Green Public Procurement as an Environmental Policy Instrument: Cost Effectiveness*

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Abstract

Estimates by the European Commission indicate that public authorities within the European Union typically purchase goods and services corresponding to approximately 16 percent of GDP per annum. Hence, it is believed, private firms can be stimulated to invest in less polluting production technologies if the market power of public bodies is exerted through Green Public Procurement (GPP) policies and legislation. It is commonly argued that there are considerable possibilities for cost-effective GPP. The aim of this paper is to scrutinize this argument by specifically answer the question whether GPP can work as a cost-effective environmental policy instrument in terms of leading firms to reducing emissions at least cost to society. Our main finding shows that this is not the case.

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Key-words: Auctions, Abatement, Compliance cost, Environmental objectives, Green technology, Investments

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1. Introduction

The idea of using the purchasing power of the public sector to achieve policy goals is not a new phenomenon (McCrudden, 2004). Ambitions include social policy outcomes as well as environmental goals. Early initiatives concerning disabled workers are dated to the period after the World War I and environmental concern in public purchasing started in the 1990s. Recently the ambitions to use public procurement as a policy instrument in several policy areas have really taken off and become more formalized. The European Commission is for example very clear in its ambition of implementing green public procurement (GPP), making an effective contribution to environmental objectives. According to European Commission (2008, p.2) there are studies that have confirmed the considerable scope for cost-effective green public procurement.[1] In the present paper this particular statement is scrutinized within the framework of welfare economics, accounting for effectively achieving environmental and natural resources objectives adopted by a country's parliament.[2] The purpose is explicitly to find out whether GPP can work as a cost-effective environmental policy instrument in terms of leading to emissions being reduced at least cost to society. From the Baumol and Oates's (1971) "least cost tax theorem", it can be inferred that specified environmental objectives are achieved cost-effectively when total pollution in society is reduced such that the costs at the margin for reducing pollution is equal for all polluting sources. Not achieving the objectives cost-effectively may be seen as a waste of resources.

The European Commission (2008) states that GPP is to be understood as: "*…a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured* (p. 4)". GPP includes environmental, climate and energy ambitions which, in this paper, also will be referred to with GPP.

The potential of the EU using GPP as an environmental policy instrument was first formally emphasized in European Commission (2003) where, building on environmental life-cycle thinking, Member States were encouraged to come up with National Action Plans (NAPs) for implementing GPP by the end of 2006. The United Kingdom, the Netherlands and Sweden, e.g., regarded as GPP frontrunners in usage rates (Kahlenborn et al., 2011), approved action

[1] In the communication the European Commission (2008) does not explicitly reveal any of those studies.
[2] Note that we do not question the environmental and natural resources objectives adopted by a country's parliament. We assume that the objectives are set optimally in a welfare economics perspective.

plans in 1994, 2003, and 2007, respectively.[3] Today public procurement is politically seen as a market-based instrument that plays a key role in the Europe 2020 strategy of turning the EU into a smart, sustainable and inclusive economy (European Commission, 2010, p. 14).

Life-cycle thinking is evidently the depicted way of reaching sustainable development in the EU community. This ambition is often expressed in terms of considering Life-Cycle Costs (LCC), which means (European Union, 2011): "…considering all the costs that will be incurred during the lifetime of a product, work or service (p. 42)". Included in the costs may also be the societal cost of negative externalities, such as the greenhouse gas effect. Adding costs for externalities to LCC is in European Union (2011) referred to as Whole-Life Costing (WLC). Hence, from now on we here refer LCC to individual procuring entities minimizing cost in supplying its own good or service. For instance, this concerns the entity minimizing energy use when consuming procured products such as office machines throughout their whole lifetime. WLC is a broader term including both LCC and cost of external effects linked to the product, which we here refer to originating from both the procuring entities' consumption and all links in the production chain (including deliverance) of the product. By addressing external effects and following previous research by Marron (1997, 2003) we regard GPP as an environmental policy instrument. However, when the European Commission argues in favor of GPP, accentuating cost-effectiveness, no sharp line between the cost of a procuring entity providing a public good or service and the cost of reducing emissions is drawn, which is crucial when judging GPP as an environmental policy instrument.

Therefore, having the same aim as the European 2020 strategy (European Union, 2010): "*...to support the shift towards efficient and low-carbon economy that is efficient in the way it uses all resources (p. 14)",* we raise a question previously not studied and in need of consideration: Does GPP work as a cost-effective environmental policy instrument?

The decision of implementing GPP and the actual implementation is in this paper modeled using a principle-agent approach. The principle represents the politicians (elected by the inhabitants) in e.g. the parliament or the local council, and decides if GPP is to be used as an environmental policy instrument or not. GPP is only one of the policy instruments available to the principle and the choice is assumed to be contingent on making a choice that leads to an

[3] See the European Commission website: Usage rate is the share of tenders including some use of GPP. The United Kingdom had its NAP revised in 2008 and the Netherlands in 2007.

emission reduction at the least cost to the society. The agent can be thought of as a civil servant at the procuring authority and the agent implements the GPP in practice.

From a welfare point of view we emphasize that public procurement is not necessarily contributing to achievement of environmental objectives when practicing GPP. Like any other policy instruments, GPP must be analyzed in a welfare economics setting. If, in comparison to other environmental policy instruments, not leading to emissions being reduced at least cost to society, there is a welfare loss that possibly outweighs environmental gains achieved by GPP and other gains achieved by the procurement auction per se, such as upholding competition. In this paper the question of whether GPP reduces emissions cost-effectively is addressed within the framework of welfare economics. This is the major contribution to the literature, also providing relevant policy implications. In fact, the internationally peer-reviewed literature addressing GPP is within the field of economics very scarce (see Section 2). In addition, a formalized approach to GPP based on welfare economics is suggested.

The paper is organized as follows. In the following section previous studies on GPP are discussed in more detail. The institutional settings and principles of GPP are presented in Section 3. In Section 4 the implementation of GPP as an environmental policy instrument is discussed. First, we bring forward the importance of understanding what different aspects of environmental and resource problems different types of environmental criteria in public procurement address. Then we explicitly ask the question whether GPP is a cost-effective environmental policy instrument. In Section 5 we briefly discuss when GPP potentially should be implemented. Finally, a summary and some conclusions are provided in Section 6.

2. **Previous research on GPP**

The internationally peer-reviewed literature addressing GPP is within the field of economics scarce. Marron (1997) concludes, based on a partial equilibrium analysis, GPP to be an objective ineffective policy instrument under most circumstances. GPP is assumed to take the form of contract environmental clauses targeting the winner of the contract. This conclusion persists even after comparing GPP to other instruments, Marron (2003). D’Amoto (2006) finds the organization of green public purchases to be important for the outcome. A decentralized structure characterized by non-cooperation between the environmental agency and the procurement agency results in a downward distortion in environmental quality.

The function of GPP as a cost effective environmental policy instrument has to our knowledge not been previously studied from a welfare perspective. Commonly, previous studies on the subject have regarded GPP as an established environmental policy measure focusing only on the potential benefits of GPP. Environmental public procurement as a mean to create private incentives for environmental win-win situations is in the context of the Coase theorem and the Porter van der Linde hypothesis discussed in Cerin (2006). Sterner (2002) illustrates how GPP can be implemented in construction procurements drawing from experiences in Sweden. In the same spirit Parikka-Alhola (2008) describes how to buy green furniture. In addition, case study examples from EU can be found in Erdmenger (2003) and the UK (Thomson and Jackson, 2007). Some studies focus on national initiatives in different parts of the world, e.g. the Chinese green public procurement program (Geng and Doberstein, 2008; Qiao and Wang, 2011) or experiences from South-Africa (Bolton, 2008) and Norway (Michelsen and de Boer, 2009). However, mainly neglected, when studying the effectiveness of GPP it is of great importance to also considering other aspects than just potential gains of GPP.

From a welfare economics point of view award methods and scoring rules play a crucial role in the implementation of GPP. Lundberg and Marklund (2011) show that after the decision of using GPP there are pitfalls leading to the procedure quickly becoming complex and non-transparent, undermining the possibilities of GPP working as an efficient and effective environmental policy instrument. In an illustrative case study based on a procurement of goods transport services Parikka-Alhola and Nissinen (2012) simulate how the bids can be evaluated based on a life cycle analysis that considers e.g. environmental impact in terms of CO_2. Award methods and scoring rules is also in focus in a case study of a waste management procurement auction with green ambitions by Arvidsson and Stage (2012). The applied scoring rule is said to be technique neutral but includes some pitfalls in its design.

Most important to emphasize is that in a welfare perspective any conclusions on GPP potentially having a positive role to play cannot be made from merely observing and reporting increased degree and frequency of GPP implementation. However, usage rate of any form of GPP in the call for tenders is the approach used in e.g. Kippo-Edlund et al. (2005), Nissinen et al. (2009), and Palmujoki et al. (2010). Also, most recently, this is also the approach adopted in a report to the European Commission (Kahlenborn, et al., 2011), where, e.g., the United Kingdom, the Netherlands and Sweden is set as examples of EU member states that successfully have implemented GPP. The successfulness is due to increased frequency of procurements including some sort of GPP dimension and, therefore, these countries are concluded to be frontrunners. The approach is based on the lack of existing high quality data understandable, but risk so-called green washing to be taken for actions that actually have an impact on the environment.

To sum up, studies on GPP as an environmental policy instrument that take a broader welfare economics perspective are rare with exception of Marron (1997, 2003). Generally, this boils down to comparing GPP with other environmental policy instruments, given a benchmark such as an efficiency perspective. In this paper we take the cost-effectiveness perspective of GPP, in terms of asking the question whether pollutants being reduced at least cost to society. However, before explicitly analyzing GPP in perspective of cost-effectiveness we first discuss the underlying institutional settings of implementing GPP.

3. Institutional environment

The institutional settings concerning GPP are explicitly based on public procurement as defined by the EU procuring directives, 2004/17/EC and 2004/18/EC:[4] "*Public procurement means the measures implemented by a contracting authority with the aim of awarding a contract or concluding a framework agreement regarding products, services, or works*" (Article 13).[5]

Following the Government Procurement Agreement (GPA) and the EU procurement directives, public contracts is allocated using competitive tendering. Explicitly implementing GPP can be done by the following practices (each of the practices used separately or in combination): (*i*) using qualification criteria and award criteria addressing the bidder and/or the subject matter; (*ii*) using bid preference programs (e.g. Hubbard and Paarsch, 2009; Kranokutskaya and Seim, 2010), and (*iii*) using contract performance clauses (e.g. Marron, 1997, 2003; Palmujoki et al., 2010). From here onwards, we pay less attention to practices (*ii*) and (*iii*) and focus on (*i*).

The fundamental idea of viewing GPP as an environmental policy instrument is, e.g., that it possibly forces potential bidders to reduce emissions in the process of producing and

[4] Directive 2004/17/EC concerns contracts within the sectors of water, energy, transport and postal services. Directive 2004/18/EC concerns contracts in public work, public supply, and public service.
[5] Note that this definition on public procurement excludes auctions of tradable permits and nature conservation contracts.

delivering the procured product. For that purpose GPP can be built on e.g., the use of environmental qualification criteria (practice (*i*)).

In general the EU procurement directives stipulate sealed tendering and after having received tenders from the potential bidders the procuring entity stands before a process of evaluation. Specifically, the tender evaluating process can be characterized as a two-step procedure. First the qualification criteria in terms of mandatory environmental requirements are evaluated. These requirements, enforcing GPP, may be in terms of technical specifications and address, e.g., emissions to air and water, energy consumption, waste generation, etc. The technical specification can include material selection, chemical content and characteristics of the product (Palmujoki et al., 2012). The potential bidders that fulfill the mandatory requirements qualify for the second step of the evaluation process, i.e., the procuring entity identifying the winning tender and awarding the contract. In this step the entity evaluate qualified bids and awards the contract either according to the lowest price or to the economically most advantageous tender (EMAT).

If the second step of allocating the contracts is based on the award method of lowest price the contract will be allocated to the bidder who offers to complete the contract at lowest price, given the qualification requirements. However, if the allocation of contracts is based on a combination of price and quality, e.g., environmental quality, the award method to use is EMAT.[6] In this case a predetermined scoring rule that combine price and quality expressed in terms of award criteria must be applied. The award criteria and their relative importance must be specified in the contract notice but the design of the specific scoring rule is the choice of the procuring authority. It is obvious that the EU directives leave the procuring entities a lot of freedom how to exactly practice GPP (see also Parikka-Alhola and Nissinen, 2012). For simplicity reasons, in this paper we disregard other aspects of qualities than environmental, which give the procuring auction the character of being two-dimensional.

Practicing EMAT allocation is not as straightforward as practicing lowest price allocation and, referring to GPP as an environmental policy instrument, there are pitfalls leading to the procedure quickly becoming complex and non-transparent; see Lundberg and Marklund (2011), where GPP in terms of a policy instrument is discussed in perspective of award

[6] Highest environmental quality only is also a principle of awarding contracts according to EMAT. In this case bidders compete in environmental quality only, given a fixed price, and the contract is allocated to the bidder supplying the highest quality in production and/or of the subject matter (Lundberg and Marklund, 2011).

methods and scoring rules.[7] For simplicity, from now on we assume that the procuring entities award contracts according to lowest price. This simplifying assumption will not affect the conclusions made from the theoretical analysis presented in Section 4.

The choice of environmental qualification and award criteria, award method, and scoring rule must be published in the call for tender and follow some basic rules. For instance, respected must be the single market principles which serve to uphold competition: equal treatment, transparency, non-discrimination, proportionality, and mutual recognition. Furthermore, the environmental qualification and award criteria must be linked to the subject matter of the contract.[8] As long as criteria do not violate the linkage to the subject matter procuring entities are allowed to stipulate inputs as well as production technology (e.g. Palmujoki et al., 2010).

Finally, one necessary condition (not sufficient though) for GPP to work satisfactory as an environmental policy instrument is that it actually has a positive impact on the environment. However, positive impacts are not as obvious as it might seem at first view. Independently of type of environmental requirements specified in a separate GPP, they may have more or less environmental impacts. If the environmental requirements mainly attract already “green” firms and the “brown” ones therefore choose not to enter the procurement auction, there will be small or no positive effects on the environment.[9] GPP will in this case only redistribute the public authority’s purchase from brown to green firms (switching), the brown ones continuing supplying less environmentally demanding buyers. For GPP to have a significant positive effect on the environment the market power of the separate GPP auction is potentially of importance. The more market power the more brown firms for which the criteria are binding will actually enter the auction and therefore the larger is the potential impact on the environment.[10]

It is important that the practice of GPP attracts firms that are brown and, therefore, leads to firms adjusting environmentally. In the next section we make the assumption of binding

[7] Scoring rules are in a more general sense discussed in, e.g., Bergman and Lundberg (2011), Asker and Cantillon (2008, 2009), and Dini et al. (2006).
[8] The subject matter can take the form of a basic description of the product, or of a performance based definition (European Commission, 2004)
[9] From a welfare economics point of view it is nearly impossible to know when a firm is to be regarded as being green. However, we simply say that a green firm satisfies the environmental criteria ex ante the procurement auction and a brown firm does not, and therefore has to adjust its environmental performance before entering the procurement auction.
[10] However, to our knowledge, there are no scientific studies that empirically confirm the market power assumption commonly used as an argument by EU when advocating increased implementation of GPP.

criteria, i.e., that all firms are brown, when analyzing whether GPP is an instrument that can be used to make firms to reduce emissions at least cost to the society.[11]

4. Implementing environmental policy by GPP

GPP is not the only policy instrument that can be used to deal with anthropogenic impact on the environment and the options differ in their character (Sterner and Coria, 2012). However, what instrument to use in a certain situation is far from obvious. In practice, irrespective of benchmark to which instruments are judged, the implementation of environmental policies is not necessarily successful from the society point of view. Generally, no policy instrument will work perfectly in practice due to the society being permeated with imperfect information. Depending on the situation, though, some instrument may be preferable to others.

If an instrument is preferable to others depend on what benchmark, or evaluative criterion, the judgment of the instrument is based on. Hanley et al. (2007) discuss four evaluative criteria: (*i*) efficiency, concerning the social cost of reaching the environmental objective; (ii) effectiveness, concerning how precise environmental objectives are achieved; (*iii*) equity and fairness, concerning costs and benefits being redistributed in society; and (*iv*) flexibility, concerning the easiness of adjusting the instrument to changing environmental, technological, and economic conditions. Generally, there is a battery of environmental policy instrument at disposal and, at the national or local level politicians of the parliaments should refer the choice of instrument to some evaluative criterion, e.g., any of the criteria (*i*) to (*iv*) enumerated above. In this paper we specifically focus on the cost-effectiveness criterion, (*i*), and whether it is proper to use this criterion to justify GPP. [12]

We analyze GPP as an environmental policy instrument based on a principal-agent approach. Representing politicians, e.g., in the county or local council, the principal decides GPP to be implemented. Then, when procuring a good, service or works, necessary for the society to fulfill its mission to the citizens, GPP is actually implemented by the agent. The agent can be thought of as a civil servant at the procuring authority, e.g., a municipality.

[11] This means that we disregard what the EU calls core criteria and put more focus on comprehensive criteria. Core criteria are defined as "…suitable for use by any contracting authority across the EU, which address key environmental impacts and are designed to be used with minimum additional verification efforts or cost increases." Comprehensive criteria, on the other hand are "… aimed at contracting authorities who wish to purchase the best environmental products available on the market. These criteria may require additional verification efforts or a slight increase in cost compared to other products with the same functionality", see Ballesteros et al., (2012).

[12] The second evaluative criteria, about whether environmental concern in public procurement could be used to precisely achieve environmental objectives in society, is studied in Lundberg et al. (2012).

4.1 Environmental concern in public procurement

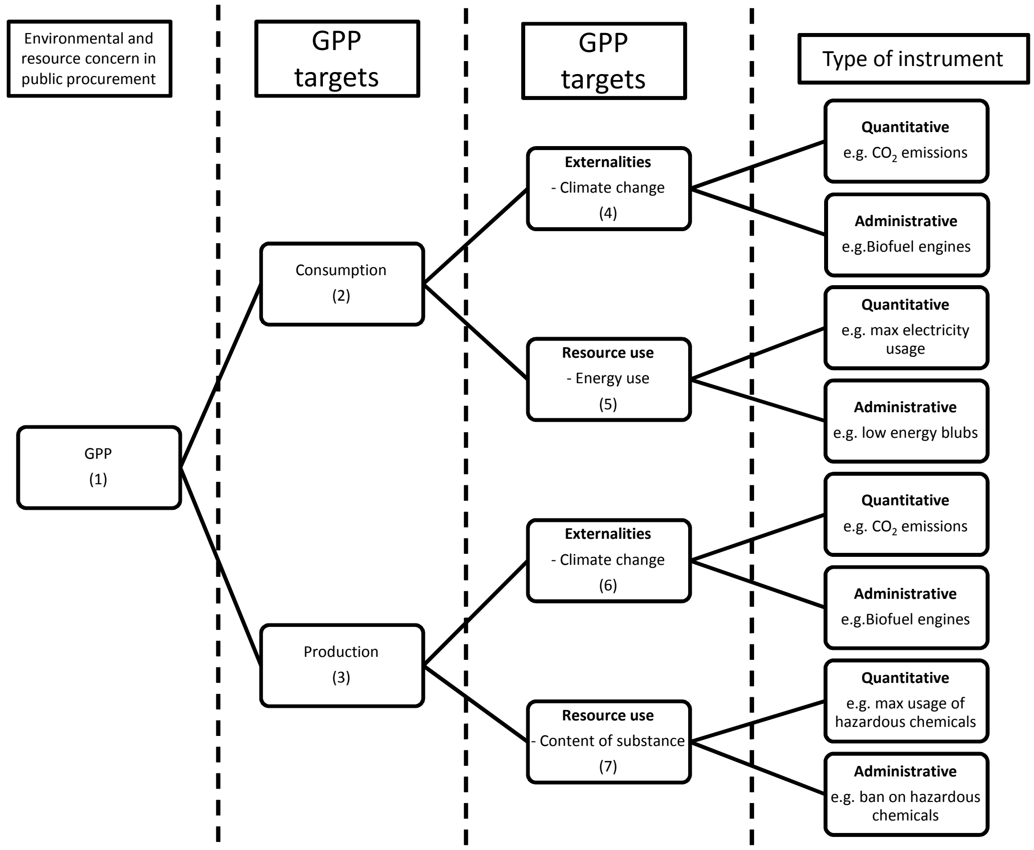
In studying GPP as an environmental policy instrument, and whether it can be used to cost-effectively reduce environmentally damaging pollutions, it is important to first divide environmental concern in public procurement into criteria addressing different aspects of environmental and resource problems. This division is shown in Figure 1. Given that the principal decides to implement environmental and resource concern in a procurement auction (defined as GPP in Box 1) the agent has in practice a choice between targeting the consumption of the product (Box 2) or the production process itself (Box 3). The target can be a mix of consumption and production process targets, but to keep things as simple as possible this is not illustrated. The consumption target refers to a situation where the agent places the environmental responsibility on the public sector's own consumption, while the production process target concerns a situation where the environmental responsibility is placed on the supplier. Having decided whether to target consumption or the production process the GPP can then target externalities (Box 4 or 6) or usage of resources (Box 5 or 7).

Furthermore, the agent can explicitly choose between different types of environmental criteria, or requirements. As actually practiced, the nature of GPP leaves the agent with a choice between different types of requirements that give GPP the character of either being an administrative or quantitative environmental policy instrument. For instance, procuring transport services and simultaneously considering an externality, e.g., global warming, an administrative requirement that target the production process would be that transports must be executed with biofuel vehicles. Further examples of how different requirements translate to different types of environmental instruments are found in Figure 1.

The distinction between GPP working as either an administrative or a quantitative environmental policy instrument is very important from a welfare economics point of view. An administrative environmental requirement is typically referring to using a specific technology, and therefore stipulating how potential bidders shall achieve the emission level. A quantitative requirement specifies, e.g., a maximally allowed emission level. Then, if deciding to enter the procurement auction, it is up to the bidder how to exactly achieve that level. These both types of requirements are in economics often referred to as *command-and-control*.[13, 14]

[13] Note that we do not consider GPP as a market-based environmental policy instrument, as is done in, e.g., Europe 2020 strategy (European Union, 2011, p 14). By market-based, or economic, instruments we refer to instruments that directly address the price mechanism on markets, such as taxes, charges, subsidies, and tradable

Figure 1. Environmental concern in public procurement



In this paper we explicitly study GPP as an environmental policy instrument that the principal can use to bring environmental pressure to bear on potential bidders. That is, referring to the lower part of Figure 1, we study environmental criteria imposed on potential bidders and, specifically, criteria in purpose of restricting emissions from their production process that causes negative externalities (Box 6). This means that we do not directly study the authority's possibilities to regulate its own environmental performance (Box 2). However, based on the results of studying the regulation of potential bidders, we will be able to comment on these possibilities indirectly.

Finally, having established the command-and-control nature of GPP, finding the answer to the question whether GPP is a cost-effective environmental policy instrument or not is then very

permits. Economic instruments do not explicitly prescribe the use of a certain technology or that all firms must reduce emissions with exactly the same amount.

[14] The scientific debate on whether regard GPP as a command-and-control instrument or as an economic instrument is to our knowledge non-existent. However, based on own experience from the internal cleaning service and waste disposal transportation sectors in Sweden during 2000 - 2009, where criteria commonly are specified in terms of certificates or as in the case of transportation of waste disposal vehicles of a certain Euroclass, we consider GPP to being mainly an administrative environmental policy instrument in practice.

much about comparing GPP to market-based, or economic, policy instruments, such as emission taxes.

4.2 Is GPP a cost-effective environmental policy instrument?

Consider an economy where $i = 1, \dots, N$ heterogeneous brown firms produce a marketable product, or a good output, Q, amounting to $q_Q = \sum_{i=1}^{N} q_i$.[15] The process of producing Q simultaneously generates emissions of a uniformly mixing pollutant, Z, amounting to $z_Z = \sum_{i=1}^{N} z_i$ where $z_i \neq z_j$.[16] This being so, politicians in the society (the principal) have the intension to reduce the emissions in accordance to the environmental objective(s). Maintaining the amount q_Q, this is the same as saying that environmental productivity in society in terms of produced amount of good output per unit of emission, q_Q/z_Z, must increase. Environmental productivity in the firms' production processes can either be increased by input substitution within existing technologies or investing in environmentally friendlier technologies, alternatively by combining these two options.

Consider a representative contracting authority (the agent) that procures the quantity $q^{pp} \leq q_Q$ of the marketable product. As there are political ambitions of reducing emissions generated in this particular market, the principal has decided that necessary reductions are to be achieved through GPP.[17] The necessary total emission reduction in society is specifically set to $\Delta z_Z = z_Z - z_Z^*$, where z_Z^* is the politically set sustainable level of emissions. Accordingly, the agent takes environmental concern through GPP to meet the emission reduction target, in this case by formulating environmental criteria in the call for tenders that address the N potential suppliers' production processes. Specifically, via the criteria the agent translates the objective Δz_Z, or z_Z^*, to correspondingly needed criteria in the call for tenders, e.g., by specifying a certain technology requirement that is the same for all potential bidders. This means that the organization of the procurement auction and the environmental requirements comply with the single market principles e.g. equal treatment and non-discriminatory stipulated in the EU procurement directives. The environmental criteria must be measureable, verifiable and treat potential bidders equally (Palmujoki et al., 2012)

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[15] Assuming N bidders is not crucial for our findings. It is a simplifying assumption.

[16] A uniformly mixing pollutant is a pollutant of which the concentration does not vary spatially, irrespective of where it actually is emitted. Examples of uniformly mixing pollutants are greenhouse gases, e.g., carbon dioxide.

[17] A simplifying assumption is that there are no other environmental policy instruments in effect with the same environmental objective as that one of the GPP. Allowing for other instruments, such as taxes already being in effect, would not make the environmental consideration in procurement auctions less difficult from an effectiveness point of view.

Explicitly, the procuring authority imposes on each potential bidder a minimum required level of technology in production in accordance to the following function:

$$T^* = f(z_Z^*, N). \quad (1)$$

The environmental requirements in the procurement auction is a function of the environmental objective set by the principal, and the number of potential bidders, with $T_{z^*}^* \geq 0$ and $T_N^* \leq 0$.

Important to consider is that the minimum required level of technology, T^*, will have differing enforcing impact on potential bidders due to them being heterogeneous in their ex ante procurement technology level, T_i (a higher T_i is equivalent to a greener technology). Hence, the technology change necessary to meet the minimum technology requirement is for bidder i:

$$\Delta T_i = T^* - T_i, \qquad i = 1, \ldots, N, \text{ and} \qquad \Delta T_i \neq \Delta T_j \quad (2)$$

The greener technology ex ante the procurement, T_i, the less technological units, ΔT_i, the potential supplier needs to invest in to achieve the required technological level, T^*, and to qualify as a bidder. As the magnitude of the needed investment differs between bidders depending on differences in their initial technology, T_i, the cost of adjusting to criteria is as follows:

$$CA_i = g(T_i, ; T^*), \qquad i = 1, \ldots, N, \text{ and} \qquad CA_i \neq CA_j \quad (3)$$

where $CA_{T_i} \leq 0$, $CA_{T_i T_i} \geq 0$. Clearly, as environmental performance differs between potential bidders ex ante the procurement auction, the cost of adjustment (or compliance cost) to reduce emissions will also differ.

Proposition 1: Potential bidders being heterogeneous in environmental performance, T_i, the cost of investing in the last technological unit will differ, i.e., $MCA_i \neq MCA_j$. GPP is therefore inconsistent with the condition for cost-effective emission reduction.

The condition for cost-effectiveness, $MCA_i = MCA_j$, states that cost minimizing firms adjust to environmental criteria so that they end up with the same marginal cost of adjustment, and that the total emission reduction therefore will be achieved at least cost to society (see Appendix A). GPP is inconsistent with this condition.[18]

Note that so far we have made the following strong assumptions: (*i*) All N potential brown bidders participate in the GPP auction; (*ii*) the environmental requirement in the auction is binding for all N bidders; (*iii*) perfect information on the market, i.e., the procuring authority knows the technology level, T^*, that, spread among all N bidders, will contribute to the achievement of the society's environmental objective, $z_Z^* = \sum_{1=1}^{N} z_i$. Yet, the total emission reduction is not achieved at least cost to society. The explanation can be referred to the principles of non-discrimination and equal treatment in the EU procurement directives. Strictly followed, the principles deny the authority to vary environmental requirements among bidders, which makes it impossible to suit the requirements such that z_Z^* is achieved at the same time as the cost of adjustment becomes the same for all bidders, i.e., $MCA_i = MCA_j$. However, relaxing the enforcement of non-discrimination and equal treatment will not make GPP a cost-effective environmental policy instrument in practice.

Proposition 2: GPP will only be a cost-effective environmental policy instrument if the procuring authorities perfectly can predict the entry decision of bidder i, and have the option of tailoring the environmental criteria to each individual bidder's production technology ex ante the procurement, i.e., have full information of T_i.

In Appendix B Proposition 2 is illustrated for a simple case with two bidders.

In reality information is not likely to be perfect. Procuring authorities does not necessarily know the number of potential bidders, N, and the entry decision of bidder i, i.e., does not exactly know what firms that will enter the procurement auction. Furthermore, even if the legal principles of the EU procuring directives would allow for individually specified environmental criteria it would be difficult to reach the environmental objective, z_Z^*, at least cost to society. The plain explanation is that the agent does not know the ex-ante procurement technology, T_i, of each participating bidder. Accordingly, the agent is not able to tailor individually addressed criteria, T_i^*, that would lead to the environmental objective, z_Z^*, being

[18] Note that all bidders adjusting to the same technological requirement does not necessarily lead to bidders becoming completely homogenous in technology after the procurement auction. That is, even though all potential bidders meet the same environmental criteria in terms of a certain technology level to be met, the technology requirement does not fully redesign the bidders' production process. Most likely, in practice, the requirements address certain parts of the production process or product.

achieved, at the same time as the cost-effective emissions reduction outcome, $MCA_i = MCA_j$, is satisfied.

Also important, cost-ineffective regulation of potential bidders' environmental externalities (Box 6 in Figure 1) does not speak for the use of Life-Cycle Analysis (LCA) [19] in public procurement. If the chain of the procured product only consists of one single link, as in the case above, and the outcome is cost-ineffective, adding more links will not alter the outcome.

The result above can be compared to the least cost tax theorem (Baumol and Oates, 1971; 1988), which states that a cost-effective policy outcome can be achieved by setting a per-unit tax on emissions. Specifically, each cost minimizing polluting firm adjust to the tax rate such that they all end up with the same marginal adjustment cost. Hence, the emission reduction they achieve altogether will be achieved at least cost to the society.

4.3 Some further aspects on cost-effectiveness

The result above also indirectly suggests how to regard public authorities' self-regulation in perspective of cost-effectiveness, specifically the regulation of environmental externalities from own consumption of goods and services (Box 4 in Figure 1). In this case environmental criteria could be, e.g., requiring the bidders to deliver a product that causes less emission when consumed by the society. A cost-effective outcome would require that each principal[20] put the same value on the pollutants marginal environmental damage, communicate that value to the agents, which specifies environmental criteria such that adjustment costs among all cost-minimizing principals (e.g. municipalities) coincide. As mentioned above, this would be difficult due to achieve since information is unlike to be perfect.

Alternatively, the agents can self-regulate the input use in their own consumption (Box 5 in Figure 1), by, e.g., procuring products that require less resource use, e.g., energy use. However, this is a pure cost minimization aspect of their own activities, corresponding to LCC considerations, which should not be confused with internalizing externalities by using environmental policy instruments. Of course, less energy use would also likely contribute indirectly to less emission of carbon dioxide. But, as shown above, if the purpose is to reduce emissions it will still not be a cost-effective way of doing that.

[19] Life-cycle analysis (LCA) may be referred to the term whole-life costing (WLC) used in European Union (2011, p. 42), where WLC is given by adding environmental externalities to life-cycle cost (LCC).

[20] The agents can be thought of as representing different municipalities (each municipality has its own principal with the political responsibility to implement GPP on the local level).

Finally, authorities can implement criteria in purpose of, e.g., influencing potential bidders to substitute environmental friendlier inputs (e.g. with less carbon content) for less environmental friendlier inputs in their production (Box 7 in Figure 1). From a cost-effectiveness perspective this will still not contribute to emission reduction at least cost to the society depending on markets not being characterized by perfect information.

Summarizing the results; compared to economic policy instruments, GPP should not be considered as a cost-effective environmental policy instrument and, therefore, the cost-effectiveness argument should be used more carefully when advocating GPP. However, this does not necessarily mean that GPP should be categorically denied as a policy instrument. The question when is it proper to implement GPP is briefly discussed in the next section.

5 When to implement GPP?

When to implement GPP as an environmental policy instrument is a question still to be scientifically answered in many respects. From above we know that if the political purpose is to reduce emissions cost-effectively economic instrument as, e.g., an environmental tax, should be used instead of GPP, not the least due to the principles of non-discrimination and equal treatment stated in the EU procurement directives. A tax is cost effective and leaves the question of how to adjust the production technology to the market.

Yet, due to information not likely being perfect in reality, a per-unit tax on pollutants is not necessarily the best option from a welfare and sustainability point of view. Since the principal does not know every polluter’s emission reduction cost (heterogeneity in technologies) it does not know beforehand how large a total emission reduction in society a certain tax rate will lead to. That is, a cost-effective tax may not be objective effective in terms of reaching environmental objectives quickly and precisely. If the tax is introduced at a too low a rate, not reaching the objective causes unnecessary emissions and therefore imposes further costs on the society. These additional costs may exceed the benefits from reducing emissions cost-effectively and, consequently, an instrument that better targets the environmental objective may therefore be preferred. In this case command-and-control instruments may be superior to economic instruments.

Facing the choice between economic and command-and-control instruments, Weitzman (1974) may serve as a guiding principle. A rule of thumb that might be useful is that command-and-control instruments, e.g., a quantitative regulation, is the best choice if the marginal damage of emissions rises sharply compared to the marginal cost of reducing emissions. Accordingly, an economic instrument, such as a per-unit tax on emissions may be preferable when the marginal cost of reducing emissions rises sharply compared to the marginal damage of emissions. However, if it is established that a command-and-control policy instrument is the best choice for reducing emissions in a certain circumstance does not necessarily mean that GPP is preferred to a, e.g., pure quantitative regulation imposed by regulating authorities.

To sum up: As the political ambition in EU is to practice GPP extensively, there is an urgent need for further research on the topic of when to actually implement GPP. The peer-reviewed literature in economics on the subject of GPP and its prerequisites to work as an environmental policy instrument compared to alternative instruments is today virtually non-existent. For instance, does GPP as an environmental policy instrument generally satisfy environmental objectiveness? If not, do the principles of non-discrimination and equal treatment prevent GPP to work objective effectively? If not, what types of pollutants are suitable for GPP to address? Should GPP be practiced on markets of certain goods and services? Should GPP be practiced on markets where large-scale production is advantageous? To the best of our knowledge, this type of questions is still to be answered within the frame of welfare economics.

Finally, whether or not an environmental policy instrument is preferable to other instruments could also be based on equity, i.e., on how it redistributes resources in society and its flexibility, i.e., the easiness of adjusting it to changing environmental, technological, and economic conditions (Hanley et al., 2007). Again, to our knowledge, there is no peer-reviewed literature in economics to consult on these topics regarding GPP.

6 Summary and conclusions

The main purpose of this paper has been to answer the question whether GPP can work as a cost-effective environmental policy instrument in terms of leading firms to reducing emissions at least cost to society. The question of cost-effectiveness is in this context of immediate policy relevance, since public procurement is increasingly seen as playing a key role in the European 2020 strategy of turning the EU into a smart, sustainable and conclusive economy (European Commission, 2010; 2011). Furthermore, the cost-effectiveness argument is used when advocating GPP (see, e.g., European Commission, 2008).

The main finding in this paper shows the opposite. GPP is in general not a cost-effective environmental policy instrument. As shown by Baumol and Oates (1971; 1988) a per-unit tax on emissions leads to cost-effective reductions. Therefore, if the purpose is to pursue a cost-effective environmental climate policy a per-unit tax is superior to GPP. In fact, for GPP to be cost-effective firms must be homogeneous or authorities able to formulate call for tenders and technical specifications that are technique neutral in the sense that they function as a tax, and do not regulate input and process choices of the firm.

An important reflection is that the analysis establishes that GPP is cost-ineffective from a static point of view. However, since way back there are voices heard urging for dynamic efficiency on which to judge environmental policy instruments (Milliman and Prince, 1989). In this case efficiency refers to policy instruments and their ability of spurring to cost-reducing technological development. Then, if GPP would be dynamically efficient it could outweigh the disadvantageous of being cost-ineffective in a static sense. However, as argued in this paper, GPP is to be seen as a command-and-control environmental policy instrument, implementing direct controls. The result in Milliman and Prince (1989) shows that direct controls give less incentives to promote technological development compared to economic instruments such as emission taxes and marketable permits. The result in Jung et al. (1996) shows a similar outcome. A hypothesis proposed is that as a per-unit emission tax rate continues to impose costs on firms even after they have adjusted to the tax rate it stimulates to cost-reducing technological development on continuous basis. A similar suggestion is made indirectly from a static analysis in Marron (1997) regarding the effects of procurement on development of green technologies: "…, when available, other policies that encourage both the government and the private sector to increase purchases of green products should be more effective in promoting innovation (p. 300)". Additionally, Porter and van der Linde (1995), discussing what is now is thought of as the Porter hypothesis, stress the importance of governments avoiding administrative requirements such as technology specific ones: "One useful change would be to alter the current practice of requiring bidders in competitive bid processes for government projects to only bid with "proven" technologies, a practice sure to hinder innovation (p. 112)."

However, GPP not being a cost-effective environmental policy instrument does not necessarily mean that GPP never should be implemented. To the best of our knowledge, though, exactly in what situations it would be proper to implement GPP is a question still to be answered within the peer-reviewed literature of economics. In all situations there are not only taxes and GPP to consider, but also other policy instruments with different characteristics. Even though a tax is considered as inappropriate in a certain context, or it is politically difficult to set sufficiently high tax rates, it does not automatically mean that GPP would be the best alternative. To find answers, further research on the prerequisites of GPP working as an environmental policy instrument is very much needed.

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Appendix A *Cost-effective emission control*

The mathematical derivation of necessary conditions for cost-effective emission control, presented in this appendix, is based on the derivation presented by Tietenberg and Lewis (2009). The presentation concerns a general case of emissions, or pollutants, in the sense that it is valid for both uniformly mixing and non-uniformly mixing pollutants.

Assume a single receptor, R. In the case of a uniformly mixing pollutant emissions from all sources have the same impact on the receptor. For instance, independently of location, all sources of CO_2 emissions contribute equally to the concentration of greenhouse gases in the atmosphere; the atmosphere being the receptor in this case.[21] The policy objective would naturally to address the pollutant concentration at the receptor, but firms' emissions are what actually can be targeted by the regulating authority. The relationship between firm i's emission, z_i, and its contribution to the pollutant concentration level at the receptor, CL_R, may be described as follows

$$CL_R = \sum_{i=1}^{N} \alpha_i z_i + BC \qquad \text{(A1)}$$

where the firm specific constant α_i is the transfer coefficient. Background pollutant concentration at the receptor is denoted BC. The BC concentration stems from natural emission sources and sources outside the region of policy control, e.g., other countries. Assume that the policy objective is to reduce the pollutant concentration level to CL_R^*, and that the social planner's optimization problem then is to find the cost-effective level of control, T_i^*, for each source of emission. Explicitly, the cost minimizing problem corresponds to the Lagrangian expression as follows

$$L = \sum_{1=1}^{N} CA_i(\Delta T_i) + \mu[\sum_{i=1}^{N} \alpha_i (T_i - \Delta T_i) + BC - CL_R^*] \qquad \text{(A2)}$$

where $CA_i(\Delta T_i)$ is the cost of achieving the control level, ΔT_i. The Lagrange multiplier is denoted μ.

The first order conditions necessary for cost-effective emission reduction are

$$MCA_i - \mu\alpha_i = 0, \qquad i = 1, \ldots, N \qquad \text{(A3)}$$

[21] In the case of a given non-uniformly mixing pollutant all emission sources have not the same detrimental impact on the receptor. For instance, in the case of firms' emissions to a water stream, and the receptor being a delta located downstream, firms located upstream have less impact on the delta compared to firms located downstream close to the delta – this due to pollutants being diluted. Hence, the environmental damages caused by the downstream firms are larger and therefore they should meet more stringent environmental regulations compared to the firms upstream.

where the marginal cost of adjustment $MCA_i = \partial CA_i(\Delta T_i)/\partial \Delta T_i$ (the marginal cost of reducing the pollutant concentration at the receptor), and

$$\sum_{i=1}^{N} \alpha_i(T_i - \Delta T_i) + BC - CL_R^* = 0 \qquad \text{(A4)}$$

The solutions to these conditions give the $i = 1, \dots, N$ optimized control variables, ΔT_i^*, and μ^*, which can be considered as the implicit cost, or shadow cost, of reducing the last unit of concentration. Welfare maximizing policies imply choosing environmental objective, CL_R^*, and pollution control, ΔT_i^*, such that μ^* equals the society's marginal utility of the last unit of reduced concentration at the receptor.

However, if the pollutant is uniformly mixing all the N transfer coefficients are set to unity, i.e., $\alpha_i = 1$ (Tietenberg and Lewis, 2009, p. 388). In this particular case the amount emission at the source coincide with the added amount to the receptor (holding BC constant). In the uniformly mixing case, Equation (A3) can be rewritten as

$$MCA_i - \mu = 0, \qquad i = 1, \dots, N \qquad \text{(A3')}$$

Clearly, for a cost-effective outcome, all N firms' marginal cost of adjustment must be equal to the marginal utility of the last reduced unit emission. Accordingly, $MCA_i = MCA_j$, $i \neq j$, must be fulfilled. Baumol and Oates (1971, 1988) show that this outcome is achieved by imposing a per-unit tax on emissions corresponding to μ and, hence, the tax is being a cost-effective environmental policy instrument.

For GPP to be a cost-effective environmental policy instrument, environmental criteria must be specified individually among the potential bidders such that the cost of adjustment for the last unit reduced emission equals μ for all bidders. That is, if bidders are heterogeneous in production and abatement technologies they should not meet exactly identical requirements in terms of environmental criteria in the call for tender.

Appendix B *Two firm illustration of Proposition 2*

Consider a situation with two potential bidders, 1 and 2, in a procurement auction with environmental requirements demanding an adjustment of the production technology from both firms corresponding to a firm level objective $T_1^* = T_2^*$. As firm 1 and 2 are heterogeneous in environmental performance they adjust according to $\Delta T_1 = 2$ and $\Delta T_2 = 4$, respectively. These adjustments are associated with firm-specific costs, $CA_1 < CA_2$ as follows:

$$CA_1 = 5\Delta T_1^2 = 20 \tag{B1}$$

$$CA_2 = 2{,}5\Delta T_2^2 = 40 \tag{B2}$$

Clearly, differencing expression B1 and B2 with respect to ΔT_1 and ΔT_2 will give marginal costs of adjustment that is equal for potential bidder 1 and 2:

$$MCA_1 = MCA_2 = 20 \tag{B3}$$

This comply with the condition for an environmental policy instrument to be cost-effective. In practice this means that the agent must have perfect information about T_i and be able to tailor the environmental requirements according to $T_1^* \neq T_2^*$. These two conditions are hardly met in practice; perfect information comes to an extremely (infinite) cost and bidder specific environmental requirements will most likely violate the principles of the single market.