Combatting Climate Change through Public Procurement:

A Big Data and Machine Learning Approach

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Abstract

While governments worldwide are taking steps to reduce greenhouse gas emissions, the role of public procurement—a major contributor to global CO2 emissions—in combating climate change remains poorly understood. This paper combines economic literature on demand and supply side innovation and public administration theory on contract management to develop an analytical framework for green public procurement. Using a big population dataset of all Danish public procurements conducted between 2021 and 2022 (>200,000 contract documents) and natural language processing techniques, we examine the prevalence of green criteria in public procurement contracts. Further regression analyses reveal that right-leaning and wealthier governments are less likely to include green criteria in their procurement contracts. Moreover, our findings indicate that governments are less inclined to integrate green procurement criteria for complex products and services compared to simpler ones. We discuss the implications of these findings for the role of public management literature and practice in driving the green transition.

Keywords: Public procurement, climate change, big data, natural language processing

Introduction

While governments have long recognized the urgent need to reduce greenhouse gas emissions, they continue to struggle to find an appropriate and adequate response. Traditionally, some governments have turned to policies and regulation by, e.g., enforcing caps on CO2 emissions for certain industries. Meanwhile, others are increasingly looking into governance approaches commonly referred to as stewardship, where governments intervene by actively engaging in activities that shape and support markets (Van Slyke, 2006; Dickinson at al., 2021; Carey et al., 2020). One major governance activity that aligns with this purpose is public procurement, which comprises up to 30 percent of GDP in the OECD countries alone (OECD, 2021). However, despite the enormous purchasing power inherent in public procurement, governments have yet to fully realize the potential in using this central governmental activity to steer markets toward a more environmentally friendly production (Leal et al., 2020).

To utilize government procurement to reduce CO2-emissions, public authorities in some countries are increasingly redirecting from traditional acquisition practices to green public procurement. Green public procurement is part of a broader development, where public purchasing has shifted from being a functional task at the periphery of public administration to a strategic profession oriented toward achieving broader social values (Hafsa et al., 2021; Walker et al., 2009). Green public procurement can support the green transition by accounting for the environmental costs of producing and consuming products and services, when buying from private markets. Specifically, when governments buy green, they apply environmentally friendly, "green" criteria to increase the market for sustainable goods and services (Cheng et al., 2018).

Despite an emerging literature on the role of public procurement in addressing climate change, the debate has so far primarily taken place in the literature on purchasing, production, and environmental management respectively (Walker et al., 2008; Varnäs et al., 2009; Zhu et al., 2013).

Thus, there is a lack of knowledge of the administrative and managerial implications of how governments can use public procurement to reduce public sector CO2-emissions and thereby contribute to the green transition. This knowledge gap is surprising in that governments themselves are responsible for a significant proportion of total greenhouse gas emissions. Utilizing the green potential in public procurement requires a focus on strategic management and how to support and implement green procurement in public administration at all levels of government.

This study examines governments' efforts to reduce CO2-emissions through green public procurement by answering the following research question: How do governments implement/use/apply green public procurement, and which factors explain the likelihood of governments opting for green procurement? We utilize a unique big dataset containing the full population of public procurement of goods, services, and infrastructure projects in Denmark (more than 70,000 documents) to develop a measure for green public procurement, to examine the extent to which governments apply green criteria in public procurement, and investigate which factors influence governments' use of green procurement. As a signatory on the Paris Agreement, Denmark is committed to reducing CO2-emissions of which the public sector is responsible for a significant share. In 2019, the Danish local, regional, and state agencies emitted 12 million tons of CO2 equivalents, which is almost as much as the emissions in the total private households (Danish Government, 2021). Thus, reducing public sector emissions through procurement of goods, services and infrastructure plays a crucial role in achieving the Paris Agreement and the even more ambitious Danish goal of a 70 percent reduction in CO2-emissions by 2030.

Using natural language processing (NLP), we systematically analyze all instances of green and environmentally friendly procurement. We identify two distinct approaches to buying green: i) use of minimum requirements, and ii) application of green criteria as competition parameters for evaluating bids. We use these distinct approaches to construct four variables for buying green and

predict why environmental criteria are used by some government agencies but not by others. The study draws on economic theory of externalities to develop a conceptual framework for investigating how governments can specify and price-in environmental requirements in contracts with the market. In particular, our framework helps to develop a conceptual and empirical understanding of how governments can learn from big data to internalize the cost of environmental externalities in exchanges with the market.

The paper proceeds as follows. In the next section, we discuss on economic literature on externalities as a conceptual lens for studying green procurement. In the third section, we draw on public administration literature about administrative capacity and transaction cost economics about product complexity to develop testable hypotheses about factors explaining the use of green public procurement. The fourth section, we then present our big dataset on public procurement contracts, the natural language processing approach, the dependent, independent, and control variables, and our estimation approach. Finally, the fifth section provides a discussion and conclusion.

Environmental Externalities and Public Procurement

Among the many theories of government and market interaction, the market-failure model has attracted great interest among economists and public administration researchers alike. In its simplest form, the market-failure model is based on the first economic welfare theorem of a perfectly competitive and Pareto-optimal equilibrium, where no individual can be made better off without reducing the welfare of others. However, the market often falls short of meeting these idealized (and unrealistic) characteristics of perfectly functioning markets. This critique has given rise to the development of the market-failure model (Bator 1958).[1] The essence of market failure is when "the

[1] For a more thorough explanation of the market failure model, see Mahoney and Qian (2013).

prices of goods and services give false signals about their real value, confounding the communication between consumers and producers" (1991, 18: also cited in Bozeman 2002, 146). Market failure implies that the market does not account for all costs and benefits of production and consumption with externalities as well-known examples of a central market failure (Bator 1958; ref.). In essence, externalities occur when the market price of a product does not reflect the negative (or positive) societal effects of producing and consuming a product (Lowery, 1998). Thus, negative externalities occur every time market prices for various products and services fail to take the environmental effects of producing and consuming those products and services into consideration. These societal effects lead to tangible and significant losses of welfare. Pollution, global warming, sustained heat waves, and floods force people out of their homes or cause ruined crops that lead to famine in different parts of the world. Through green procurement, governments internalize the unaccounted-for costs of environmental externalities by pricing-in the environmental footprint of production and consumption. As such, green procurement becomes a form of government intervention in private markets, when said markets fail to efficiently price-in the environmental externalities of production and consumption.

Environmental Externalities in Green Public Procurement

There are several ways to engage in green public procurement such as using new forms of tender procedures to support innovation, early market engagement, and environmentally friendly standards in award criteria and technical specifications when preparing tender documents (Kristensen et al., 2021). The different approaches depend on the different phases of the procurement process. Public procurement comprises several key steps before (ex ante) and after awarding the contract (ex post) (Brown and Potoski, xx). Roughly put, the process requires identifying user needs and specifying product requirements, selecting the appropriate tendering procedure, calling for bids, and awarding,

enforcing, and terminating contracts (Warren, 2014). In the following, we distinguish between a supply- and demand-side approach to the pricing-in of environmental externalities in public procurement.

Supply-side Approach: For pricing-in environmental externalities, using award criteria and technical specifications in preparing of tender documents is particularly relevant. By using green award criteria, governments develop competitive parameters by which the received bids are evaluated and the contract awarded. In a green purchase, the public buyer determines how much weight to assign environmental and/or climate considerations in the evaluation of bids. In the European Union, procurement regulation makes it possible to include green criteria when evaluations are based on cost or price and quality, but not when lowest price is used as the only award criteria. The advantage of using green award criteria is that bidders will compete to optimize the ways in which their respective bid reduces the negative climate or environmental impact of producing and delivering their product or service. However, it requires objective and realistic criteria, thus incurring high transaction costs on the public buyer's part.

Demand-side Approach: In the demand-side approach, governments develop technical specifications, that is, green minimum requirements, that all bidders must fulfill, e.g., industry-specific environmental certifications and standards. The advantage of this approach is that it may impose fewer transaction costs on the public buyer, as it requires less work to assess and follow-up. However, minimum requirements do not incentivize bidders to compete on having the "greenest" bid, potentially setting a low bar for, e.g., reducing carbon footprint. The demand-side approach is particularly suited when the buying government has a good idea of the precise green qualities, e.g., product features, production processes, it demands from providers in the market. Table 1 below summarizes the demand- and supply side approaches to green public procurement.

Table 1. Demand- and Supply Side Approaches to Green Procurement

	Description	Strengths and weaknesses
Technical specifications	Demand-side approach: Minimum requirements	Low transaction costs, (risk of) low environmental/climate benefits
Award criteria	Supply-side approach: Competitive parameter	High transaction costs, (chance of) high environmental/climate benefits

Hypotheses

To explain whether local governments opt for green public procurement, we draw on stewardship theory and transaction cost economics to develop five hypotheses. First, we expect that green public procurement requires both administrative and financial capacity. Guiding and steering the market toward more environmentally friendly production necessitates trained staff. Administrative personnel must have the knowledge and skills to effectively engage in market research and dialogue, developing appropriate green criteria that either fosters competition to secure the greenest bid possible and/or sets a certain minimum environmental standard for all bids. MORE HERE

> **Hypothesis 1:** Governments with higher administrative capacity are more likely to use environmental criteria and requirements in public procurements.

> **Hypothesis 2:** Governments with higher financial capacity are more likely to use environmental criteria and requirements in public procurements.

Besides government capacity, we expect the political ideology of the government to influence the propensity to use green public procurement. Previous studies on public procurement have provided

mixed evidence on the impact of ideology on contracting out (Christoffersen and Paldam, 2003; Bhatti et al., 2008), in some cases demonstrating that right-wing government contract out to a higher degree than left-wing. However, contracting out temporarily outsources services to private providers, which is in line with the general conviction of right-winged governments that private providers are more efficient than public. Meanwhile, we argue that green public procurement is a more direct form of market intervention to address climate change, where governments actively steer businesses toward a common goal of green transition, which is usually associated with left-wing political ideology of voters and politicians.

> **Hypothesis 3:** Right-wing governments are less likely to use environmental criteria and requirements in public procurement than left-wing governments.

In addition to hypotheses about government capacity and ideology, we draw on transaction cost economics and propose that governments are more likely to use green procurement criteria for simple than for complex products. First, we expect that governments are more likely to use green criteria in procurements for products that are relatively simple because green properties of simpler products are easier to describe and verify. Second, we expect that governments are more likely to use green criteria in procurements for products that are exchanged in markets with relatively modest sunk costs because this makes it less risky for buyers and sellers to develop and exchange products that are environmentally friendly. This leads to two hypotheses about the importance of measurability and asset specificity in green public procurement.

Hypothesis 4: Governments are less likely to use environmental criteria and requirements for products and services that are difficult to measure than for products and services that are easy to measure.

Hypothesis 5: Governments are less likely to use environmental criteria and requirements for products and services with high asset specificity than those with low asset specificity.

Methods and Data

We draw on three data sources to examine the extent of green public procurement and which factors influence the use of green public procurement in local governments. First, we employ a unique dataset containing the entire population of all public procurements in Denmark from 2021 to 2022. The dataset consists of a total of 22,048 procurement documents that we use to create our dependent variables. To measure three of our independent variables on capacity and ideology, we draw on local government register data that are publicly available. Finally, we use survey data to measure the transaction attributes of the procured goods and services. We elaborate on the variables and data sources in the subsequent sections.

Creation and Exploratory Analysis of Dependent Variables

In contrast to existing studies that measure green procurement based on qualitative samples and surveys (Preuss and Walker, 2011; Björklund 2011; Igarashi et al 2015), we measure green procurement systematically based on the entire population of Danish public procurement contracts from January 2021 to August 2022. To make this possible, we use a Natural Language Processing (NLP) inspired approach. NLP combines linguistics with machine learning and uses algorithms to

derive the “natural language” from the content of documents to classify new information into variables for use in common social science research methods (Bird et al. 2009; Hollibaugh 2019). Using the NLP approach, , we create and classify four dependent variables to measure green public procurement based on 22,048 procurement documents:

1) Green award criteria (dummy): A dichotomous measure of whether green elements are included or not in the award criteria used to evaluate bids.
2) Green award criteria (fractional): A continuous measure of the weight prescribed to green elements out of the total award criteria. We derive this manually by extracting the text near the green award criteria.
3) Green minimum requirements (dummy): A dichotomous measure of whether green certifications are included or not in the technical specifications.
4) Green minimum requirements (count): A count variable for how many different types of green certifications that are included as minimum requirements in the technical specifications.

To create these variables from the content of the procurement documents, we first cleaned the unstructured text-data to ensure that all the documents are read in the same way. In this process, we manipulate the text-data in several ways by including regular expressions, separating text into words (Word Tokenization), reducing all words to a common base (Lemmatization) and applying a list of stop-words. The Python notebook for extraction, data cleaning, and the following search strategy is available as an online appendix.

We classify whether the documents use green award criteria and green minimum requirements using a dictionary-based bag-of-words approach as opposed to supervised machine

learning approaches (Grimmer & Stewart 2013). This paper's procurement material consists of many and long documents, where the green aspects are only a minor element that cannot be defined in advance. This makes a supervised machine learning approach, based on pattern recognition, difficult and calls for a dictionary-based approach. While such an approach is often challenged by the context-dependent meaning of words and difficulties in identifying all relevant search terms, these caveats are less pronounced in public procurement documents that use formal language and relatively uniform terms for green criteria.

To identify green award criteria and green minimum requirement with this NLP inspired approach requires deep qualitative knowledge of the practical reality that we are studying. Therefore, we use a dictionary to identify green award criteria based on information from the Danish Competition and Consumer Authority. The dictionary for green minimum requirements in the technical specifications consists of climate-oriented certifications such as the Forest Stewardship Council (FSC), which we determined based on input from public procurers and interest organizations in the field. The two dictionaries appear in appendix AX and AX. We limited the search for green award criteria to 1,706 documents and found green award criteria in 103 documents and public tenders. We then searched for green minimum requirements among all 22,048 documents and found green minimum requirements in 812 documents distributed across 416 public tenders. To ensure the validity of our search strategy, we tested the results against practitioners' expectations.

Figure 1 shows which words are used to describe green award criteria in the procurement documents. They predominantly use broad and generic words to describe this green criterion. Typically, the documents will elaborate more on these generic green award criteria, which is why figure X illustrates the overall green award criteria. Figure 2 shows how the tenders use green labels and certifications as minimum requirements. The most used certifications concern the construction

industry (DGNB), but labels about purchasing and consumption (The Nordic Swan Ecolabel, FSC, MSC and EU Ecolabel) are also prominent as well as labels about transportation (Euronorm and Green Vehicles). The labels may appear several times in the same procurement, which increases their word frequency. In the numerical variable for number of green minimum criteria, the specific label can only occur once per procurement.

Figure 1. Word Frequency for Green Award Criteria

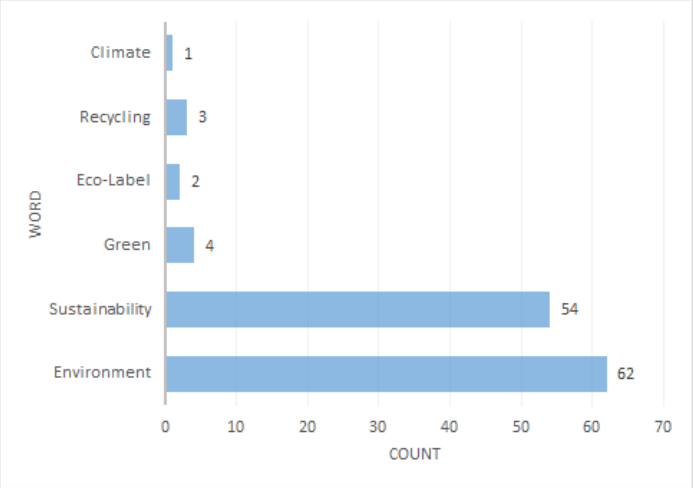


Figure 2. Word Frequency for Green Minimum Requirements

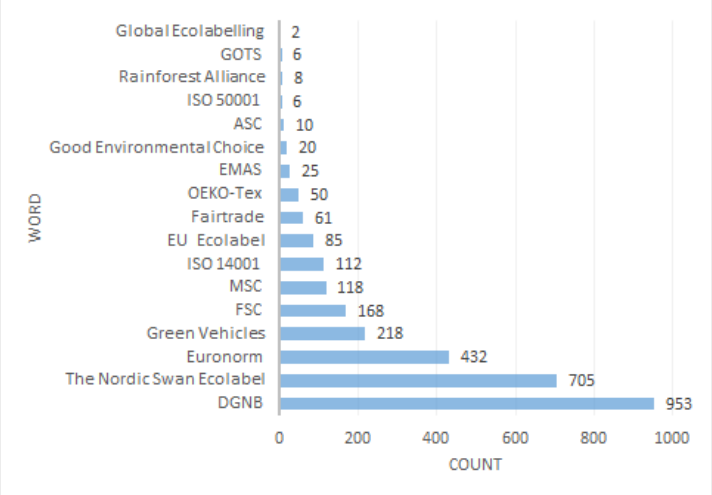


Table 2 suggests that only a minor proportion of the public tenders use green procurement criteria. Green award criteria appear in only 5.7 percent of the procurements, while green minimum requirements appear in 28.5 percent. Among the procurements in our dataset, there is a considerable variation in the degree to which green elements are weighted when evaluating bids ranging from 0 to 60 percent. Conversely, although the number of green certifications used in the procurements range from 0 to 7, one or two green requirements is by far the most common. In fact, more than half of the green procurements, we only find one type of green certification in the minimum requirements

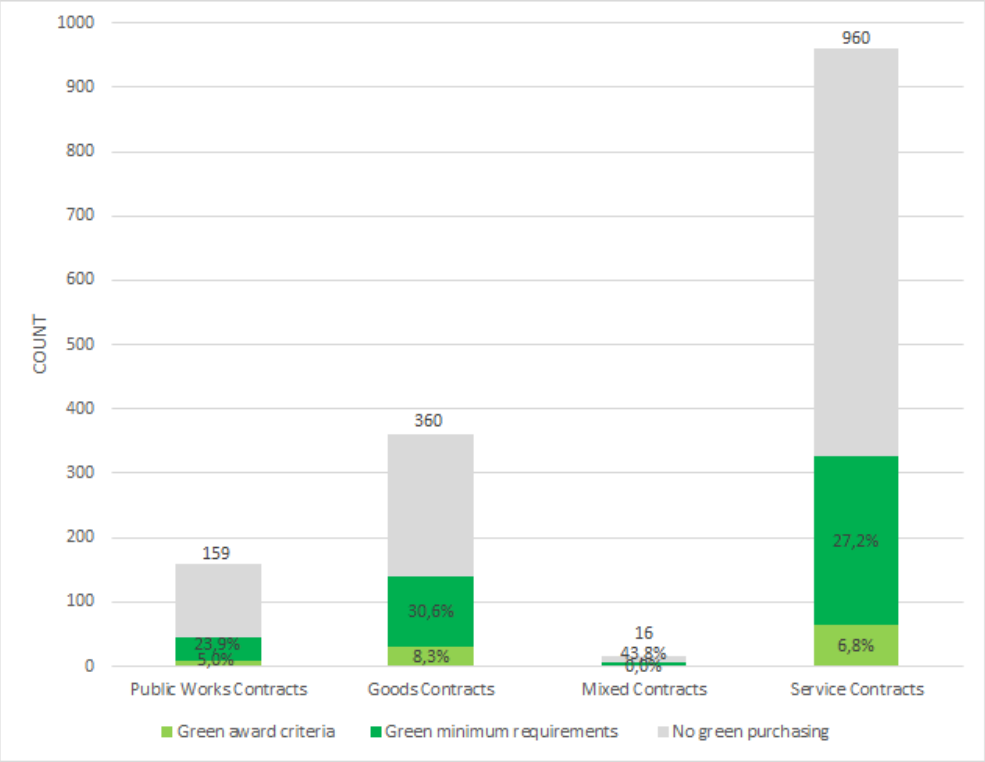
Table 2. Descriptive Statistics for the Green Procurement Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Green award Criteria (dummy)	1,018	.057	.232	0	1
Green award Criteria (fractional)	1,018	.011	.053	0	.6
Green Minimum Requirements (dummy)	1,018	.285	.452	0	1
Green Minimum Requirements (count)	1,018	.468	.936	0	7

Next, figure 3 divides the green public procurements into contracts for goods, services and public works contracts The figure 3 results suggest that the use of green criteria in public procurements is slightly more common in goods procurement than in public works and service procurements.[2]

[2] Figure AX in the appendix shows the distribution for the two numerical measures for green procurement criteria. The picture is the same and we find no significant difference across contract areas. Table AX in the appendix shows a more detailed distribution of tenders based on product types and we find specific product types that use green procurement criteria to a greater extent, including particularly Cleaning of work apparel and Special driving and referred driving.

Figure 3. Tenders Divided Product Type



Independent Variables

We draw on administrative registers for Danish local governments to build our independent variables respectively for ideology, administrative capacity, and financial capacity (our hypothesis 1, 2, and 3). We measure the variable *Administrative Capacity* as the number of full-time employees working with public administration and management per 1,000 inhabitants, while the *Financial Capacity* independent variable is measured as tax base per inhabitant in the municipality. Next, the independent variable *Ideology* is a dichotomous variable distinguishing between right-wing and left-wing ruling majority based on the party of the elected mayor in the municipality.

To measure transaction attributes, specifically measurability and asset specificity, we build on research in the transaction costs tradition (Brown and Potoski, 2003; Levin and Tadelis, 2010; Hefetz and Warner, 2012) and conduct a comprehensive survey of 987 public procurement officers

to measure the transaction cost attributes of the procurements in our data. We include the 60 most common products in the big procurement data set and measure the transaction attributes of these products using well-tested questions and scales. The variable *Measurability* is based on the respondents' evaluation of how easy or difficult it is to describe each product on a scale from 1-5. The variable *Asset Specificity* measures respondents' assessment of sunk costs on a five-point scale from very small to very high. Each respondent was randomly assigned either to the measurability or asset specificity items and then received a random selection of 30 products which appeared in random order (block and question order randomization). The questionnaire was administered as an online survey with two general reminders and a third reminder of personalized emails to all respondents. We received 554 useful responses for a survey response rate of slightly over 50%, which is significantly more responses than previous surveys on this topic (e.g., Brown and Potoski, 2003; Levin and Tadelis, 2010; Hefetz and Warner, 2012.

Control Variables

We include several control variables for our contract data sets and administrative records. From our contract data, we build the following checks. The variable *Contract Type* is a set of dummy variables measuring whether the procurement relates to a public works, goods, services, or mixed contract with public works contracts as the reference category. The variable *Framework Contract* is a dummy variable measuring the extent to which the procurement is a single contract or a framework agreement contract. The *Procurement Procedure* variable measures whether the procurement followed the open, negotiated/restricted or other procurement procedures.

In addition, we import data from administrative registries to construct control variables for several background factors. The variable *Area Size* controls for the geographical size of the contracting government. Next, the variable *Female Candidates Elected* is a continuous variable

controlling for the proportion of female city councilors in each municipality. The variable *Government Contracting Indicator* measures the government's expenditure spent on procurement from the market as a percentage of the government's total net expenditure. The variables *Income Corporate Tax* and *Long-term Debt* measure respectively the government's income from local corporate taxes and long-term debt. Finally, we include *Year Dummies* to control for time trends in our pooled data set.

Table 3. Descriptive Statistics for Independent and Control Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Independent variables:					
Administrative capacity	1,018	15.258	1.378	11.6	26.8
Financial capacity	1,018	201.077	37.389	163.761	420.453
Asset specificity	1,018	2.459	.362	1.36	4.12
Measurability	1,018	2.864	.484	1.95	3.75
Mayor party dummy:					
Left-wing	1,018	.637	.481	0	1
Right-wing	1,018	.363	.481	0	1
Control variable:					
Female Candidates Elected	1,018	34.607	15.562	1	58
Contract Type					
Public works	1,018	.076	.265	0	1
Goods	1,018	.214	.41	0	1
Mixed	1,018	.006	.077	0	1
Services	1,018	.704	.457	0	1
Framework Contract					
Public contract	1,018	.705	.456	0	1
Framework	1,018	.295	.456	0	1
Procurement Procedure					
Open	1,018	.738	.44	0	1

Restricted or negotiated	1,018	.248	.432	0	1
Others	1,018	.015	.121	0	1
Year Dummies:					
2021	1,018	.634	.482	0	1
2022	1,018	.366	.482	0	1
Government Contracting Indicator	1,018	26.319	3.453	19.8	36.7
Income Corporate Tax (ln)	1,018	6.99	.843	4.762	9.835
Long-term Debt	1,018	50.053	29.07	1	97
Area Size (ln)	1,018	5.601	1.236	2.163	7.295

Results

Table 4 displays the results from the four regression analyses. Models 1 and 2 estimate the likelihood of local governments using green award criteria in evaluating bids as either a binary (yes/no) or fractional outcome (share of award criteria that include green words). Models 3 and 4 estimate the likelihood of using green certifications as minimum criteria in the technical specifications as either a binary (yes/no) or count outcome (number of different green certifications). For a more intuitive interpretation of the models, the average marginal effects are included in the right-hand column of each model in table 4.

From the results, it appears that ideology has a statistically significant impact on using green award criteria (models 1 and 2) but not green minimum requirements (models 3 and 4). Corresponding to our expectations in hypothesis 3, we find that governments with a right-wing mayor are less likely to use green award criteria compared to governments with left-wing mayors. Specifically, the probability of using green award criteria decreases, on average, by 5.9 percentage points when governments have a right-wing mayor compared to a left-wing. Moreover, the share of the award criteria that has a green element decreases by 1.1 percentage points.

The table 4 results moreover indicate that administrative and financial capacity have a negative and statistically significant influence on the probability of local governments using green minimum requirements in their technical specifications. Meanwhile, neither of the capacity variables has a significant impact on green award criteria. The negative direction of the coefficients is surprising, suggesting that wealthier municipalities and those with more administrative capacity are less likely to engage in green public procurement, which is contrary to our hypotheses 1 and 2. The table 4 results suggests that with every increase in financial capacity, the probability of local government using green certifications as minimum requirements decreases by as much as 34.8 percentage points and the number of green certifications decreases by 0.87. Administrative capacity only has a statistically significant impact on whether the local government uses green certifications overall, which decreases by 2.8 percentage points, while the coefficient for the number of different certifications is insignificant.

Finally, concerning our two measures of transaction cost attributes, asset specificity does not appear to have a significant impact on any of the dependent variables, while measurability has a negative and statistically significant association with the dependent variables across all four models. This finding supports our hypothesis 4, suggesting that with higher levels of product complexity, 1) the probability of using green award criteria decreases by 11.9 percentage points, 2) the weighting of award criteria with a green element decreases by 1.1 percentage points, 3) the probability of using green minimum requirements decreases by 28.6 percentage points, and 4) the number of green certifications used in the technical specifications decreases by 0.58.

Overall, the models provide two important insights. First, the findings lend support to two out of five of our hypotheses. Specifically, we find that ideology matters. Governments with a right-wing mayor are less likely to apply green award criteria as a competitive parameter in procurement contracts. It also appears that product complexity is a consistent factor influencing if and to which

degree local governments opt for green public procurement. Thus, with more complex products and services, the likelihood of buying green diminishes. Meanwhile, the hypothesis on asset specificity is not supported. Finally, in contrast to our expectations, the results for financial and administrative capacity suggest that governments with more financial and administrative resources are less likely to procure green than governments with less administrative and financial resources. We discuss these findings in the next section.

Table 4. Regression Analyses of Factors Associated with the Use of Green Public Procurement

	Model 1: Green Award Criteria (binary)		Model 2: Green Award Criteria (proportion)		Model 3: Green Min. Requirements (binary)		Model 4: Green Min. Requirements (count)	
	Coef.	AMEs	Coef.	AMEs	Coef.	AMEs	Coef.	AMEs
Independent variables:								
Right-wing mayor	-1.303***	-0.059***	-1.197**	-0.011*	-0.316	-0.057	-0.271	-0.120
(Ref.: Left-wing)	(0.318)	(0.012)	(0.396)	(0.004)	(0.262)	(0.047)	(0.219)	(0.104)
Administrative capacity	-0.139	-0.008	-0.025	-0.000	-0.155*	-0.028*	-0.043	-0.020
	(0.151)	(0.008)	(0.164)	(0.002)	(0.063)	(0.012)	(0.065)	(0.030)
Financial capacity	-2.619	-0.142	-0.286	-0.003	-1.905*	-0.348*	-1.809**	-0.846*
	(1.947)	(0.110)	(2.489)	(0.028)	(0.795)	(0.154)	(0.620)	(0.369)
Asset specificity	0.249	0.014	0.091	0.001	0.507	0.092	0.137	0.064
	(0.429)	(0.024)	(0.489)	(0.005)	(0.285)	(0.054)	(0.252)	(0.120)
Measurability	-2.184***	-0.119*	-1.469*	-0.016	-1.568***	-0.286***	-1.239**	-0.579*
	(0.658)	(0.047)	(0.637)	(0.010)	(0.389)	(0.073)	(0.431)	(0.277)
Control variables								
Percent female candidates elected	0.018	0.001	0.013	0.000	0.002	0.000	0.007	0.003
	(0.015)	(0.001)	(0.015)	(0.000)	(0.008)	(0.001)	(0.005)	(0.003)
Contract type dummies (ref. Public works):								
Goods	-0.166	0.000	14.815***	0.013*	-0.415	-0.073	-0.374	-0.151
	(0.403)	(.)	(0.696)	(0.005)	(0.566)	(0.102)	(0.561)	(0.250)
Mixed	0.000	0.000	0.095	0.000	-0.516	-0.090	-0.597	-0.218
	(0.000)	(.)	(1.076)	(0.000)	(1.090)	(0.174)	(0.952)	(0.309)
Services	0.000	0.000	14.695***	0.011*	-0.067	-0.013	0.118	0.061
	(0.000)	(.)	(0.654)	(0.005)	(0.406)	(0.077)	(0.376)	(0.184)
Framework	-0.449	-0.023	-0.221	-0.002	0.163	0.030	0.426**	0.215*
(Ref.: Public	(0.244)	(0.013)	(0.306)	(0.003)	(0.222)	(0.042)	(0.155)	(0.106)

contract)								
Tender procedure dummies (ref. open procedure):								
Restricted and negotiated	0.277	0.016	0.050	0.001	0.193	0.036	0.254	0.130
	(0.405)	(0.025)	(0.297)	(0.003)	(0.242)	(0.047)	(0.250)	(0.142)
Other	0.000	0.000	-15.440***	-0.011**	-0.814	-0.123	-0.957*	-0.276***
	(0.000)	(.)	(0.611)	(0.004)	(0.586)	(0.071)	(0.460)	(0.082)
Year=2022 *(Ref.: 2021)*	0.146	0.008	0.089	0.001	0.492**	0.092**	0.366**	0.179**
	(0.386)	(0.022)	(0.423)	(0.005)	(0.155)	(0.030)	(0.127)	(0.065)
Government contracting indicator	0.009	0.000	0.020	0.000	-0.021	-0.004	0.001	0.000
	(0.055)	(0.003)	(0.066)	(0.001)	(0.044)	(0.008)	(0.035)	(0.016)
Income corporate tax (ln)	0.757*	0.041*	0.470	0.005	0.002	0.000	-0.002	-0.001
	(0.301)	(0.017)	(0.325)	(0.004)	(0.104)	(0.019)	(0.075)	(0.035)
Long-term debt	-0.003	-0.000	-0.002	-0.000	0.003	0.001	0.001	0.001
	(0.009)	(0.000)	(0.009)	(0.000)	(0.007)	(0.001)	(0.004)	(0.002)
Area size (ln)	0.019	0.001	0.049	0.001	-0.396***	-0.072***	-0.251***	-0.117***
	(0.215)	(0.012)	(0.248)	(0.003)	(0.115)	(0.021)	(0.050)	(0.028)
Clustering at local government level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustering at product level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	923	923	1018	1018	1018	1018	1018	1018
Pseudo R^2	0.14	0.14	0.08	0.08	0.09	0.09	.	.

Note: Two-way clustering of standard errors at municipalities and 60 unique product codes. * $p < .05$, ** $p < .01$, *** $p < .001$

Discussion and Conclusion

To be written later….

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Appendix

Table A1. The Dictionary for Green Award Criteria

Search words (Danish)	English translation
Biodiversitet	Biodiversity
Bæredygtig	Sustainable
CO2	CO2
Emission	Emission
Forurening	Pollution
Grøn	Green
Vandkvalitet	Water Quality
Luftkvalitet	Air quality
Udledning	Emission
Reducere	Reduce
Reduktionsmål	Reduction target
Mikroplast	Microplastics
Ftalater	Phthalates
Sustainab	Sustainab
Svanemærket	The Nordic Swan Ecolabel
EU-Blomsten	EU Ecolabel
Økologimærke	The organic logo
Ø-mærke	The red Ø-logo
Ecolabel	Ecolabel
The EU Organic Logo	The EU Organic Logo
FSC	FSC
PEFC	PEFC
Global Organic Textile Standard	Global Organic Textile Standard
Textile Standard	Textile Standard
OEKO-tex	OEKO-Tex
MSC	MSC
ASC	ASC
EMAS	EMAS
Good Environmental Choice	Good Environmental Choice
Bra Miljöval	Good Environmental Choice
Charter for Sustainable Cleaning	Charter for Sustainable Cleaning
Rainfores Alliance	Rainfores Alliance
Fairtrade	Fairtrade
Pro planet	Pro planet
Sustainable Cleaning	Sustainable Cleaning
Miljømærke	Ecolabel
Energy-star	Energy-star
EU-Energy Label	EU-Energy Label
Energimærke	Energy Label
Energiforbrug	Energy consumption

Energieffektiv	Energy efficient
ISO 50001	ISO 50001
ISO 26000	ISO 26000
DS 49001	ISO 26000
ISO 14001	ISO 14001
ISO 14020	ISO 14020
ISO 14067	ISO 14067
ISO 20400	ISO 20400
ISO 21931	ISO 21931
ISO 37101	ISO 37101
ISO 14064	ISO 14064
ISO 22766	ISO 22766
ISO 38200	ISO 38200
EN 1717	EN 1717
IEC 52000	IEC 52000
ISO 14024	ISO 14024
ISO 34101	ISO 34101
Livscyklus	Life cycle
Cradle to cradle	Cradle to cradle
Genanvend	Recycle
Genvinding	Retrieval
Genbrug	Recycling
Cirkularitet	Circularity
Levetidsforlængelse	Lifetime extension
Drivhusgas	Greenhouse gas
Klima	Climate
Klimaændring	Climate change
Miljø	Environment
Environment	Environment

Note: The dictionary is based on information from the Danish Competition and Consumer Authority (2020). We removed certain words from the authority's original list, as we consider these words too vague for the article's focus on green procurement. These words is “efficienc”, “responsib”, “sustainable development goals”, “global compact” and “TCO”. We identify the dictionary's search words using several search strategies depending on whether the search words consist of several words, consist of numbers, the meaning of capital letters, etc.

Table A2. The Dictionary for Green Minimum Requirements

Search words (Danish)	English translation
FSC	FSC
Fairtrade	Fairtrade
ASC	ASC
MSC	MSC
Energy star	Energy star
EU-blomsten	EU Ecolabel
Ecolabel	Ecolabel
DGNB	DGNB
EuroNorm	EuroNorm
Tiltro til tekstiler	OEKO-TEX
GOTS	GOTS
ØKO-TEX / OEKO-TEX	OEKO-TEX
EU-mærket	The EU Organic Logo
TCO-certified	TCO-certified
Svanemærket	The Nordic Swan Ecolabel
Grønne køretøjer	Green Vehicles
Rainforest alliance	Rainforest alliance
EMAS	EMAS
PFEC	PFEC
Pro Planet	Pro Planet
Bra Miljöval	Good Environmental Choice
Good Environmental Choice	Good Environmental Choice
Charter for Sustainable Cleaning	Charter for Sustainable Cleaning
ISO 14001	ISO 14001
ISO 14040:2006	ISO 14040:2006
ISO 14040:2008	ISO 14040:2008
ISO 14040	ISO 14040
ISO 14044	ISO 14044
ISO 50001	ISO 50001
DS 49001	ISO 26000

Note: The dictionary is determined based on input from public procurers and interest organizations in the field. We identify the dictionary's search words using several search strategies depending on whether the search words consist of several words, consist of numbers, the meaning of capital letters, etc.

Figure A1. Green Award criteria and Green Minimum Requirements by Contract Type

Table A3. The 20 Most Common Green Procurement Product Types

Product type	Count	No green purchasing, in percent	Use of green award criteria, in percent	Green Award criteria, average percentage weighting	Use of green green minimum requirements	Average number of green minimum requirements
Other products and services	450	69,3%	9,6%	19,5%	26,9%	1,6
Engineering and architect consultancy	179	75,4%	3,4%	28,3%	22,3%	1,7
Special driving and referred driving	70	42,9%	5,7%	20,0%	54,3%	1,2
Turnkey and individual trade contracts in construction	60	75,0%	0,0%	0,0%	25,0%	1,6
Cleaning and window cleaning in public buildings	53	54,7%	7,5%	13,8%	43,4%	1,3
IT consultancy and program development	52	82,7%	0,0%	0,0%	17,3%	1,2
Insurance services	44	95,5%	0,0%	0,0%	4,5%	2,0
Cleaning of work apparel	43	11,6%	34,9%	16,3%	79,1%	2,8

Winter services - snow plowing/sanding	43	83,7%	0,0%	0,0%	16,3%	1,0
Medical equipment and products - beds, wheelchairs, walkers, shower chairs, and commodes	33	54,5%	3,0%	10,0%	45,5%	1,2
Tradesman services	31	80,6%	0,0%	0,0%	19,4%	1,8
Home services for the elderly - practical and personal assistance	27	85,2%	3,7%	20,0%	14,8%	1,3
Light vehicles - cars, mini busses, etc.	27	70,4%	0,0%	0,0%	29,6%	1,0
Job training programs	25	92,0%	4,0%	15,0%	4,0%	2,0
Medical consumption materials - health service items, ostomy products, compression products, diabetes aids	25	68,0%	12,0%	31,7%	28,0%	1,4
Waste containers	24	75,0%	12,5%	26,7%	20,8%	1,2
Banking and asset management	19	94,7%	0,0%	0,0%	5,3%	1,0
Maintenance of green areas, sports facilities, etc.	19	68,4%	15,8%	25,0%	26,3%	1,2
Maintenance of street lights, signs, and lane markings	19	52,6%	5,3%	10,0%	42,1%	1,9

Note: Product types is based on Central Business Register number