

Fostering Small and Medium-sized Enterprises through Public Procurement in Canada: A Data Analytics Approach

ShiKui Wu (✉ shikui.wu@lakeheadu.ca)

Lakehead University <https://orcid.org/0000-0001-9039-8603>

Kem Z.K. Zhang

Lakehead University

Kiana Farrokhi

Lakehead University

Research

Keywords: Public procurement, SME, Government of Canada, Supplier performance, Data analytics approach, Data mining

Posted Date: September 22nd, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1794334/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Abstract

Public procurement has been considered as a policy tool to foster small and medium-sized enterprises (SMEs), while the effectiveness remains unclear. This study aims to assess the participation and performance of SMEs in Canadian public procurements. We adopt a data analytics approach in assessing the tenders' data from the Government of Canada over a ten-year period (2009–2019). We analyzed key factors, identified patterns and profiles in winning contracts, compared the performance between SMEs and large enterprises (LEs), and developed prediction models for contract value. Contract value is found to vary across firm sizes, levels of competitiveness, and supplier's locations and industries. SMEs are top performers and are strongly complementing LEs with diverse and specialized offerings. A majority of public contracts with SMEs are awarded with relatively small value, short terms and limited to certain service contracts. The random forest regression model is shown to be the best in predicting contract value. The findings provide insights for both governments and SMEs in using procurement more effectively as a policy tool. Future work may validate this research in other countries with traditional method and primary data.

Introduction

The rapid development in information technologies has allowed many businesses to build linkages and speed up information flow and sharing with others in their supply chains. In particular, electronic procurement (e-procurement) technologies facilitate the transactions between organizations and their suppliers for exchanging information such as requests for proposals, purchase orders, and payments. The most notable benefits of e-procurement include cost saving, ordering faster, wider range of vendor choices, better control over procurement spending, less paperwork and duplication of tasks, and reengineered procurement workflows (Moon 2005).

Public procurement is a key economic activity of governments (Brammer and Walker 2011). It refers to the acquisition of goods and services by governments or public sector organizations through a public contract (Kiiver and Kodym 2014), and allows public sector organizations to perform their functions and deliver its services (Uyarra et al. 2014). Governments use procurement to not only obtain goods and services from external sources (Ginsberg et al. 2009, Xu and Huang 2015), but also leverage their policies for various societal goals (Grandia and Meehan 2017, Zabala-Iturriagagoitia 2022). Further, e-procurement by governments has often been advocated that such technologies can bring a number of social and economic benefits to citizens. For instance, it may provide fair opportunities and competition to various businesses (e.g., small vs. large enterprises) and increase the transparency in procurement processes and contracts (Flynn and Davis 2014, Kohler et al. 2015). This will in turn benefit citizens with not only lower cost and higher quality of products and services, but also higher levels of trust and satisfaction (Kastner 2010, Brammer and Walker 2011).

This study profiles suppliers, especially small- and medium-sized enterprises (SMEs), to the Government of Canada via electronic public procurement (hereafter called as public procurement). The growth of

SMEs accounts for a disproportionate share of job creation, innovation and the accompanying economic prosperity (Liao et al. 2017). Because their purchasing represents a significant portion of government expenditure, strategic procurement tends to hold the potential to stimulate further economic development and innovation (Loader 2005, Grandia and Meehan 2017). The goal of this research is thus to assess how procurement has been used by governments to obtain goods and services from SMEs, and also to provide a landscape of Canadian public procurement and to assess effective factors on the performance of Canadian public procurement practices.

This research adopts a data analytics approach in assessing e-procurement based on tenders' data from the Government of Canada. It will analyze tendered items (i.e., products and services to be procured), government departments, suppliers, and awarded contracts over the past ten years (2009–2019). The purpose is to provide insights for both the government and SME suppliers in using e-procurement more effectively. The present research aims to address the following questions: *To what extent have SMEs utilized e-procurement to participate in government tenders? What are the influential factors for SMEs' success, and how they can be used to predict SMEs' future performance in public procurement?*

The paper is organized as follows. First, it provides a review of relevant studies on public procurement. Then, a data analytics approach is presented to study public procurement in Canada. The paper concludes with the implications to research, practice and government policies for public procurement.

Literature Review

This section reviews relevant studies in public procurement and provides the motivation of the present study. It focuses on main factors in selecting and awarding public contracts, and then summarizes main findings in different countries and regions. This drives the present research focusing on suppliers especially SMEs in Canadian public procurement.

Public procurement adoption and performance

Public procurement is a key economic activity of governments (Brammer and Walker 2011), and there are usually two considerations: adoption and performance.

The adoption stream focuses on the factors that influence the government and suppliers in public goods and services procurement. The success of public procurement adoption depends upon technological, behavioral, and organizational factors (Moon 2005, Garrido et al. 2008, Hardy and Williams 2008). Moon (2005) argued that organizations that are large, managerially innovative, and have strong centralized offices are more likely to adopt. Hardy and Williams (2008) discussed the implications of social and technical factors on how public procurement constitutes and is constrained by a network of human and technical factors in e-procurement policy implementations. Other studies also explore country differences in the adoption of public procurement (Batenburg 2007, Flynn et al. 2013). Gunasekaran and Ngai (2008) studied and developed a framework for the adoption of e-procurement in Hong Kong. In summary, the main success factors in these studies include: employees and management commitment to the success

of adoption, reliability of information technology and supplier performance, monitoring the performance of e-procurement systems, user acceptance of e-procurement systems and top management support.

The benefits and outcomes of public procurement are related to increased market transparency, lowering of transaction costs, additional information, and more competition (Carayannis and Popescu 2005, Mamavi et al. 2014). It has also been used to further public policies in a wide range of fields, such as the national industrial policy, reducing unemployment, improving employment conditions, support for small businesses, local development, employment of disabled workers, and equal pay for men and women (McCrudden 2004).

In addition, performance is another key concern in the public procurement literature. Several studies have examined the determinants of winning contracts, including: degree of centralization, auction characteristics, geographical factors, social factors, competences and incentives of procurement officials. Chiappinelli (2019) found municipalities and utilities are less efficient than other institutional categories, particularly more central levels of government. Compliance by public contractors is a challenge and a range of actions is required to enhance its achievement, such as training to improve familiarity with the policy, dedicated buyers, better recognition of the importance of SME success and use of organizational incentives (Gelderman et al. 2006, Flynn and Davis 2015, Coviello and Gagliarducci 2017).

Public procurement with SMEs

Small- and medium-sized enterprises (SMEs) have been defined as firms with less than 499 employees (Liao et al. 2017). SMEs play an important role in the economic development of a country. Further, SMEs have been attempting to harness the benefits from e-commerce, which is a strategic management for their rapid growth (Grandón et al. 2011, Ramanathan et al. 2012). SMEs can use e-commerce for creating added value, new services, and new business models, expanding their businesses and competing in the global market (Savrul et al. 2014).

Supporting the growth of SMEs is a priority of most governments (Loader 2005, Grandia and Meehan 2017, Zabala-Iturriagagoitia 2022). This is an important focus of public policy for two reasons: (1) the growth of young SMEs disproportionately generates economic prosperity through the creation of new jobs; and, (2) many SMEs are innovative (ISED 2016). Governments worldwide recognize SMEs as business networks to facilitate innovation and economic development (Besser and Miller 2011). Although SMEs in both developing and developed countries are not big in terms of size, these enterprises contribute significantly to the economy (Savrul et al. 2014).

Public procurement is undoubtedly a challenging environment for SMEs (Loader 2013). Scholars from across public administration and management disciplines have examined SMEs' participation and performance in competing for public contracts (e.g., Glas and Eßig 2018, Hoekman and Taş 2022). Prior studies have shown SMEs to be interested in doing business with the public sector but highly critical of procurement procedures and practices (Flynn and Davis 2017). In the context of public sector tendering, there is a capability to have separate relational and procedural dimensions and factors. Both capability

types are integral to explaining SME participation and success in contract competitions (Flynn and Davis 2017). SMEs are capable of offering competitive pricing arrangements because of their minimal administrative overheads and streamlined operations. Having SMEs to compete for public contracts intensifies competition and provides buyers with greater choice in the supply marketplace (European Commission 2008). Kim and Lee (2006) found that the user-friendliness of IT systems is significant in affecting employees' knowledge sharing capabilities in both private and public organizations, which is a frequent concern in public procurement (Loader 2013), and also highly valued by SMEs (Saastamoinen et al. 2018).

Summary of main factors

The literature review indicates a number of success factors for suppliers including SMEs in public procurement, including:

- **Competitiveness:** Most studies have shown that the level of competitiveness (e.g., the number of suppliers or the competing procedures) affects contract value and price (Reis and Cabral 2015, Yakovlev et al. 2016).
- **Location:** Local environments affect suppliers' performance (Ng and Kee 2012, James Mauti et al. 2013), while mixed results suggest that the effect of business environments on suppliers may vary by national or regional economic contexts (Batenburg 2007, Svidroňová et al. 2016).
- **Firm size:** The size of a supplier or the number of its employees affects its performance. Firm size has always been a core debate on supplier involvement in procurement. Overall, the bigger the supplier, the better resource it has to tender for public contracts (Flynn et al. 2013, Svidroňová et al. 2016).
- **Industries or sectors:** Public procurement has been used for acquisition of various goods and services. Studies have shown the different roles and performance of SMEs in certain industries (James Mauti et al. 2013, Reis and Cabral 2015, Grandia and Meehan 2017).
- **Contract duration:** The length of public contracts also indicates its scale, and it has been found that longer contracts with certain service procurements are negatively associated with price savings (Reis and Cabral 2015, Yakovlev et al. 2016).
- **Contract value:** The scale of public contracts in terms of volume and dollar value is considered as an important performance measure for suppliers (MacDonald et al. 2002, Moretti and Valbonesi 2015, Yakovlev et al. 2016).

It's worth to note that various success factors have been identified and discussed in the literature, depending on the research settings (e.g., countries, regions, methods, data sources). The above list shows

the most common success factors that are available in public procurement contracts particularly with secondary datasets.

Research motivation and objectives

The purpose of this study is to address the gaps in the literature and advance our knowledge and understanding of suppliers, especially SMEs, in public procurement.

Research has put much effort on the barriers SMEs face when competing in the public sector marketplace (Loader 2013). There is a need to move forward and provide explanations and evidence on the factors and processes that enable SMEs to compete for and win public contracts (Flynn and Davis 2017, Di Mauro et al. 2020). Additionally, recent studies have investigated the success factors and performance in public procurement in the European Union (Svidroňová et al. 2016, Grega et al. 2019). The present study extends and examines the performance of suppliers including SMEs in the Canadian public procurement. Further, studies that focus on the standard tendering process mostly identify the determinants of its adoption, whereas few have investigated the effectiveness of such process in public procurement. Also, the participation and performance of SMEs are mostly measured subjectively (e.g., survey) in the literature (Liao et al. 2017, Di Mauro et al. 2020), while there is a call for data-driven decision making in public procurement (Halsbenning and Niemann 2019). The present study therefore applies a data analytics approach to profile the public contracts and assess the performance with real transaction data.

Methodology

The present study follows a data analytics approach to conduct data mining and analytics for a secondary dataset. The research is carried out through the following steps:

1. We first extract and clean the data downloaded from the Government of Canada's public procurement and select variables that are relevant to the purposes of this research;
2. We then conduct descriptive analytics on the data to generate an overview of Canadian public procurement, which allows us to understand the landscape of procurement contracts in this context;
3. We also verify the effects of main factors by examining how contract value differs or distributes across various variables. This allows us to examine the performance of suppliers especially SMEs in detail.
4. We finally conduct prediction models and compare their prediction accuracies to allow for better prediction of the performance variable: contract value.

The data is from the website of the Government of Canada tenders (<https://buyandsell.gc.ca/>). It records all the public contracts for goods and services since 2009, and the database contains 46 variables. The variables include the details about the contracts in both English and French, including contract number, dates, value, solicitation procedure, public contractor information, and supplier information. Major variables for this study are listed in Table 1.

Table 1
Variables, definition and range

Variable	Definition	Range
Contract value	The monetary value of a public contract.	From \$1 to \$5.22 billion CAD
Award date	The start date for the standing offer or supply arrangement.	From 2009-01-01 to 2019-12-31
Expiry date	The date on which a contract legally expired.	From 2009-01-09 to 2119-04-01
Contract duration	The length of a public contract.	Difference between award date and expiry date, from 1 day to 39013 days
Solicitation procedure	The solicitation method for a contract.	Competitive - Open Bidding - Traditional Competitive Non-Competitive - Advance Contract Award Notice - Traditional Non-Competitive
Competitiveness	Whether or not a contract was awarded by a competitive solicitation procedure.	Yes / No
Same province	Whether a supplier and procurement entity are located in the same province.	Yes / No

Variable	Definition	Range
Firm size	The category coding of suppliers' size based on the number of employees.	1 = 1 to 4 employees; 2 = 5 to 9 employees; 3 = 10 to 19 employees; 4 = 20 to 49 employees; 5 = 50 to 99 employees; 6 = 100 to 199 employees; 7 = 200 to 499 employees; 8 = 500 to 999 employees; 9 = 1000 to 1499 employees; 10 = 1500 to 2499 employees; 11 = 2500 to 4999 employees; 12 = 5000 employees and over
SME	Small- and medium-sized enterprises as suppliers for the public contracts	Firm size < 8 (500 to 999 employees)

[Table 1 *Variables, definition and range*]

After the tenders' data from 2009 to 2019 (i.e., award date) is extracted, we review it and select records based on the following criteria:

- New contracts, which have no amendments (or revisions);
- Contracting entities or suppliers which are located in Canada;
- Contracts with positive contract value and contract duration (award date < expiry date);
- Contract expiry date < 2120 (abnormal lengthy contracts are not selected); and,
- Suppliers with the number of employees (e.g., suppliers labeled as self-employed are not selected).

A total of 132,853 contracts are finally extracted for our data analysis. It contains 121 unique contractors and 22,395 unique suppliers.

Data Analyses And Results

The data analyses involve data mining and analytics of the data. We conduct three steps of analyses on the data. First, we analyze the data to provide an overview of Canadian public procurement, which examines the distribution of the performance variable: contract value, top suppliers and public contractors, and trends of awarded contracts. Next, we delve into the dimensions of firm size, industry, province, supplier-contractor location, and solicitation procedure to generate insights for suppliers. Finally, we assess different prediction models and identify the most accurate one to predict contract value. To demonstrate the role of SMEs in the current context, we compare the performances of both SMEs and large enterprises (LEs) in these steps. Details of the procedures and results are presented as follows.

Overview of Canadian public procurement

A descriptive analysis on contract value shows that its mean is \$739,012, with the median \$46,407 and standard deviation \$25,274,920. Given that the maximum contract value is \$5.22 billion, it indicates that

contract value has a skewed distribution, and there are a small portion of contracts with very large values. A percentile analysis confirms such distributions for all contracts and contracts in both SMEs and LEs. It further shows that only 10% of the contracts have values larger than \$597,224, which is even smaller than the mean of contract value.

We then identify major public contractors and suppliers. In terms of total contract value, the Public Works and Government Services Canada is the top contractor, whereas Brookfield Global Integrated Solutions Canada LP is the top supplier. Groupe Signature Sur Le Saint-Laurent is a SME supplier in this list. In terms of the number of contracts, the Department of National Defence is the top, offering close to 38% of all contracts. Meanwhile, the top 3 suppliers are all from Quebec, and interestingly they are all SMEs. These findings provide preliminary evidence about the importance of SMEs in Canadian public procurement.

We also perform trend analysis to examine the distributions of contracts over the years. Figure 1a shows that SMEs have received higher total value of contracts than LEs since 2015. Figure 1b depicts a clear declining trend for the number of contracts, with more contracts awarded to SMEs than LEs in each year and fewer and fewer contracts from SMEs over the course of time. The findings of the trend analysis provide additional and dynamic evidence regarding SMEs, with fewer of them each year but playing an increasing important role in Canadian public procurement.

[Fig. 1 *Total value (a) and number of contracts (b) from 2009 to 2019 (M = million)*]

Supplier performance in public procurement

Next, we delve into detailed dimensions (e.g., firm size, industry, province, supplier-contractor location, and solicitation procedure) of the data and analyze suppliers in the current context. Note that contract value is highly skewed in the data. Thus, instead of using mean contract value, we use median contract value to reflect the central tendency of this performance variable.

Prior studies (Flynn et al. 2013, Svidroňová et al. 2016, Flynn and Davis 2017) have shown that firm size affects its capability in contracting with governments. In this section, we start with the analysis of firm size. Figure 2a shows the distribution of contracts over the 12 firm sizes. It seems to suggest that SMEs have lower median value. Figure 2b provides further evidence to this point. To provide statistical evidence, we conduct a median test based on Fig. 2b and find that the median value for SMEs is significantly smaller ($\$45K < \$54K$, $\chi^2 = 108.585$, $p < 0.001$) than that for LEs. On the other hand, SMEs have secured 109,807 (82.65%) contracts, which are much more than what LEs have. In short, the results imply that SMEs have a higher likelihood to get contracts, but with relatively lower value.

[Fig. 2 *Firm size (a) and SME (b): median value and number of contracts (K = thousand)*]

In addition, we identify top industries where contracts take place based on the Goods and Services Identification Number (GSIN) in Canada. Table 2 shows that the top list of industries for SMEs is totally different from that for LEs regarding the median value of contracts. It suggests that the two groups of

enterprises derive contract values from different areas. For instance, SMEs excel in the *Aircraft Maintenance and Repair Shop Specialized Equipment – Repair* industry, whereas LEs outperform in the *Property and Facilities Management – Buildings* industry. Meanwhile, Table 3 shows that SMEs in the *Hotels, Motels and Commercial Accommodation* industry secure the most contracts (12,206 out of 12,341), much more than any other industries for both SMEs and LEs. In addition, it also shows that SMEs and LEs have certain level of competitions in the automatic data processing (*ADP*) *Software* industry, where SMEs obtain about twice more contracts than LEs.

Table 2
Top three industries for SME and LE suppliers in median value (K = thousand)

	Industry	Median Value
SMEs	Aircraft Maintenance and Repair Shop Specialized Equipment - Repair	\$104,028K
	Submarines	\$74,670K
	Claims Administration/Processing (insurance plans)	\$58,886K
Large Enterprises	Property and Facilities Management - Buildings	\$881,000K
	Fishing Vessels	\$488,260K
	Security Printing, Passports	\$230,589K

Table 3
Top three industries for SME and LE suppliers in contract quantity

	Name	Number of Contracts
SMEs	Hotels, Motels and Commercial Accommodation	12,206
	ADP Software	5,359
	Advertising Media Planning/Buying	2,213
Large Enterprises	ADP Software	2,682
	Trucks and Truck Tractors, Wheeled	2,174
	Passenger Motor Vehicles	1,627

[Table 2 *Top three industries for SME and LE suppliers in median value (K = thousand)*]

[Table 3 *Top three industries for SME and LE suppliers in contract quantity*]

We also analyze the locations of suppliers and their contracting public entities. As shown in Fig. 3, the results from SME and LE suppliers are different in certain provinces or territories. More specifically, Fig. 3a illustrates that SMEs in Newfoundland and Labrador and Nunavut have the highest contract

values, suggesting SME suppliers from these two areas are likely to receive higher values of contracts. In addition, Fig. 3b shows that SMEs in Quebec and Ontario are rather active, and they are awarded with the most contracts: 27,294 and 46,107. Together, that is more than half of all contracts (55.25%).

[Fig. 3 *Province: median value (a) and number of contracts (b) (K = thousand)*]

Previous research (James Mauti et al. 2013, Svidroňová et al. 2016, Liao et al. 2017) has indicated that public sectors intend to contract with local suppliers to support and boost the local economy. Bearing this in mind, we create a new variable “same province” to denote whether or not contracts are awarded within the same province. As shown in Fig. 4a, both SMEs and LEs appear to receive higher values from public contractors of the same province. We further conduct a median test on SMEs and confirm that their contract values are significantly higher when contractors are in the same province than in other provinces ($\$50K > \$38K$, $\chi^2 = 422.457$, $p < 0.001$). In addition, Fig. 4b depicts the numbers of same-province vs. non-same-province contracts for SMEs and LEs. A chi-square test of independence demonstrates a significant association between the two factors, that is, whether a contract is same-province and whether it will be awarded to a SME is statistically related ($\chi^2 = 416.512$, $p < 0.001$). SMEs tend to obtain much more same-province contracts.

[Fig. 4 *Same province: median value (a) and number of contracts (b) (K = thousand)*]

Moreover, the solicitation procedure determines how the contracts are awarded. The Government of Canada has implemented several solicitation procedures to promote public procurement practices and encourage more suppliers to participate. The solicitation procedures can be categorized into two types: competitive (i.e., open bidding and traditional competitive) and non-competitive (i.e., advance contract award notice and traditional non-competitive). Research has shown that different solicitation procedures affect the level of competitiveness, which in turn leads to different contracting performance (Reis and Cabral 2015, Yakovlev et al. 2016). In this study, we therefore analyze how contract value and quantity may differ across different solicitation procedures and level of competitiveness. As shown in Fig. 5a and 5b, SMEs obtain high contract values but much less than LEs in the advance contract award notice group, while SMEs dominate in the number of open bidding contracts. According to Fig. 5c and 5d, SMEs appear to receive higher value and more contracts in competitive than non-competitive procedures. Meanwhile, compared with LEs, SMEs are able to obtain more contracts, but lower values in both competitive and non-competitive procedures. This finding is consistent with what Fig. 2b demonstrates.

[Fig. 5 *Solicitation procedure and competitiveness: median value (a, c) and number of contracts (b, d) (K = thousand)*]

In summary, Table 4 illustrates the key findings of SME performance in public procurement.

Table 4
Summary of SME performance in public procurement

Dimension	Finding
Firm size	- Compared with LEs, SMEs have lower median contract values but much more contracts.
Industry	- SMEs and LEs excel in different industries; - Almost all contracts in the <i>Hotels, Motels and Commercial Accommodation</i> industry are awarded to SMEs.
Province	- Compared with other provinces, SMEs in Newfoundland and Labrador and Nunavut receive higher value contracts; - SMEs in Quebec and Ontario are the most active, and they are awarded with the most contracts.
Supplier-contractor location	- SMEs tend to receive higher value and much more contracts in same provinces than other provinces.
Solicitation and competition	- Among all solicitation procedures, SMEs obtain the highest value in the advance contract award notice group, though LEs perform even better in this group; - SMEs dominate in the number of open bidding contracts; - Compared with non-competitive procedures, SMEs receive higher value and more contracts in competitive procedures.

[Table 4 *Summary of SME performance in public procurement*]

Supplier performance prediction models

While Table 4 demonstrates the state-of-the-art of SMEs performance and is expected to elicit strategic insights for SMEs regarding where to look for high value and more contracts, in this section, we also believe that it will be important for individual SMEs to predict possible contract values in future procurement processes. This will help SMEs plan ahead, perfect their procurement strategies, and increase the success rate. In addition, it will allow government departments to predict how much contract value should be assigned to a specific supplier, which helps to ensure that procurement policies, goals, and procedures are consistently followed.

To implement this, we employ machine learning algorithms on the historical procurement data. More specifically, we refer to the literature and incorporate important factors assessed in previous analyses, such as firm size, supplier-contractor location, and competitiveness. In addition to these *organizational* and *location* factors, we further include *contractual* factors like contract duration and award date information (i.e., year, month, and day) as the predictors given the potential impacts suggested in the literature (Reis and Cabral 2015, Yakovlev et al. 2016). Contract value is then denoted as the target variable. Next, we adopt these predictors and target variable to construct four common prediction models, including linear regression, artificial neural network, support vector machine, and random forest

regression for the prediction of contract value. Compared with linear regression, which has a higher interpretability, the other three machine learning algorithms have lower interpretability and work like a “black box” (Chou et al. 2021). Artificial neural network uses non-linear hidden layers to infer patterns from the data and make predictions. In this study, its max iteration is set to 500, with 100 hidden layers, the Rectified Linear Unit (ReLU) activation function, and Adam optimizer. The support vector machine algorithm employs a Radial Basis Function (RBF) kernel, whereas the random forest regression uses 100 trees in the forest and mean squared error as the criterion.

To run the prediction models, we randomly split the data into training (80%) and testing (20%) subsets. Since contract value is positive and has a skewed distribution in the data, we also log-transform it before evaluating the models. To compare prediction accuracy, three performance measures are considered, including mean error (ME), root mean squared error (RMSE), and mean absolute error (MAE). Table 5 demonstrates the results of the three performance measures for the full dataset, SME and LE subsets, across the four prediction models. The finding suggests that the *random forest regression* consistently outperforms other models, with the ME scores closest to zero, lowest RMSE scores, and lowest MAE scores for all suppliers including SMEs and LEs.

Table 5 Prediction models and performance measures									
	ME			RMSE			MAE		
	All	SMEs	LEs	All	SMEs	LEs	All	SMEs	LEs
Random Forest Regression	0.001	0.010	0.009	1.645	1.636	1.705	1.197	1.178	1.247
Support Vector Machine	0.037	0.045	0.129	1.821	1.817	1.911	1.339	1.320	1.405
Linear Regression	-0.020	-0.013	0.025	1.892	1.868	2.069	1.373	1.336	1.514
Artificial Neural Network	-1.012	-0.313	0.784	13.899	2.186	2.121	3.180	1.375	1.572

[Table 5. *Prediction models and performance measures*]

Discussions And Implications

Governments have widely adopted electronic public procurement to obtain goods and services from external sources. The intention and purposes of such practices are often not limited to cost savings and operational efficiency; instead, it has become a policy tool for governments to leverage their resources and opportunities for various societal goals. SMEs have become an important component of economy and society, and supporting their growth is a priority of most governments. While SMEs may face more

challenges when competing against LEs in the market, public procurement can potentially offer great opportunities to SMEs in participating and winning business contracts.

The present study intends to assess the Canadian public procurement practice with regard to the performance of SMEs. A number of key factors are identified from the relevant studies, and the 10-year tenders' data from the Government of Canada is analyzed. A data analytics approach is used to identify the patterns of winning contracts, to profile SMEs in winning contracts, and to develop prediction models for supplier's performance in public procurement. The results are mostly consistent with prior studies on public procurement in other countries or regions, while distinct patterns and additional important factors are identified in the Canadian context.

The study contributes to the public procurement literature and practices with the several implications. First, SMEs do play an increasingly important role in the national economy, and they could and should be supported by governments. In Canada, SMEs are top performers in public procurement and are strongly complementing LEs with diverse and specialized offerings. A greater number and higher value of public contracts are awarded to suppliers within the same province as government contractors. Moreover, while public procurement has been long adopted in certain countries, the actual scope appears to be still limited. In Canada, more than 88% of public contracts are relatively small (average value of \$250,000) and shorter (average duration of 223 days). Most contracts are offered by only two departments (i.e., Department National Defence and Public Works and Government Services Canada). SMEs are also mostly awarded in certain service contracts (e.g., about 99% of contracts in hospitality). Governments may further explore the potential of e-procurement and broaden its scope to other departments. Furthermore, we identify SME performance patterns across several dimensions, including firm size, industry, province, supplier-contractor location, solicitation and competition (in Table 4). We believe that this will help SMEs develop tactical strategies regarding these dimensions to better secure more and high value contracts. Finally, there are many influential factors that affect suppliers' performance in public procurement. We identify key factors from the literature and then verify their effects with the Canadian tenders' data. We develop several prediction models based on those factors. In particular, we identify the prominent prediction accuracy from the random forest regression model in the current e-procurement context. This should help suppliers especially SMEs quickly predict contract value if they have information related to organization sizes, locations and contract characteristics. It may also support government departments' intention to predict a contract value and assign it to a specific supplier. Note that caution should be taken when applying these models to other countries, and future studies may validate and extend our findings with more data in different contexts.

Abbreviations

SMEs: small and medium-sized enterprises

LEs: large enterprises

RBF: Radial Basis Function

ME: mean error

RMSE: root mean squared error

MAE: mean absolute error

Declarations

Availability of data and materials

The dataset analysed during the current study is from the tenders' data on the website of the Government of Canada (<https://buyandsell.gc.ca/>).

Competing interests

Not applicable.

Funding

This work was supported by the Regional Research Fund (Lakehead University, #1467084).

Authors' contributions

All authors have seen and approved the manuscript, and they have contributed significantly to the work. SW led the research project, formulated the research questions and framework, provided the datasets, reviewed the analyses/results and writing the paper. ZZ conducted data analyses, formulated the results, and discussed the findings and implications. KF conducted the initial literature review and the data cleansing with preliminary analysis.

Acknowledgements

Not applicable.

References

1. Batenburg, R., (2007). "E-procurement adoption by European firms: A quantitative analysis", *Journal of Purchasing and Supply Management*, 13, 182-192.
2. Besser, T.L. & Miller, N., (2011). "The structural, social, and strategic factors associated with successful business networks", *Entrepreneurship & Regional Development*, 23, 113-133.

3. Brammer, S. & Walker, H., (2011). "Sustainable procurement in the public sector: an international comparative study", *International Journal of Operations & Production Management*, 31, 452-476.
4. Carayannis, E.G. & Popescu, D., (2005). "Profiling a methodology for economic growth and convergence: learning from the EU e-procurement experience for central and eastern European countries", *Technovation*, 25, 1-14.
5. Chiappinelli, O., (2019). "Decentralization and Public Procurement Performance: New Evidence from Italy", *Economic Inquiry*, 58, 856-880.
6. Chou, P., Chuang, H.H.-C., Chou, Y.-C. & Liang, T.-P., (2021). "Predictive Analytics for Customer Repurchase: Interdisciplinary Integration of Buy till You Die Modeling and Machine Learning", *European Journal of Operational Research*, (In Press).
7. Coviello, D. & Gagliarducci, S., (2017). "Tenure in Office and Public Procurement", *American Economic Journal: Economic Policy*, 9, 59-105.
8. Di Mauro, C., Ancarani, A. & Hartley, T., (2020). "Unravelling SMEs' participation and success in public procurement", *Journal of Public Procurement*, 20, 377-401.
9. European Commission, (2008). European Code of Best Practices Facilitating Access by SMEs to Public Procurement Contracts.
10. Flynn, A. & Davis, P., (2014). "Theory in public procurement research", *Journal of Public Procurement*, 14, 139-180.
11. Flynn, A. & Davis, P., (2015). "The policy–practice divide and SME-friendly public procurement", *Environment and Planning C: Government and Policy*, 34, 559-578.
12. Flynn, A. & Davis, P., (2017). "Explaining sme participation and success in public procurement using a capability-based model of tendering", *Journal of Public Procurement*, 17, 337-372.
13. Flynn, A., Mckevitt, D. & Davis, P., (2013). "The impact of size on small and medium-sized enterprise public sector tendering", *International Small Business Journal: Researching Entrepreneurship*, 33, 443-461.
14. Garrido, M.J., Gutiérrez, A. & San José, R., (2008). "Organizational and economic consequences of business e-procurement intensity", *Technovation*, 28, 615-629.
15. Gelderman, C.J., Ghijsen, P.W.T. & Brugman, M.J., (2006). "Public procurement and EU tendering directives – explaining non-compliance", *International Journal of Public Sector Management*, 19, 702-714.
16. Ginsberg, J., Mohebbi, M.H., Patel, R.S., Brammer, L., Smolinski, M.S. & Brilliant, L., (2009). "Detecting influenza epidemics using search engine query data", *Nature*, 457, 1012-1014.
17. Glas, A.H. & Eßig, M., (2018). "Factors that influence the success of small and medium-sized suppliers in public procurement: Evidence from a centralized agency in Germany", *Supply Chain Management: An International Journal*.
18. Grandia, J. & Meehan, J., (2017). "Public procurement as a policy tool: using procurement to reach desired outcomes in society", *International Journal of Public Sector Management*, 30, 302-309.

19. Grandón, E.E., Nasco, S.A. & Mykytyn, P.P., (2011). "Comparing theories to explain e-commerce adoption", *Journal of Business Research*, 64, 292-298.
20. Grega, M., Orviska, M., Nemec, J. & Lawson, C., (2019). "Factors Determining the Efficiency of Slovak Public Procurement", *NISPAcee Journal of Public Administration and Policy*, 12, 43-68.
21. Gunasekaran, A. & Ngai, E.W.T., (2008). "Adoption of e-procurement in Hong Kong: An empirical research", *International Journal of Production Economics*, 113, 159-175.
22. Halsbenning, S. & Niemann, M., (2019). The European Procurement Dilemma-First Steps to Introduce Data-Driven Policy-Making in Public Procurement. *2019 IEEE 21st Conference on Business Informatics (CBI)*. IEEE.
23. Hardy, C.A. & Williams, S.P., (2008). "E-government policy and practice: A theoretical and empirical exploration of public e-procurement", *Government Information Quarterly*, 25, 155-180.
24. Hoekman, B. & Taş, B.K.O., (2022). "Procurement policy and SME participation in public purchasing", *Small Business Economics*, 58:383–402. <https://doi.org/10.1007/s11187-020-00414-z>.
25. Ised, (2016). *Innovation, Science and Economic Development - Key Small Business Statistics*. Small Business Branch of Innovation, Science and Economic Development Canada
26. James Mauti, M., James Muranga, N. & Peterson Obara, M., (2013). "The critical success factors and challenges in e-procurement adoption among large scale manufacturing firms in Nairobi, Kenya", *European Scientific Journal, ESJ*, 9.
27. Kastner, T., (2010). "The Persisting Ideal of Agreement in an Age of Boilerplate", *Law & Social Inquiry*, 35, 793-823.
28. Kiiver, P. & Kodym, J., (Year). *The Practice of Public Procurement: Tendering, Selection and Awarded*.^eds.
29. Kim, S. & Lee, H., (2006). "The Impact of Organizational Context and Information Technology on Employee Knowledge-Sharing Capabilities", *Public Administration Review*, 66, 370-385.
30. Kohler, J.C., Mitsakakis, N., Saadat, F., Byng, D. & Martinez, M.G., (2015). "Does Pharmaceutical Pricing Transparency Matter? Examining Brazil's Public Procurement System", *Globalization and health*, 11, 34-34.
31. Liao, D., Orser, B. & Riding, A., (2017). *Federal Procurement as a Strategy to Lever Innovation and SME Growth*. Telfer School of Management, University of Ottawa: Ottawa, Ontario, Canada.
32. Loader, K., (2005). "Supporting SMEs through Government Purchasing Activity", *The International Journal of Entrepreneurship and Innovation*, 6, 17-26.
33. Loader, K., (2013). "Is Public Procurement a Successful Small Business Support Policy? A Review of the Evidence", *Environment and Planning C: Government and Policy*, 31, 39-55.
34. Macdonald, J.M., Handy, C.R. & Plato, G.E., (2002). "Competition and Prices in USDA Commodity Procurement", *Southern Economic Journal*, 69, 128.
35. Mamavi, O., Nagati, H., T. Wehrle, F. & Pache, G., (2014). "Out of sight, out of mind? Supplier spatial proximity in French public procurement", *International Journal of Public Sector Management*, 27, 486-

36. McCrudden, C., (2004). "Using public procurement to achieve social outcomes", *Natural Resources Forum*, 28, 257-267.
37. Moon, M.J., (2005). "E-procurement management in state governments: Diffusion of e-procurement practices and its determinants", *Journal of Public Procurement*, 5, 54-72.
38. Moretti, L. & Valbonesi, P., (2015). "Firms' Qualifications and Subcontracting in Public Procurement: An Empirical Investigation", *Journal of Law, Economics, and Organization*, 31, 568-598.
39. Ng, H.S. & Kee, D.M.H., (2012). "The Issues and Development of Critical Success Factors for the SME Success in a Developing Country", *International Business Management*, 6, 680-691.
40. Ramanathan, R., Ramanathan, U. & Hsiao, H.-L., (2012). "The impact of e-commerce on Taiwanese SMEs: Marketing and operations effects", *International Journal of Production Economics*, 140, 934-943.
41. Reis, P.R.C. & Cabral, S., (2015). "Public procurement strategy: the impacts of a preference programme for small and micro businesses", *Public Money & Management*, 35, 103-110.
42. Saastamoinen, J., Tammi, T. & Reijonen, H., (2018). "E-procurement and SME involvement in public procurement of innovations: an exploratory study", *International Journal of Procurement Management*, 11, 420.
43. Savrul, M., Incekara, A. & Sener, S., (2014). "The Potential of E-commerce for SMEs in a Globalizing Business Environment", *Procedia - Social and Behavioral Sciences*, 150, 35-45.
44. Svidroňová, M.M., Meričková, B.M. & Gondášová, L., (2016). "E-procurement in Contracting-out of Public Goods and Services: Evidence from Slovakia", *NISPAcee Journal of Public Administration and Policy*, 9, 57-71.
45. Uyarra, E., Edler, J., Garcia-Estevez, J., Georghiou, L. & Yeow, J., (2014). "Barriers to innovation through public procurement: A supplier perspective", *Technovation*, 34, 631-645.
46. Xu, S.X. & Huang, G.Q., (2015). "Auction-based transportation procurement in make-to-order systems", *IIE Transactions*, 47, 1236-1251.
47. Yakovlev, A., Vyglovsky, O., Demidova, O. & Bashlyk, A., (2016). "Incentives for repeated contracts in public sector: empirical study of gasoline procurement in Russia", *International Journal of Procurement Management*, 9, 272.
48. Zabala-Iturriagagoitia, J.M., (2022). "Fostering regional innovation, entrepreneurship and growth through public procurement", *Small Business Economics*, 58, 1205–1222.
<https://doi.org/10.1007/s11187-021-00466-9>.

Figures

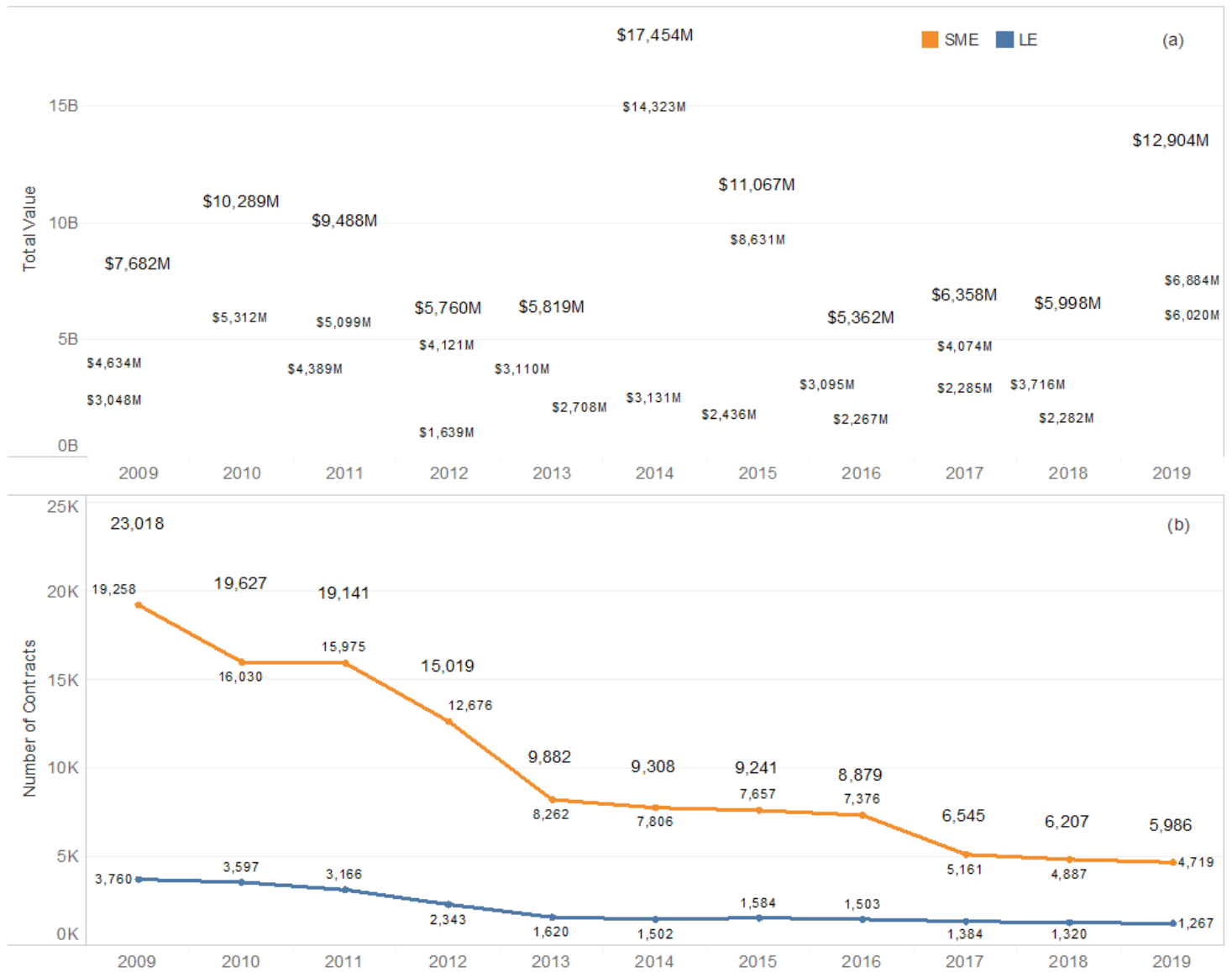


Figure 1

Total value (a) and number of contracts (b) from 2009 to 2019 (M = million)

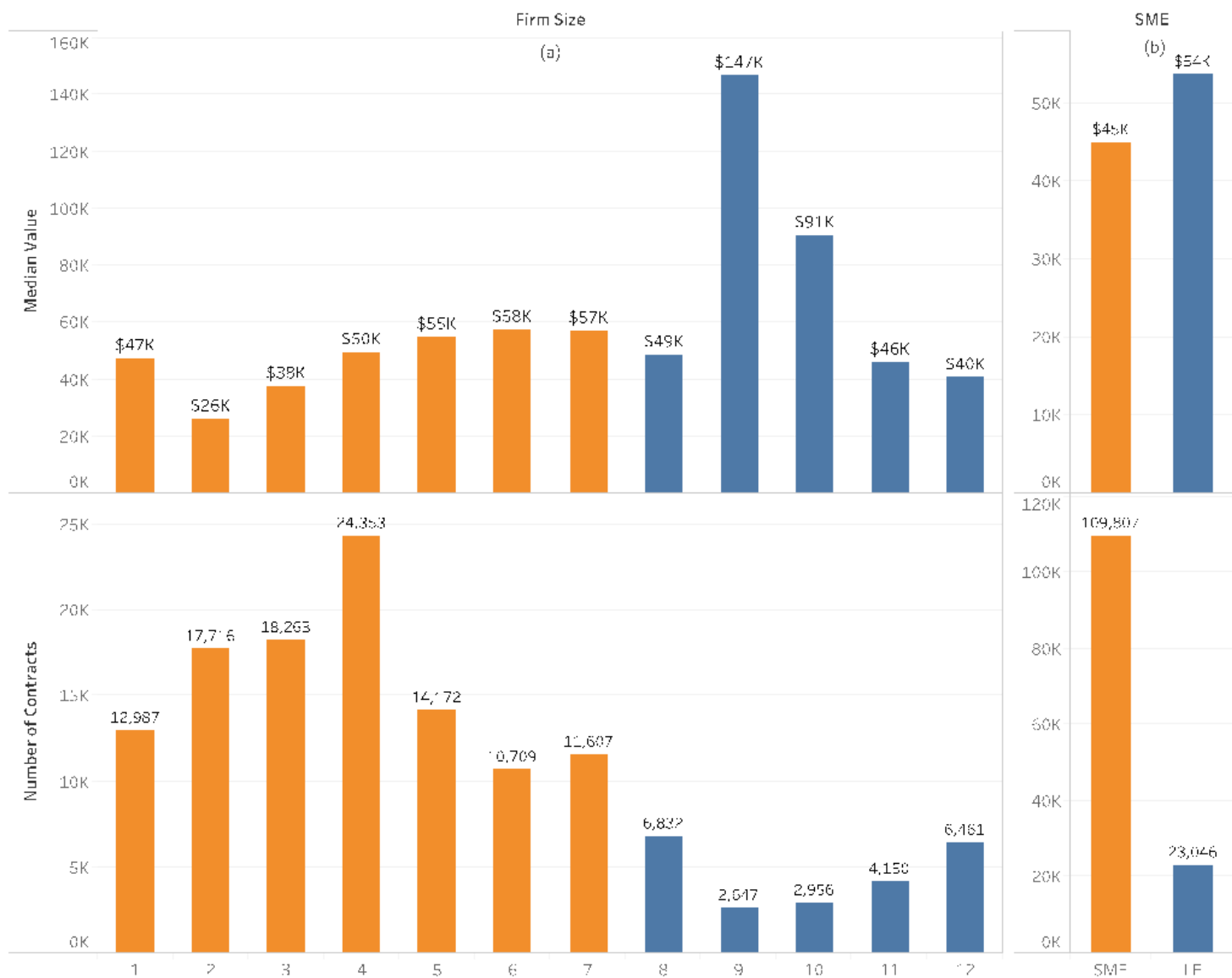


Figure 2

Firm size (a) and SME (b): median value and number of contracts (K=thousand)

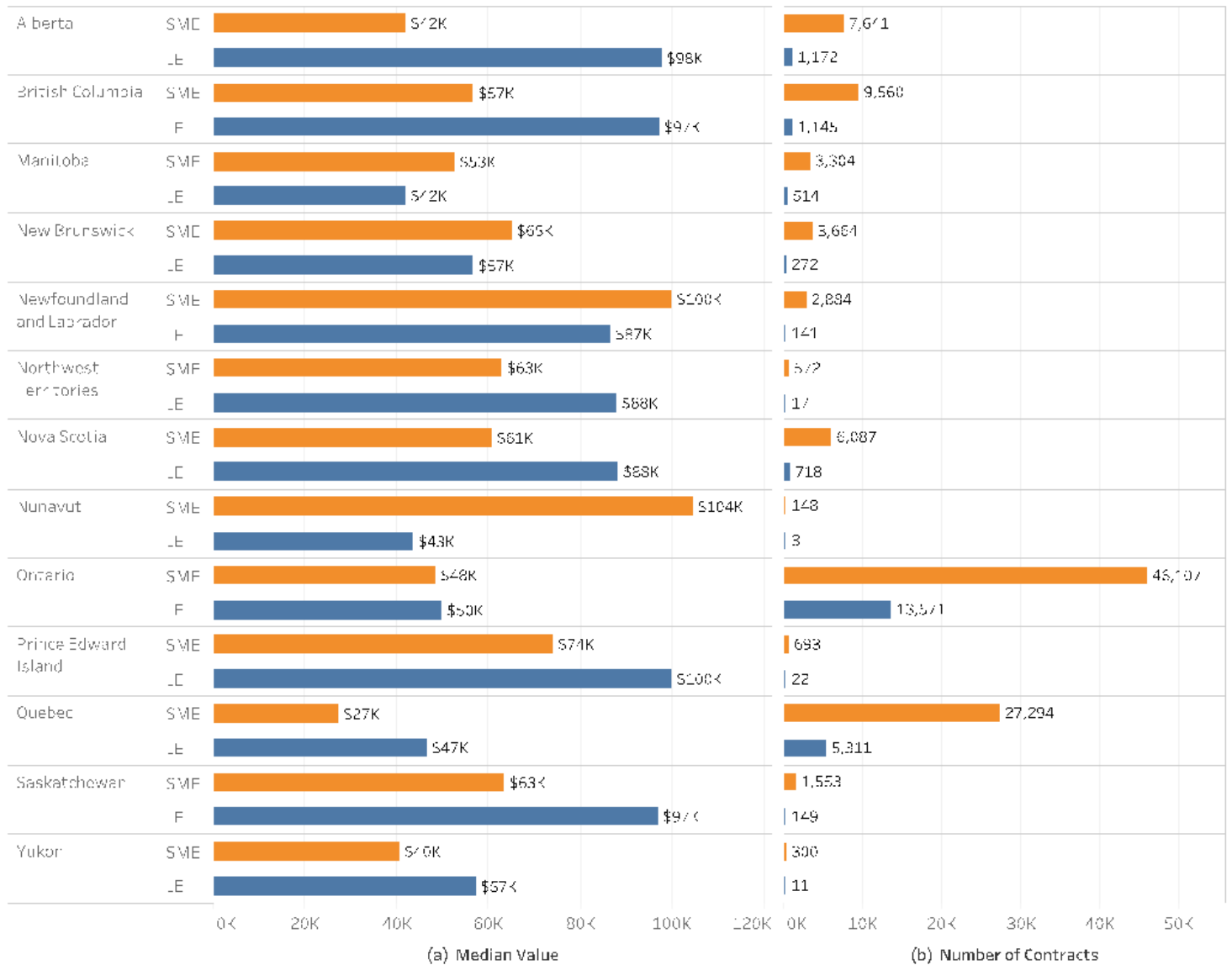


Figure 3

Province: median value (a) and number of contracts (b) (K=thousand)

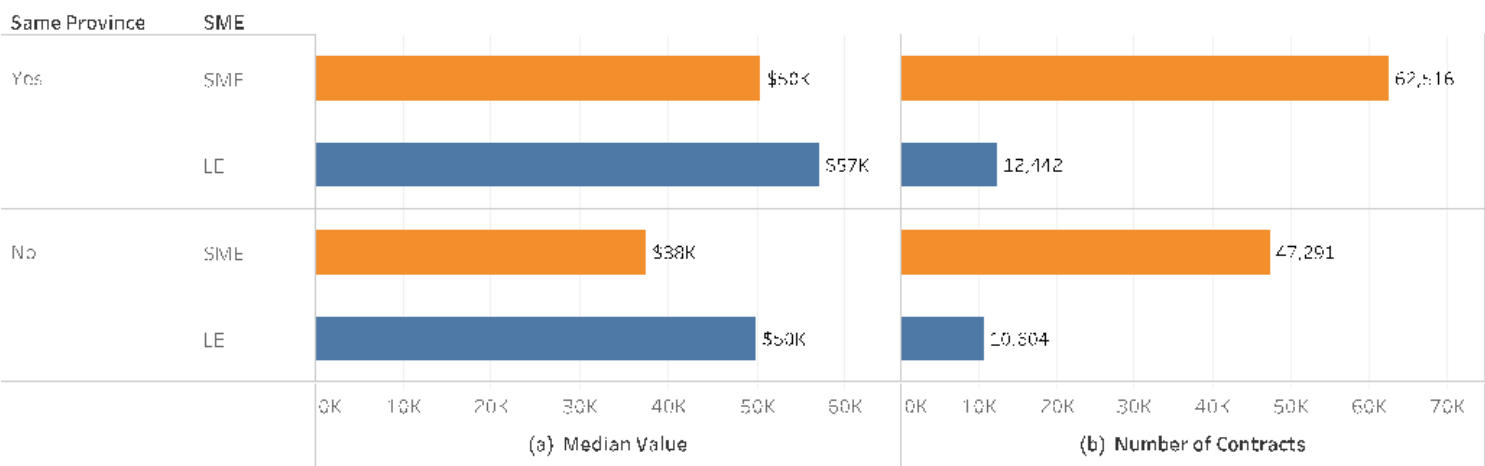


Figure 4

Same province: median value (a) and number of contracts (b) (K=thousand)

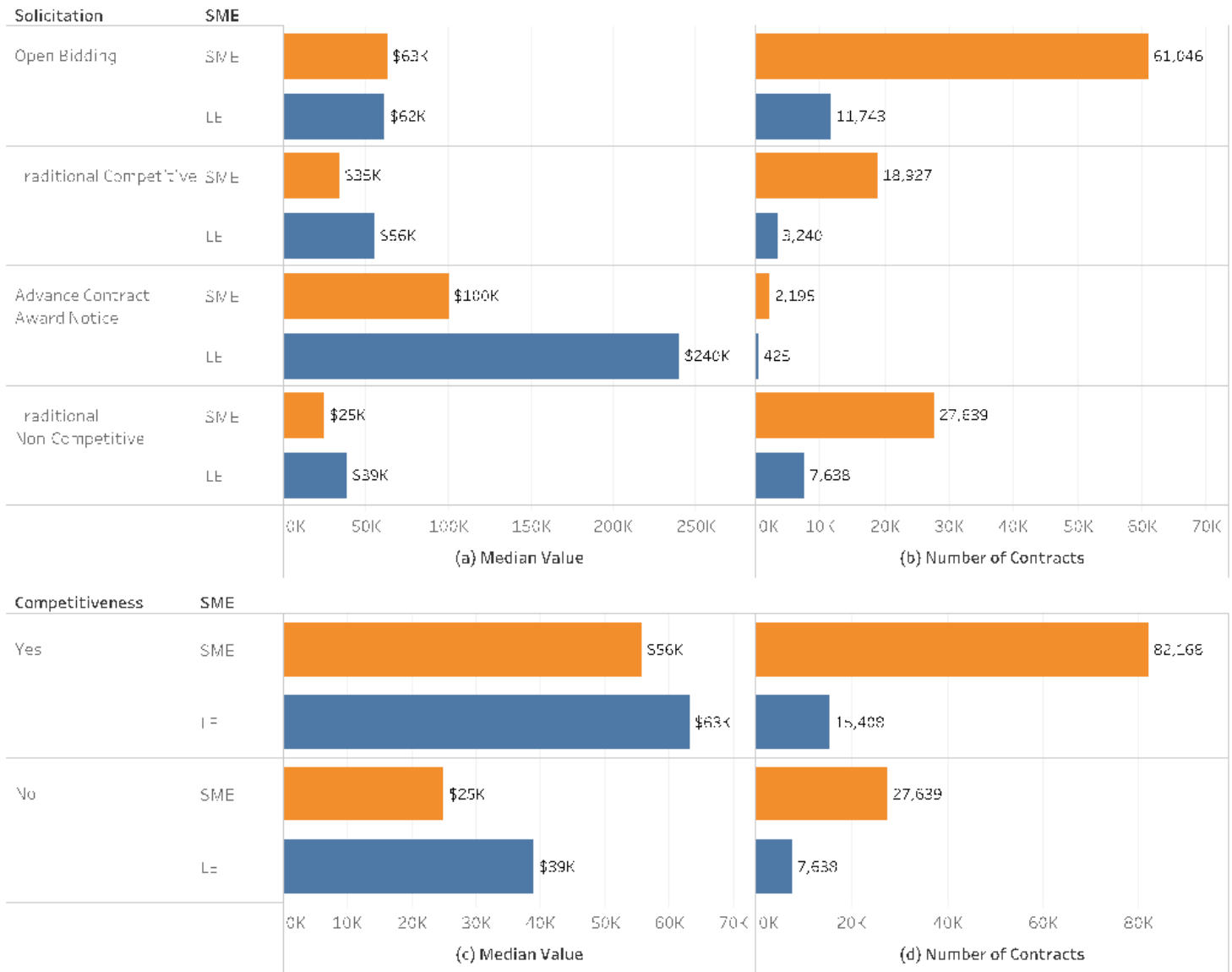


Figure 5

Solicitation procedure and competitiveness: median value (a, c) and number of contracts (b, d) (K=thousand)