values for all 10 years, resulting in a(high), b (high), and R^2(high) in the equation $y = a.\ x^b$. The same values were computed for the low infrastructure groups, where the total of m_1+m_2 +…+ m_{10} organizations resulted in a(low), b (low) and R^2(low).

The abovementioned three steps were then repeated to validate our second hypothesis:

(1) First, the following variables are identified per organization for each of the 10 years:
a. The average infrastructure factor (IF);
b. The number of workstations (x);
c. The revenue (y); and
d. The business productivity value (*y/x*).

(2) For each year (1, 2, until 10) the business productivity value of each organization was computed. To verify H2 (values 1–IF have a significant and positive correlation with business productivity values), the group of organizations with the highest IF values were compared to a group (of the same size) with the lowest IF values in terms of productivity values (the middle group was excluded). If both ANOVA and Mann-Whitney tests were statistically significant (i.e., $p < 0.05$), it implies a substantial difference between the business productivity values of the two groups for a particular year. In year 1, the high (and low) IF group consists of m_1 organizations. The value of m_1 was determined as follows. The initial sample size is $m_1 = n_1$ /2–1. In the event when there was no substantial difference, the group size was, subsequently, decreased until the two groups were significantly different. We refer to these groups as m_1 organizations in year 1, m_2 organizations in year 2, until m_{10} organizations in year 10. If for a certain year, no substantial difference could be found for any group size, then the data of that year was excluded from the next step (three).

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The technique to find the subgroups with relevant dis/economies of scale is inspired by data trimming techniques, which has been utilized to obtain more precise indicators in performance management (Menascé & Bennani, 2003), and support vector machine techniques (Viaene, Derrig, Baesens, & Dedene, 2002). Data suspected of containing local optima must be trained by systematic supervised elimination of records in view of particular goal functions, such as economies of scale in this study. The technique is not about bypassing data, but rather, trying to identify relevant subsets.

Data analysis and findings

This section presents findings from our data analyses. Table 1 summarizes the results from steps one and two of the analytical procedure outlined in the preceding methodology section. The number of organizations with low IF and high IF values is mentioned together with the corresponding *p*-value, which reflects the maximum of the ANOVA *p*-value and the Mann-Whitney *p*-value. Results are summarized in columns three and

Table 1. Results from ANOVA /Mann-Whitney Analyses (steps one and two).

Year	Total number of organizations	H1: IT productivity = workstations /IT cost		H2: Business productivity = revenue /workstations	
		No. organizations w/ low/high IF	*p*-Value	No. organizations w/ low/high IF	*p*-Value
2002	23	6	0.15	6	0.037*
2003	24	7	0.018*	5	0.011*
2004	35	15	0.035*	7	0.179
2005	39	8	0.024*	12	0.021*
2006	37	10	0.041*	5	0.009*
2007	38	7	0.004*	13	0.043*
2008	41	3	0.046*	4	0.149
2009	34	7	0.025*	16	0.522
2010	40	6	0.015*	19	0.013*
2011	39	4	0.064	15	0.178
Number of organizations [$p < 0.05$]		63		60	

*Significant at $p < 0.05$.

four of Table 1. For example, in the year 2007, the total number of 38 organizations was divided into seven organizations with high IF values, seven organizations with low IF values, and a middle group of 24 organizations. The associated *p*-value is significant at $p = 0.004$. We will draw on these outcomes to validate our first hypothesis.

For the validation of our second hypothesis, we are comparing the business productivity values (revenue/workstations) between the low and high IF groups. The first two steps have been recalculated as outlined in the previous section. Results are summarized in columns five and six of Table 1. For instance, in year 2007, the total number of 38 organizations was divided into 13 organizations with high IF values (corresponding with low application services), 13 organizations with low IF values (corresponding with high application services), and a middle group of 12 organizations. The corresponding *p*-value is significant at $p = 0.043$. These outcomes will be drawn on to validate the second hypothesis.

Table 1 illustrates that for H1, there is a statistically significant difference between the low and high IF groups (that are the same size year after year according to step two of the methodology) for eight of the 10 years for the period from 2002 to 2011. The sum of the low IF (and high IF) organizations for the relevant years 2002 to 2011 is 63. For H2, there is a significant difference for six of the 10 years. The sum of the low IF (and high IF) organizations for the relevant years stands at 60.

We subsequently undertake step three of our analyses. We differentiate between those organizations with high (i.e., high IF in Table 1) and low (i.e., low IF in Table 1) spending on infrastructure. Power regression analysis was employed to determine the values of *a* and *b* in the function $y = a.\ x^b$. Table 2 presents the results for the 63 organizations in Table 1, which have been identified as those with low spending on infrastructure. Simultaneously, another group of 63 organizations has been identified as those with high spending on infrastructure. A similar analysis was performed with regards to the revenues generated by organizations with low and high spending on infrastructure. Again, Table 2 summarizes the analytical results for 60 organizations with low spending on infrastructure (i.e., corresponding to high application services) and another group of 60 organizations with high spending on infrastructure (i.e., corresponding to low application services). Table 2 shows the expected values of *b* according to our hypotheses (*Exp. b* in column three), the realized values of *b* (*Real. b* in column six), the corresponding residual square values (R^2 in column seven), and average productivity values (in column eight).

Table 2 corroborates H1a, H1b, and H2a, as the realized values of *b* match their expected values. Nevertheless, H2b was not verified because the realized value of *b* is smaller than 1. This implies that high values of business productivity do not have a positive and significant correlation with 1–IF values (i.e., with low IF values corresponding with high application services).

Figures 4 and 5 illustrate the IT productivity curves and the business productivity curves for organizations employing low infrastructure values (IF low) and

Table 2. Results from regression analyses (step three).

Hypotheses		Exp. *b*	IF	No. organizations	Real. *b*	R^2	Average productivity
H1: IT productivity = workstations /IT cost	H1a	>1	low IF	63	1.01	0.93	1 workstation /€8850
	H1b	<1	high IF	63	0.88	0.91	1 workstation /€6540
H2: Business productivity = revenue /workstations	H2a	<1	high IF	60	0.94	0.94	€376,000 /workstation
	H2b	>1	low IF	60	0.99	0.92	€461,000 /workstation

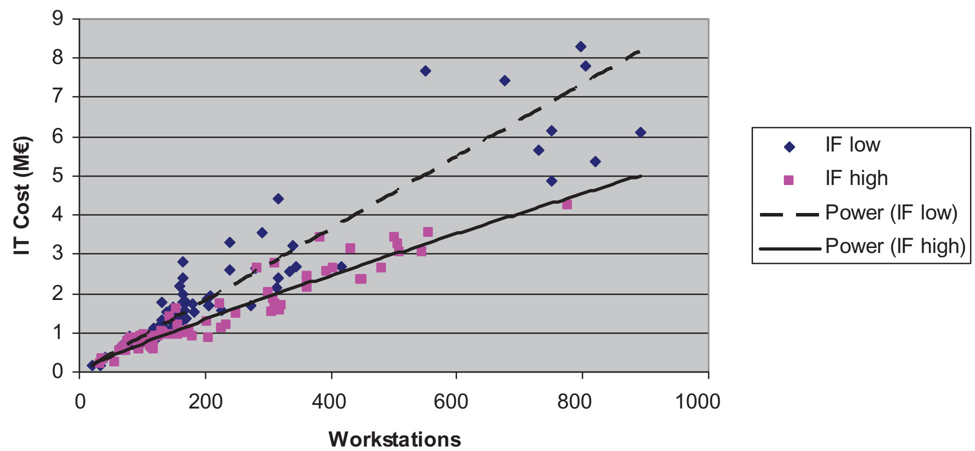

Figure 4. IT productivity for organizations with high and low spending on infrastructure.

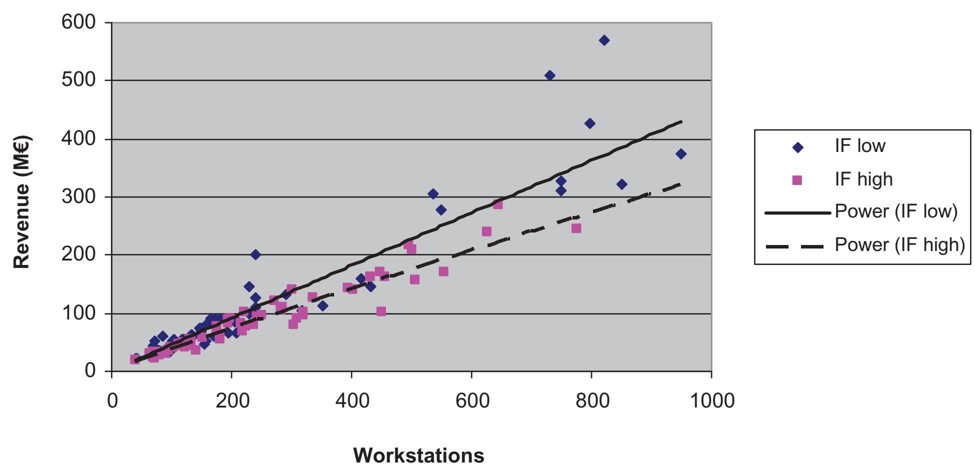

Figure 5. Business productivity for organizations with high and low spending on infrastructure.

organizations employing high infrastructure values (IF high). Note that in both Figures 4 and 5, the solid lines depict high IT and business productivity curves that resonate with high infrastructure values in Figure 4 and with low infrastructure values (i.e., high level application services) in Figure 5, respectively.

In Figure 4, the IF low curve corresponds to low average IT productivity (one workstation/€8850), whereas the IF high curve corresponds to high average IT productivity (one workstation/€6540), according to Table 2. Moreover, the average IT productivity of IF high organizations is a factor 1.35 (=8850/6540) higher than the average IT productivity of IF low organizations.

In Figure 5, the IF low curve corresponds to high average business productivity (€461,000/Workstation, see Table 2) and the IF high curve corresponds to low average business productivity (€376,000/Workstation). Moreover, the average business productivity of IF low organizations is a factor 1.23 (=461,000/376,000) higher than the average business productivity of IF high organizations.

Our first hypothesis is concerned with economies of scale of the IT conversion process. We hypothesized that a high degree of ("many") shared IT services coincide with economies of scale in the IT conversion process (H1a). We therefore expect a value of $b < 1$ in the equation $y = a.\ x^b$ for the IF high curve in Figure 4. From our data analysis, H1a was corroborated as $b = 0.88$ when the infrastructure factor is high (see Table 2). At the same time, when the infrastructure factor is low, then $b = 1.01$ according to what we would expect ($b > 1$), as in H1b (see Table 2). Likewise, rows three and four in Table 2 represent similar analyses for the revenue data of 60 organizations. Here, we postulated that a high degree of ("many") application services coincide with economies of scale in the business processes (H2a). In the IF low curve (i.e., corresponding to high application services) in Figure 5, we expect a value of $b > 1$ in the equation $y = a.\ x^b$. This hypothesis, however, was not substantiated through our empirical evidence, as Table 2 shows $b = 0.99$ when the infrastructure factor is low. On the other hand, H2b was substantiated because $b = 0.94$ when IF is high (i.e., corresponding to low application services) and we expect a value of $b < 1$. Our results thus validate H1 concerning (dis)economies of scale of (IF low) IF high organizations, and also show there is a significant difference in average IT productivity (35% higher) for the IF high versus the IF low categories. Although H2 is only partially supported, there is a notable discrepancy in average business productivity (22% higher) for the IF low (i.e., corresponding to high application services) versus the IF high categories (i.e., corresponding to low application services). We summarize the results from our hypotheses testing in Table 3.

Next, we give an indication of how low, average, and high IF values evolved over time. In the period 2002 until 2011, the average IF value of all organizations of the corresponding year is decreasing from 0.58 in 2002 to 0.50 in 2011 (see Figure 6). In the same period, the average IF value of the IF low organizations decreased from 0.44 in 2002 to 0.36 in 2011; the IF high organizations went down from 0.73 in 2002 to 0.65 in 2011. It seems reasonable to deduce that economies of scale in the IT conversion process can be realized if at least 60% of IT costs are spent on shared infrastructure services in the housing industry investigated in this study. In the discussion section, we highlight the implications of our findings for theory and practice.

Discussion

Our goal in this study is to examine the effects of economies of scale in IT management. Through analyzing a large sample of 338 data points from a single industry (housing corporations), we discovered empirical support for economies of scale in organizations with a high degree of shared IT services (i.e., H1, see Table 3). As discernible from Table 2 and Figure 4, increased sharing of IT services by applications ameliorates economies of scale in infrastructure. This answers our first research question.

Empirical evidence further reveals that the productivity of the business processes corresponds with the level of shared application services: the lower the value of IF (i.e., infrastructure part of total IT costs), the higher the level of application services and corresponding business processes productivity (see Table 2 and Figure 5). Nonetheless, we find little support for H2a (see Table 3) because insufficient economies of scale in business processes were identified for low IF values (or conversely, high level of application services). This answers the second research question.

From our empirical study, it can thus be inferred that the level of application services is a necessary but insufficient condition to realize economies of scale in business processes. This stands in contrast to shared infrastructure services, which by their presence, constitute sufficient conditions for economies of scale in the IT conversion process. This difference could be explained by the existence of other resources that also serve as inputs into business processes and hamper the effect of otherwise profitable investments. From a theoretical standpoint, we hence uncovered evidence suggesting resource complementarity of IT application services in business processes is less important than resource complementarity of shared infrastructure services in IT conversion processes for cost reductions.

In order to realize high productivity levels in the IT conversion process, organizations should invest in infrastructure above a certain threshold (i.e., a minimum level of investment in IT infrastructure). For our dataset of housing corporations, we ascertained that expenses in IT infrastructure shared services should comprise at least 60% of total IT costs in order to realize economies of scale in the IT conversion process (see Figure 6). Our study therefore affirms the earlier claims of Davern and Kaufman (2000) as well as Weill, Subramani, and Broadbent (2002), who argued failure to invest in flexible IT infrastructure to integrate new applications may curtail the benefits of technological investments in general. Consequently, this study is the first of its kind to quantify the order of magnitude of infrastructure investments.

Table 3. Summary of results from hypotheses testing.

Hypotheses		Finding
H1a	A high degree of ("many") shared IT services coincides with economies of scale in the IT conversion process.	**Supported**
H1b	A low degree of ("few") shared IT services coincides with diseconomies of scale in the IT conversion process.	**Supported**
H2a	A high degree of ("many") application services coincides with economies of scale in the business conversion process.	**Partially supported**
H2b	A low degree of ("few") application services coincides with diseconomies of scale in the business conversion process.	**Supported**

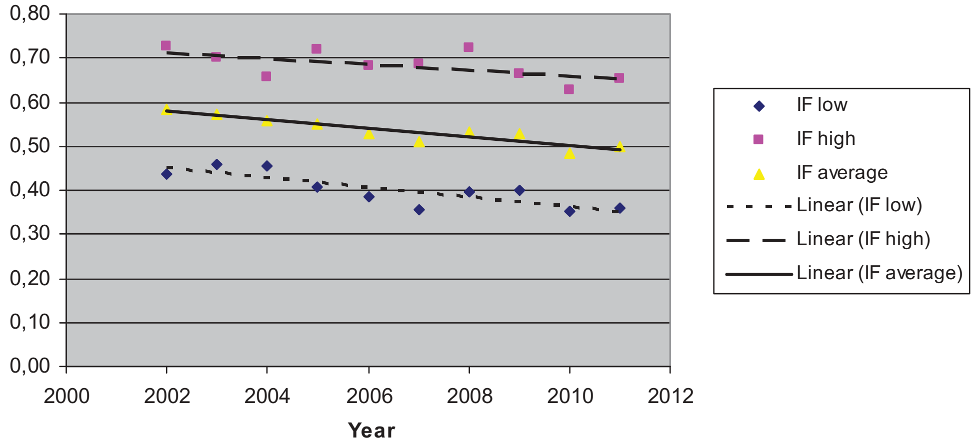

Figure 6. Development of IF values over time.

In this study, investments in IT infrastructure were determined by the average infrastructure part of an organization's total IT costs during the past years (i.e., IF as a measure of shared IT services). However, investments in IT infrastructure do not necessarily lead to shared IT (infrastructure) services if there is no overall vision and underlying architecture. The same holds for investments in applications that do not result in appropriate application services if there is no effective process in specifying and realizing these application services. We do, however, believe that, on average, challenges to realize appropriate shared IT services and application services are comparable for all organizations from a single industry (i.e., housing corporations in this case). Therefore, the "process losses" in the realization of appropriate services should be comparable for these organizations.

Figure 4 on IT productivity illustrates eight low IF organizations operating more than 600 workstations, contrasting a single high IF organization. An obvious question is whether we are merely comparing differences in size instead of efficiencies of scale. In this case, larger organizations would be less efficient, although this would contrast theories of economies of scale (Mendelson, 1987). This assumption is violated because the average company size of low IF organizations hardly differs from the average high IF organizations (i.e., 243 versus 226 workstations). This is also true for Figure 5, which includes seven low IF organizations (with high application services) and only three high IF organizations that retain over 600 workstations and where low and high IF organizations are, on average, comparable in size (i.e., 252 versus 247 workstations).

Figure 6 also illustrates that the average infrastructure expenses of housing corporations decrease from 58% in 2002 to 50% of their total IT costs in 2011, which is equivalent to a reduction of 0.8% per year. This finding is consistent with earlier findings by Weill and Johnson (2005), who observed financial services were able to decrease their mean infrastructural expenses from 54% to 46% of their total IT costs in the period 2001 to 2005. This equals a reduction of 1.6% per year. The average IT spending in financial services exceeds similar spending categories of housing corporations (i.e., 7.5% versus 2.1%), where wholesale, retail, and transport sectors spend approximately 3.6% of their total costs on IT (Weill & Johnson, 2005). Lower IT spending sectors require additional managerial scrutiny to decrease their IT expenses and concentration on consolidation of services is therefore paramount.

Conclusion

The goal of our study is to identify and analyze economy of scale effects in IT management. Although many researchers applied the RBV to IT management and IT value conversion (Melville et al., 2004; Soh & Markus, 1995), past studies faced difficulties in identifying resource complementarity in the effective use of IT resources (Wade & Hulland, 2004). We identified resource complementarity as a significant moderator mitigating the impact of IT on organizational performance. Sharing IT services increases economies of scales in the IT conversion process. Shared IT services facilitate improved utilization of technological resources and labor (or skills), which has become increasingly important with respect to the leverage of commodities. In H1, it is proposed that a higher degree of shared IT services will decrease the organization's IT expenditure given a similar scale of IT assets. Based on empirical data on 109 housing corporations, we were able to demonstrate economies of scale with respect to IT assets for (comparable) organizations with high levels of shared IT services. Furthermore, we proved diseconomies of scale for organizations with a low degree of shared IT services.

In this study, the relationships among the degree of application services, the scale of IT assets, and the organization performance have been analyzed. Better support of business processes by application services leads to economies of scale in business processes. In H2, we proposed that a higher degree of application services will increase an organization's performance given a similar scale of IT assets. We were able to demonstrate higher business productivities with respect to IT assets for (comparable) organizations with high levels of application services. Furthermore, we identified decreased business productivity for organizations with lower levels of application services. Nevertheless, we were unable to find support for economies of scale with respect to IT assets for (comparable) organizations with high levels of application services. For this reason, H2 is only partially validated.

We also highlighted economies of scale for IT departments controlling low IT budgets. Weill and Broadbent (1998) argued lower IT spending organizations should sufficiently invest in their IT infrastructure. This study is the first to confirm their view in that our results complement their line of reasoning. In order to realize high productivity in the IT conversion process, organizations need to sufficiently invest in IT infrastructure. We identified that housing corporations should, on average, spend at least 60% of their IT expenditure on infrastructure in order to attain economies of scale in their IT conversion process.

The implication for theory of this research stems from defining and operationalizing equilibrium between infrastructure and applications. Specifically, our study investigates the impact of resource complementarity on economies of scale in the IT conversion and business processes concurrently. Our findings yield, in particular, better theoretical insights to evaluate the contribution of shared IT services in managing the level of IT expenditure within organizations. Furthermore, this study is the first to apply in-company organization data to this form of analysis. Last but not least, our study counters Carr's (2003) allegation of IT commoditization as the cause of eroding competitiveness for technological investments.

This study carries certain limitations due to the confinement of our data analysis to housing corporations. While this constraint is crucial for the validity of our data analysis, it does restrict the generalizability of our results. Future research can therefore replicate our study in other homogeneous industries (e.g., hospitals or municipalities) in order to explore whether our findings hold across variations in IF.

Given the importance of economies of scale in IT management, future studies could also examine the effects of economies of scale in IT management in more detail. Examples could include studies of economies of scale of cloud services, Platform-as-a-Service (PaaS) or Services-as-a-Service (SaaS), and their effects on the IT conversion and business conversion process. We should endeavor to provide IT managers with better guidance in their efforts to allocate appropriate investments to shared IT services, while at the same time, taking appropriate account of application services.

Although IT has proven to be a commodity for organizations investigated in this study, its effective deployment is by no means a straightforward matter. We therefore conclude that large-scale rather than small-scale infrastructure investments are prerequisites for efficient deployment of IT. Analytical findings outlined in our research clearly produced novel and valuable insights into the influence of the degree of shared IT services on IT productivity.

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