Efficiency Implications of E-Procurement System Capabilities and Usage Behavior: Status Quo and Directions for Future Research

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Abstract
As the major Information System (IS) of procurement departments, e-procurement systems have already received a significant amount of attention by researchers. However, an integrated view on the efficiency implications of both e-procurement system capabilities and the corresponding usage behavior of purchasers from a welfare economics perspective is still missing. The work at hand closes this gap by providing the results of a comprehensive literature review aiming at the integration of related scientific findings. These results include the major processes typically supported by e-procurement systems, as well as a detailed view on efficiency issues of single system components. Based on a thorough discussion of these results, a number of efficiency measures, managerial implications, as well as a well-grounded agenda for future efficiency-oriented research are derived.

1. Introduction
Throughout the last decade, the activities of procurement departments were often characterized by strategic sourcing initiatives such as supply base rationalization and globalization, outsourcing, spend consolidation, or sole sourcing agreements [1]. As a result, many enterprises now feature a very low degree of vertical integration, and, in turn, are often highly dependent on their primary material suppliers. This development has often resulted in an increasing competition between entire supply chains instead of competition between single firms [2], and respective planning and coordination tasks (e.g., in the case of new product development) require a balanced consideration of the interests of all partners of a supply chain. Thereby, from the perspective of economics, it is the ultimate objective to come to a resource allocation that maximizes the welfare generated along a supply chain, including its end customers [3]. To this end, the corporate procurement function as the primary upstream process to the supply networks of an enterprise plays a vital role. Its procurement practices, nowadays often enabled by e-procurement systems, have a major impact on the welfare allocation in supply networks.

1.1. E-procurement systems

From an IS point of view, many tactical and operational benefits generated by procurement departments were achieved by employing web-based e-procurement systems supporting all major procurement innovations such as e-auctions, e-RFx and e-catalogs [4]. Peary, Giunipero and Wilson [5] summarized that the use of e-auctions within sourcing processes led to purchase price reductions of 30% in cable TV equipment, 20% in power equipment, 39% in medical supplies, 37% in public utilities, and 53% in U.S. armed forces’ purchases. Further, Robinson, Sahin and Gao [6] found that the application of an automated e-replenishment system instead of a manual-based system leads to buyer-side operational cost reductions of 19.6%, 29.5%, and 12.5% in traditional decentralized, decentralized with information sharing, and coordinated supply chain structures, respectively. Besides, supplier-provided, standardized e-catalogs along with electronically enabled self-service procurement processes disburden procurement departments from operational purchasing activities of non-production materials [7]. Generally speaking, the benefits of e-procurement can be summarized as product-related, process-related and inventory-related efficiency gains. A lot of research on different aspects of e-procurement systems has already been conducted. These aspects include procurement performance impact [8], [9], success factors [10], adoption issues in different geographical areas and industries, as well a variety of related analytical approaches, e.g., for bid selection [11]. Furthermore, as also depicted in more detail in section 3, a considerable amount of research was conducted related to single e-procurement system components such as e-auctions, e-negotiation tools or reputation mechanisms.
1.2. Welfare economics

As a sub-discipline of economics, welfare economics evaluates the efficiency of economic activities in terms of social welfare relative to a general competitive benchmark [12]. Thereby, a resource allocation is called Pareto efficient if the situation of one party cannot be improved without making the situation of another party worse. If an economic state is Pareto efficient, individuals are maximizing their utility. Under the Kaldor-Hicks efficiency, in turn, a more efficient outcome (i.e., an increased overall welfare) allows for leaving some parties worse off if the gains of those better off exceed the loss of those worse off, and if those better off in theory could compensate those worse off in a way that leads to a Pareto efficient outcome. Finally, allocative efficiency is a theoretical measure for the benefit derived through a particular distribution of scarce resources. It is possible to have Pareto efficiency without allocative efficiency, whereas a Kaldor-Hicks efficient outcome is always allocative efficient, too. Although research on single system components of e-procurement systems sometimes considers aspects of welfare economics, an integrated view of implications of e-procurement system capabilities and usage behavior from a welfare economics perspective is missing. The work at hand closes that gap by presenting the results of an integrative literature review aiming at building a holistic understanding of the impacts of e-procurement system capabilities as well as e-procurement system usage behavior on the efficiency of the resulting resource allocations.

The remainder of this article is as follows: After this introduction, section 2 details the research methodology. Section 3 reveals the results of the literature review. These results include a transitive closure of tactical and operational procurement processes typically conducted by means of e-procurement systems, as well as an overview of e-procurement system components with welfare allocation impact. Section 4 provides a synthesis and discussion of these results. Based thereupon, managerial implications are provided in section 5. Possible future research endeavors related to e-procurement efficiency are briefly described in section 6. Lastly, section 7 concludes the article and outlines the limitations of the work at hand.

2. Research methodology

In order to get an overview of both e-procurement system characteristics and e-procurement system usage, a two-staged literature review process was conducted. In the first stage, typical software features of e-procurement systems were identified by means of a literature-driven requirements analysis [13]. Out of these software features, components with scientifically documented impact on welfare distribution were selected for the further analysis. After the examination of e-procurement system characteristics, the research agenda was dedicated to e-procurement system usage, resulting in the second stage of the literature review. This approach corresponds to two iterations of the review research methodology proposed by vom Brocke et al. [14]. Publication outlet and article selection processes of both stages are described in more detail in the following paragraphs.
selected and intersected with AIS-listed journals that have 20 average rank points or less. As the AIS does not include conferences into its ranking, the three highest ranking conferences of the JOURQUAL2 IS and Information Management and Electronic Commerce rankings were directly included. The procedure resulted in an overall amount of 14 publication outlets considered for the first stage of the literature review process.

Thereby, the archives of each selected IS journal and conference were reviewed manually, issue by issue, year by year. During this initial search covering the period from 2005 to 2009, the relevance of an article was determined considering title and abstract. As title and abstract do not always allow for an inference on the actual content of an article [16], every article potentially covering the topic was included, resulting in a very broad literature index covering most aspects of e-procurement, electronic commerce, e-business, and inter-organizational systems. This rather broad index was reduced in the next step by eliminating all articles with explicit B2C or C2C focus. An article was considered B2C or C2C related, if respective datasets were analyzed (e.g., EBay or Amazon datasets), or if the articles frequently referred to consumers. All remaining papers were considered for further analysis, if they explicitly referred to e-procurement systems, B2B electronic markets, B2B intermediaries or corresponding synonyms. These articles were then analyzed for typical software features offered by e-procurement systems (e.g., Pflügler [13]). Based on this analysis, system components with scientifically documented impact on welfare allocation were identified. The results provided valuable insights into welfare implications of different configurations of e-procurement system components, but hardly provided an overview of their compound usage. Thus, triggering a renewed literature review dedicated to e-procurement system usage was considered necessary in order to ensure a holistic understanding.

To the best knowledge of the authors of the work at hand, there is no internationally accepted ranking for business publication outlets. Thus, for identifying relevant publication outlets for the second stage of the literature search process, the JOURQUAL2 General Business, Logistics, Production, and Operations Research rankings were used. After probing the scope of each journal contained in the aforementioned rankings, 25 publication outlets were selected for the review.

Likewise to the first stage, the second stage consisted in a manual review of the selected journals. Thereby, all articles from the period from 2001 to 2010 dealing with topics related to sourcing practices (e.g., expenditure/spend management, procurement, auctions, out-/insourcing, supply/value-chain management) were selected by title and abstract. After obtaining respective full-text versions, the chosen articles were analyzed with the objective of creating a consolidated overview of typical e-procurement processes.

In order to confirm and/or consolidate the results of the literature review, important references of relevant articles as well as articles citing the article under review were reviewed in an additional step. This procedure was complemented by keyword searches in the EBSCO4 and proQuest5 databases for each relevant research domain identified in the initial literature reviews. The research agenda derived from the discussion of the results was again verified by means of corresponding keyword searches in the EBSCO and proQuest databases.

3. E-Procurement efficiency

The results of the literature review provide a comprehensive and well-grounded overview of both e-procurement system usage behavior and efficiency-related system components. After a basic classification of possible procurement orientations, sections 3.2 and 3.3 depict the two major processes typically supported by e-procurement systems, i.e., the tactical and the operational procurement process. The fourth subsection will provide an overview of the software features driving the efficiency potential of e-procurement systems from a welfare economics perspective.

3.1. Orientation

The ultimate objective of supply chain management from a welfare economics perspective is to come to a resource allocation that maximizes the welfare generated along a supply chain, including its end customers [3]. Formally, this objective can be expressed as maximizing the utility $u$ of all $n$ customers $c$ of a focal firm $f$, the utility of the focal firm, as well as the $m$ suppliers $s$ of the focal firm.

$$\max \left( \sum_{j=1}^{n} u_{f}^{c} + u_{f}^{s} + \sum_{j=1}^{m} u_{j}^{f} \right)$$

Procurement practices have a major impact on the resource allocation of the upstream side of a supply chain. Three possible orientations of procurement practices can be differentiated. On the one side, the

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4 http://www.ebscohost.com/
5 http://www.proquest.com/
efficient orientation tries to maximize the overall utility \( u \) of a resource allocation by considering both the buyer utility function and supplier utility function simultaneously. For a buyer \( b \), an enterprise-wide purchase \( \Theta \), \( m \) procurement lots \( \theta \), and \( n \) company-wide suppliers, the objective function can be defined as follows:

\[
\max (u_b(\Theta) + \sum_{j=1}^{m} \sum_{i=1}^{n} u_i(\theta_j))
\]

\[
s.t. \sum_{j=1}^{m} \theta_j = \Theta
\]

On the other side, the myopic procurement orientation exclusively focuses on the maximization of buyer utility regardless of possible impacts on the supply side.

\[
\max u^b(\Theta)
\]

The third distinguishable orientation, co-operative procurement, opts for a maximization of the buyer’s utility in the first step, but in the case of an existence of more than one utility-maximizing alternative for the buyer maximizes utility for the supply side in a second step. A formalization of this second step can be found subsequently.

\[
\max \sum_{i=1}^{n} \sum_{j=1}^{m} u_i(\theta_j)
\]

\[
s.t. \max u^b(\Theta)
\]

\[
\sum_{j=1}^{m} \theta_j = \Theta
\]

It is assumed that the efficient orientation provides an increased amount of overall welfare created compared to the co-operative orientation, and that the co-operative orientation provides an increased amount of overall welfare created compared to the myopic orientation.

### 3.2. The tactical e-procurement process

The objectives of the tactical procurement process can be divided into i) the generation of framework agreements and ii) the fulfillment of a specific demand of high volume or importance. Framework agreements typically oblige a supplier to deliver some good or service with well-defined attributes (quality, delivery time etc.) over a fixed time horizon at a best possible price. These contracts typically specify a certain quantity bandwidth the price is guaranteed for, a unit price for extra units that exceed the quantity bandwidth, as well as penalties for falling below the contractual quantity bandwidth. In contrary, the fulfillment of a specific demand aims at satisfying one specific demand with well-defined quantity, quality and other attributes at a best possible price.

On a regular basis, or if the overall demand or the supply base of an enterprise changes significantly, the tactical procurement process (c.f. figure 2) begins with a company-wide spend data collection and analysis [17]. Thereby, in the first step, procurement managers try to capture as much spend (both for primary and secondary goods and services) of the enterprise as possible in order to identify potential for savings. This consolidation step may be supported by taxonomies or ontologies in order to ensure a consistent spend classification over time. Besides leveraging possible economies of scale and scope, a comparison of the prices paid for certain goods or services with the ones paid by peers may reveal savings potential. In the next step, all purchase items need to be specified. Especially to allow for an employment of advanced pricing techniques such as auctions in the later phases of the tactical procurement process, but also to avoid possible post-contract claims by suppliers, the specification should be as precise as possible [18]. Given a measure \( e^{spec} \) for the efficiency of a single specification, the objective for a set of \( s \) specifications can be defined as

\[
\max \frac{\sum e^{spec}}{s}
\]

In order to leverage supply-side economies of scale and scope, the entire purchase (or large groups of it)
should be *segmented* into bundles that can be procured as a whole. As an orientation, buyers may send a Request-for-Information (RFI) containing large portions of the demand to their qualified suppliers, who can then communicate their bundle preferences [18]. The objective of the segmentation activity can be defined as the maximization of the expected value of the utility of a resource allocation with respect to the entire purchase of an enterprise. In efficiency-oriented purchasing environments, it can be defined as follows (analogous definitions for the other orientations):

\[
\max E(u^b(\Theta) + \sum_{j=1}^{m} \sum_{j=1}^{n} u_j^b(\theta_j))
\]

s.t. \( \sum_{j=1}^{m} \theta_j = \Theta \)

Depending on the characteristics and the completeness of the specification of the items to procure, as well as the procurement manager’s preferences, a Request-for-Quotations (RFQ), Request-for-Bids (RFB) or a Request-for-Proposals (RFP) will be issued. In the first case, suppliers submit their quotations in a sealed-bid, single-round auction process, the second case results in a price-only or multi-attribute procurement auction. In order to avoid post-contract supplier claims, the completeness of the specification of the items to procure is of paramount importance, especially in latter two procurement auction types [18]. In the case of incomplete specifications, complex goods to procure, or bundling of the purchase, RFPs are frequently employed. Thereby, suppliers submit proposals for bundles of procurement items including price and other attributes (i.e., a combinatorial bid), or proposals for complex, buyer-specific products. Correspondingly, a trading mechanism fitness function \( TMF \) can be defined as:

\[
TMF = \begin{cases} 
RFQ & \text{if low specification quality} \\
RFP & \text{if buyer-specific, complex product} \\
eAuction & \text{if high specification quality}
\end{cases}
\]

For a more detailed overview of eAuctions, see section 3.4. Before issuing a RFQ, RFB or RFP, the buyer usually also determines supplier selection criteria [19] (in the case of price-only procurement auctions, the only supplier selection criteria is price). Whether the supplier selection criteria are included in full detail into the RFQ, RFB or RFP depends on the preferences of the purchasers. After one or more rounds of collecting and refining bids, quotations or proposals, a preliminary set of winners is usually selected using, e.g., Multiple-Criteria-Decision-Making (MCDM) or Total Cost of Ownership (TCO) models [20]. In this regard, supplier level costs incurred by, e.g., necessary plant visits are often underestimated [21]. Given a measure \( \varepsilon^{\text{quot}} \) for the efficiency of the collected quotations in a purchase segment, the objective of efficient tactical procurement for \( p \) procurement process instances can be formalized as the maximization of the average quotation efficiency.

\[
\max \frac{\sum_{i=1}^{p} \varepsilon^{\text{quot}}_i}{p}
\]

Due to sourcing strategy considerations (e.g., supply base diversification, certification requirements), the efficient set of quotations does not always correspond to the preliminary set of winning quotations. From an efficiency point of view, however, efficiency losses caused by such strategic selection criteria should be kept as small as possible. In other terms, the supplier selection efficiency \( \varepsilon^{\text{sel}} \) over a set of \( p \) procurement process instances should be maximized.

\[
\max \frac{\sum_{i=1}^{p} \varepsilon^{\text{sel}}_i}{p}
\]

The preliminary set of winners is often also called the short list of suppliers. The preliminary winners are then typically invited to negotiations. Such negotiations can be conducted face-to-face, but are also conducted via so-called e-negotiation solutions. Formally, the objective of a set of \( q \) negotiations can be described as the maximization of the average of a given negotiation efficiency measure \( \varepsilon^{\text{neg}} \).

\[
\max \frac{\sum_{i=1}^{q} \varepsilon^{\text{neg}}_i}{q}
\]

In order to be prepared for failing negotiations, waiting lists containing substitute suppliers for the suppliers of the short list can be created. If a final set of suppliers for a certain item or a bundle of items is selected, the respective supplier(s) are contracted according to the sourcing strategy. In dependency of a contracting efficiency measure \( \varepsilon^{\text{cont}} \), the objective of the contracting activity can be formalized as the maximization of the contract efficiency efficiency over a set of \( r \) contracts:

\[
\max \frac{\sum_{i=1}^{r} \varepsilon^{\text{cont}}_i}{r}
\]

After fulfilling the contract (one delivery satisfying a specific demand or multiple deliveries triggered by the operational procurement), the respective supplier(s) get evaluated according to pre-defined criteria. This evaluation may partly also consist of aggregated evaluations resulting from the operational procurement process described in the next subsection. In case the
demand or supply base of the enterprise changes significantly (e.g., due to the introduction of new products or a changed sourcing strategy), another complete process iteration is triggered. Otherwise, purchasers may directly proceed with a renewed RFQ, RFB or RFP.

3.3. The operational e-procurement process

Considering framework agreements generated by the procurement department, operating departments usually cover their demand of primary and secondary materials themselves [7]. Such an operational procurement process begins after a demand arises, e.g., by falling below ordering or safety stock level of a primary material, or by the need to replace a secondary material (e.g., a laptop). Especially in the case of primary materials procurement, operating departments increasingly deploy automated e-replenishment systems for triggering the operational procurement process [6]. In order to select adequate supplier(s) to order from, as well as to derive optimal order lots, respective policies based on mathematical programming approaches are applied [22]. Thereby, in order to achieve a reasonable degree of efficiency, vertical information sharing (e.g., open book accounting, production schedule sharing) strategies are frequently employed [23], [24]. Given a measure \( e^{\text{repl}}_i \) denoting replenishment efficiency for a purchase segment, the objective of the operational procurement can be described as the maximization of the replenishment efficiency for all \( n \) purchase segments:

\[
\max_{n} \sum_{i=1}^{n} e^{\text{repl}}_i
\]

After a one- or multilevel authorization procedure, order(s) are submitted to the supplier(s), and the order is fulfilled (incl. invoicing, quality checks, warehousing, etc.). At the end of the procurement transaction, the supplier(s) are evaluated according to company-wide supplier reputation metrics.

3.4. Component efficiency issues

A number of software components drive the efficiency potential of an e-procurement system. For the work at hand, features that have an impact on allocative efficiency were considered, whereas industry-specific functionality that enhances the overall supply network efficiency without necessarily having an allocative effect (e.g., VMI) was not. The resulting set of drivers of the efficiency potential of e-procurement systems includes negotiation protocol abilities, reputation mechanism properties, and the auction efficiency maximization potential which can be further decomposed into supported auction types, information feedback abilities and auction parameterization abilities. Figure 4 provides a respective overview; each driver is described in more detail in the following paragraphs.

The objective of negotiation is to arrive at a mutually beneficial agreement that maximizes settlement efficiency [25]. In this regard, efficient negotiation protocols are identified as the key enablers for reaching these objectives by electronic negotiation. Besides protocols that exclusively focus on negotiation between software agents, sequential-single offer and simultaneous-equivalent offer protocols have been identified as major design alternatives [26]. Thereby, it has been shown that simultaneous-equivalent offer protocols that also provide for the possibility of both an immediate and a delayed acceptance of an offer have the maximum potential to increase the overall efficiency of a settlement by avoiding pre-mature closures.

Problems arising from the Principal-Agent Theory such as moral hazard and adverse selection constitute a major component of market mechanism inefficiency. E-procurement systems address this issue by so-called reputation mechanisms which allow buyers to rate the extent to which they were satisfied by a seller. Related research exclusively concentrates on binary reputation mechanisms, although other sources suggest that it should be possible to rate sellers in a broad array of categories such as credibility, reliability and
product/service quality [19], [27]. It has been shown that reputation mechanisms with infrequent updates of reputation profiles [28] as well as reputation mechanisms in which older ratings have less weight than newer rankings or have no weight at all [29], [30] have the potential to increase the level of cooperation and thus the level of overall efficiency.

E-Procurement systems typically support a variety of different auction formats (e.g., price-only procurement auctions, multi-attribute procurement auctions, combinatorial auctions). Thereby, all auction types may be configured to be of iterative or continuous nature. Depending on the characteristics of the goods to procure, the type of auction used has an impact on the economic efficiency. If aspects other than price affect the value of an outcome of a procurement transaction, it has been shown that the usage multi-attribute procurement auctions instead of price-only procurement auctions increases both buyer utility and the seller’s profit [31]. Further, if a bundle of complementary goods is to be procured, the usage of combinatorial auctions increases the joint economic efficiency [32-34]. An auction type fitness function ATF can be defined as follows:

\[
ATF = \begin{cases} 
\text{price - only,} & \text{if standardized commodities} \\
\text{multi - attribute,} & \text{if medium product complexity} \\
\text{combinatorial,} & \text{if complementary goods/services}
\end{cases}
\]

Selecting the right parameters for a given auction type influences the overall efficiency of an auction result, as well as the buyer’s and bidders’ economic outcome. Such parameters include the reserve price, the bid decrement, the auction duration, the auction closure policy, or bid withdrawal policies. It was shown that allowing for optional bid withdrawal during auctions at a penalty leads to higher overall efficiency but lower surpluses for bidders [33]. Setting reserve prices based on a set of discount factors may constitute an option to counteract supplier collusion [35]. Further, Mithas and Jones [36] found that setting a reserve price relatively lower than the historical price increases the buyer surplus. An auction parameter fitness function APF can therefore be defined as:

\[
APF = \begin{cases} 
\text{bid withdrawal at penalty,} & \text{if realizable} \\
\text{reserve price(t) < reserve price(t - 1),} & \text{if } \neg \exists \text{ supplier collusion} \\
\text{max (reserve price(t) < (reserve price(t - 1))),} & \text{if } \exists \text{ supplier collusion}
\end{cases}
\]

In this regard, the application of learning techniques to derive auction parameters from historical auction data has been proposed [37].

Information feedback refers to the type and amount of information disclosed to bidders in auction settings. This information is typically used to assist bidders in planning and executing their bidding strategies [38]. Different levels of information feedback influence the overall efficiency of the resulting contract, but also the economic outcome of bidders and the buyer. The “right” amount of information feedback depends on the nature of the chosen auction type, however. Adomavicius et al. [33] found that a medium level of information feedback consisting of all submitted bids and the winning bid combination in combinatorial auctions on average produces the best economic outcome for buyers and the worst one for bidders, whereas a high level of information feedback including additional bid evaluation metrics (deadness levels, winning levels) [38] maximizes the overall efficiency and produces the best economic outcome for bidders (but not for the auctioneer). In a subsequent study, Adomavicius et al. [34] found that a high level of information feedback consisting of the relative rank, the status of the bid, as well as attribute update vectors maximizes the overall efficiency as well as the bidder’s economic outcome, but minimizes the buyer’s utility in multi-attribute procurement auctions. In contrary, a low level of information feedback consisting of the bidder’s rank only minimizes the overall efficiency as well as the bidder’s surplus, but maximizes buyer utility. A medium level of information feedback consisting of the bid rank and status slightly decreases buyer utility compared to the low information feedback level, but increases both the economic efficiency and the seller surplus. Hence, for the case of the efficient procurement orientation, an auction information feedback fitness function AIFFF can be defined as:

\[
AIFFF = \begin{cases} 
\text{high,} & \text{if combinatorial auction} \\
\text{high,} & \text{if multi - attribute auction}
\end{cases}
\]

For both the co-operative orientation and the myopic orientation, the AIFFF is:

\[
AIFFF = \begin{cases} 
\text{medium,} & \text{if combinatorial auction} \\
\text{low,} & \text{if multi - attribute auction}
\end{cases}
\]

Besides, the buyer surplus is found to be higher if bidders are not provided with information feedback before submitting a bid below reserve price [36].

4. Synthesis and discussion

The results of the literature review revealed a complex interplay of e-procurement system capability and usage behavior factors on the e-procurement allocative efficiency. First of all, the quality of the specification of a purchase item is of outstanding importance as it enables the employment of advanced auction formats such as price-only or multi-attribute procurement auctions with the potential of realizing a major savings potential. Assuming such efficient pricing along a supply chain, the welfare generated for the end customers, but also for the most efficient suppliers is maximized. However, in such cases, it is
important to consider that an increased price competition may lead to collusion in procurement competition, decreasing the overall welfare generated. In that regard, reserve prices based on a set of discount factors may constitute an option to counteract collusion while sustaining procurement competition and the resulting efficiency [35]. Besides the impact on auction type selection, the specification quality also has a direct impact on the efficiency of resulting quotations as a precise specification allows suppliers to satisfy the demand of a buying organization in an efficient manner, and avoids possible post-contract claims, e.g., due to ambiguities. Such post-contract claims may serve as a basis for measuring the efficiency $e_{\text{cont}}$ of a single contract. A corresponding measure can be defined as

$$e_{\text{cont}} = \frac{1}{1 + \rho}$$

where $\rho$ denotes the number of post-contract claims occurred for the contract under consideration.

The procurement bundles resulting from the purchase segmentation constitute another impact factor for the auction type selection. Thereby, buyers try to leverage supplier-side economies of scale and scope by auctioning respective bundles as a whole. In order to derive appropriate bundles, demand forecast information, e.g., based on product-lifecycle considerations, is required as a prerequisite. As already depicted, combinatorial auctions constitute a promising approach for efficiently purchasing the resulting product or service bundles. However, purchase segmentation has also some wider implications. Especially in the case of a non-homogeneous supplier landscape, the actual bundling strategy may prejudice certain suppliers, thereby directly influencing the maximum achievable efficiency of the quotations in the resulting segment. The quotation efficiency $e^{\text{quot}}$ in a purchase segment $\psi$ can be defined as the ratio between the overall utility of the best $m$ quotations for procurement lots $\theta$ collected from the $n$ qualified suppliers of the segment and the $l$ quotations $\theta^*$ of the same set of suppliers that would have maximized joint utility from a theoretical perspective. However, determining the joint utility is a challenging or even impossible task in practical applications as supplier utility functions are usually not or only partly known to the buyer.

$$e^{\text{quot}} = \frac{u^b(\psi) + \sum_{i=1}^{n} \sum_{j=1}^{m} u_i^x(\theta_j)}{\max(u^b(\psi) + \sum_{i=1}^{l} \sum_{k=1}^{l} u_i^x(\theta^*_k))}$$

s.t. $\sum_{j=1}^{m} \theta_j = \sum_{k=1}^{l} \theta_k = \psi$

$$e^{\text{quot}} \in [0,1]$$

Once a suitable auction type is selected from the available ones, the auction needs to be configured. As depicted in the previous section, this configuration has a major impact on the allocative efficiency of the resulting quotations. Depending on the available configuration options, the level of co-operation and

Figure 5. Interplay of system capabilities and usage behavior on e-procurement efficiency
mutual dependencies between the buyer and her suppliers, either a Kaldor-Hicks-efficient configuration maximizing the overall welfare or a Pareto-efficient configuration dedicated to the maximization of the buyer’s surplus can be composed.

In order to create the short list and waiting list of suppliers, tactical supplier selection criteria are considered in addition to the quotations. These criteria typically also reflect sourcing strategies of an enterprise aiming at, e.g., supply disruption risk mitigation or sustainability issues. Thereby, the supplier selection efficiency \( \varepsilon^{sel} \) for a purchase segment can be defined as the ratio between the quotation efficiency of the selected quotations \( \varepsilon^{quotSEL} \) and the quotation efficiency of the best quotations \( \varepsilon^{quot} \) collected:

\[
\varepsilon^{sel} = \frac{\varepsilon^{quotSEL}}{\varepsilon^{quot}}
\]

\( \varepsilon^{sel} \in [0,1] \)

Supplier data is typically collected frequently, e.g., in the course of instant supplier commercial assessment activities. Therefore, besides the supplier selection criteria, the reputation mechanism properties play an important role in ensuring the generation of efficient resource allocations. Recall that reputation mechanisms with infrequent reputation profile updates and reputation mechanism in which older rankings have less weight or are disregarded increase the overall efficiency. Once a short list of suppliers is selected based on quotations and the aforementioned supplier selection criteria (e.g., by using an Analytic Hierarchy Process model or by conducting a TCO analysis), negotiations with these suppliers are typically conducted. The efficiency \( \varepsilon^{neg} \) of these negotiations can be formalized as the ratio between the difference of the quotation efficiency before the negotiations \( \varepsilon^{quotBN} \) (which usually corresponds to \( \varepsilon^{quotSEL} \)) and after the negotiations \( \varepsilon^{quotAN} \), and the difference between the quotation efficiency \( \varepsilon^{quot} \) maximum achievable with the suppliers invited to the negotiations and \( \varepsilon^{quotBN} \). It is assumed that \( \varepsilon^{quotAN} \) is always equal or higher than \( \varepsilon^{quotBN} \), and that no negotiations are conducted if \( \varepsilon^{quot} \) equals or is smaller than \( \varepsilon^{quotBN} \).

\[
\varepsilon^{neg} = \frac{\varepsilon^{quotAN} - \varepsilon^{quotBN}}{\varepsilon^{quot} - \varepsilon^{quotBN}}
\]

\( \varepsilon^{neg} \in [0,1] \)

In the negotiation phase, the first decision is whether to conduct face-to-face or electronic negotiations. In comparison with traditional face-to-face negotiations, electronic negotiation facilitates simultaneous negotiations with multiple suppliers [39], potentially leading to process efficiency gains. Further, at the expense of direct, personal interaction, electronic negotiation is able to eliminate personal idiosyncrasy or affection between buyer and supplier representatives. The mode of negotiation thus directly influences feasible negotiation protocols as well as the overall negotiation efficiency. As described in the previous section, simultaneous-equivalent offer protocols that also provide for the possibility of both an immediate and a delayed acceptance of an offer have the potential to maximize the allocative efficiency of a settlement. However, in order to realize that potential, a negotiator also needs to take advantage of the features of such a protocol by sending simultaneous offers and by following an adequate acceptance strategy.

Capped by the framework agreement / contract efficiency, the operational procurement operations also impact the overall e-procurement allocation efficiency by both allocating operational costs and order lots. Thereby, based on the demand forecast of the buyer, replenishment strategies and corresponding policies are defined. In this regard, it is important to consider that due to inventory costs [21], an optimal replenishment policy from the buyer’s point of view usually leads to more frequent replenishments of smaller order quantities. These smaller order quantities lead to reduced inventory costs for the buyer, but higher equipment setup and administrative costs for the supplier, especially if the supplier’s administration is characterized by a low degree of automation. Therefore, independent decision making by the buyer regarding the ordering policy can cause unintended supply chain inefficiencies [6]. Such inefficiencies may be Pareto-efficient. However, depending on the degree of co-operation with a supplier, buying organizations may consider the efficiency of the entire supply chain and opt for a Kaldor-Hicks efficient outcome, e.g., by collaborative inter-organizational cost management [24]. From an order level cost point of view, one sub-objective of \( \varepsilon^{repl} \) in efficiency oriented environments can thus be expressed as a minimization of the order level costs \( c \) for all \( n \) replenishments \( \varphi \) occurring in a purchase segment, for both the buyer and the \( m \) suppliers.

\[
\min \left( \sum_{i=1}^{n} c^b(\varphi_i) + \sum_{i=1}^{m} \sum_{j=1}^{n} c^j(\varphi_j) \right)
\]

In case of multiple-sourcing strategies, likewise to the tactical procurement, operational supplier selection criteria partly derived from the tactical supplier selection criteria, as well as the reputation mechanism properties influence the welfare allocation in the operational procurement as they constitute the basis for decision-making regarding operational supplier.
selection and order lot allocation. Thereby, supply chain efficiency may be increased by a dedicated maximization of the resource utilization of all suppliers of a certain good or service [40], based on corresponding vertical information sharing (e.g., production schedule). Thus, a minimization of the variance of the resource utilization $\mu$ of each of the $n$ suppliers of a purchase segment may constitute a second component of $\varepsilon^{rep}$ in efficiency oriented environments.

$$\min\left(\frac{1}{n-1} \sum_{i=1}^{n} (\mu_i - \bar{\mu})^2\right)$$

5. Managerial implications

As depicted in the discussion, much of the potential for efficiency enhancement is enabled by the capabilities of an e-procurement system, but the actual realization of the potential mainly depends on the system users, i.e., the responsible purchasers. Therefore, procurement managers trying to foster efficient supply chains are well advised to i) check whether their e-procurement system provides all required efficiency enhancing functionalities and/or configurations, ii) to assess whether an efficiency-oriented restriction of the functionality offered to purchasers (e.g., available information feedback for a given auction type) is applicable, iii) to check the appropriateness of and in case it is reasonable adapt the employed procurement performance measures and iv) to develop appropriate incentive schemes for their purchasers based on these performance measures in order to foster an efficient system usage behavior. However, it is important to notice that some factors required for a comprehensive supply chain efficiency-oriented incentive scheme, e.g., supplier surplus or specification quality, may be hard to quantify.

6. Burgeoning research questions

The work at hand revealed a number of possibilities for future research. First of all, although the work at hand has shown the importance of the purchase segmentation activity, related research is not available. Future research may therefore consist of a closer examination of purchase segmentation strategies. In order to get an overview of the topic, as well as to derive best business practices, such research may start with exploratory case or field studies. This initial step may then be complemented by analytical approaches dedicated to, e.g., the derivation of purchase segments based on supplier responses to respective RFIs.

Also, processes for ensuring as well as metrics for assessing the quality of purchase specifications could not be identified. Although there is some research on different types of specifications in the construction and the software industry, there is a need to further develop this area of research in order to generate scientifically grounded knowledge and best practices helping to ensure unambiguous and efficient specifications of different types of purchase items.

The domain of electronic auctions is under intensive research for quite a while now. However, some questions still remain unanswered. First of all, continuous and iterative auction formats are frequently distinguished. However, efficiency-oriented research does not distinguish these two different formats at all [36], or exclusively examines one specific format [33], [34], [38]. Thus, a structured evaluation and comparison of iterative and continuous procurement auction formats regarding their effects on welfare generation and allocation may reveal new insights. Further, the work of Mithas and Jones [36] on the effect of auction parameters focuses on buyer-side effects only. A more holistic approach examining both the buyer and the supplier side may therefore constitute another future research challenge. Besides, decision support for determining the optimal auction duration for a given purchase setting is missing.

Analytic auction-integrated tactical supplier selection approaches dedicated to co-operative supply chain structures also constitute an opportunity for future efficiency-oriented research. Thereby, multi-attribute combinatorial auctions in make-to-order environments with volume discounts may be of particular interest. Existing approaches do either not support volume discounts [41], [42], or provide a very low level of information feedback [43] which has shown to be inefficient from a supply chain-wide perspective. In this regard, besides heuristics, procedures based on the Data Envelopment Analysis may constitute a promising option for solving the NP-hard winner determination problem in multi-attribute combinatorial auction formats [11].

Many technology-oriented approaches for e-negotiation have been proposed so far. However, an examination of factors determining the mode of negotiation, i.e., determining whether to negotiate face-to-face or electronically, is missing. In this regard, the work of Kaufmann and Carter [17] may provide a starting point. However, they compare a procurement process entirely based on face-to-face negotiations with an entirely auction-based one. Future research may opt for an examination of factors determining the mode of negotiation and resulting efficiency implications in the negotiation phase of electronically
enabled sourcing processes as the one depicted by the work at hand.

As already discussed in the previous section, replenishment policies optimal for the buyer may lead to supply chain inefficiencies due to increasing costs at the supplier-side. However, analytical approaches for joint order lot sizing considering both buyer and supplier costs as well as resource utilization are missing. Such an approach could be enabled by vertical information sharing practices and may consist of mathematical optimization models on the one hand, and benefit distribution models on the other.

7. Conclusion and critical remarks

The work at hand provided the results of a thorough literature review aiming at building a holistic understanding of the efficiency implications of e-procurement system capabilities and the corresponding usage behavior of purchasers from a welfare economics perspective. These results include a well-grounded overview of both major e-procurement processes and efficiency-related system components. Based on the discussion of these results, a number of procurement efficiency measures, managerial implications as well as a comprehensive agenda for future efficiency-oriented research were derived.

Although the publication outlets considered for the work at hand were carefully selected, the results of many studies are often generated based on computational or other controlled experiments. As the realism of such experiments continues to be an issue in IS research, these results need to be carefully reflected. Nevertheless, these studies provide the latest scientifically grounded findings and are therefore incorporated into the work at hand.

8. References


