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Reducing Transaction Costs of Tradable Permit Schemes Using Blockchain Smart Contracts

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Abstract

Tradable Permit Schemes (TPS) are market-based policy instruments, which are claimed to be more statically and dynamically efficient in achieving their policy objectives, compared to the traditional regulatory instruments. However, some researchers argue that high level of transaction costs associated with these policy instruments might undermine their efficiency. This paper addresses this issue through exploring the use of Blockchain technology in order to lower transaction costs that arise from TPS transactions. More specifically, it identifies the benefits of using Blockchain smart contracts in implementing TPS that include: increasing the amount of relevant information available to interested actors thus reducing uncertainties; reducing the amount of irrelevant information available to interested actors thus decreasing complexities; correcting information asymmetries among the actors involved thus limiting opportunistic behaviours; lowering the need for the involvement of intermediaries thus decreasing direct monetary costs; and facilitating the linkage between buyers and sellers thus improving trading quality. These potential benefits can increase the efficiency of TPS through decreasing policy-related transaction costs.

Keywords: Policy Instruments; Tradable Permit Schemes; Transaction Costs; Smart Contracts; Blockchain.

1. Introduction

In the recent decades, the world has been grappling with a myriad of challenges, with climate change being on the forefront. There are numerous environmental policy instruments designed to address climate change and its severe impacts. These instruments can be classified into two main categories: the traditional regulatory instruments and the Market-Based Instruments (MBIs). While environmental standards and regulations are common traditional regulatory instruments, taxes, tradable permit schemes, market friction reductions, and voluntary agreements are examples of MBIs (OECD, 1994). The traditional regulatory approach, which is more prescriptive, has long been the dominant approach to policy intervention. However, having recognised the drawbacks of these instruments, an increasing number of researchers have been proposing the implementation of the alternative market-based approach (Oates et al., 1989, Hanley et al., 2013, Stavins, 2001). It is argued that MBIs, in theory, are more statically (least cost) and dynamically (encourage continuous improvement) efficient, compared to the traditional regulatory instruments (Baumol and Oates, 1988, Jaffe and Stavins, 1995). From various MBIs, Tradable Permit Schemes (TPS), such as Emissions Trading Schemes (ETS) and Transferable Development Rights (TDR), have gained traction among policy researchers and decision makers.

Recent research, however, challenged the relative merits of these alternative MBIs, arguing that the claims surrounding the cost-effectiveness of these instruments, particularly TPS, might have been exaggerated. The high transaction costs associated with designing and implementing these instruments have been one of the main concerns (Stavins, 1995, Shahab et al., 2018a, Jaraite et al., 2010, Heindl, 2017). This paper addresses this issue through exploring the use of Blockchain smart contracts in implementing TPS in order to reduce their associated transaction costs. The application of Blockchain smart contracts have had success in numerous sectors, such as supply chain management (Chang et al., 2019) and land administration (Bennett et al., 2019). However, their application in the fields of planning and environmental policy have remained very limited. This paper argues that the attributes of the Blockchain technology and smart contracts, which include decentralisation, transparency, automation, and immutability (Fu et al., 2018), have the potential to considerably contribute to the design and implementation of TPS. To this end, the paper briefly discusses the theoretical aspects of TPS, before paying particular attention to the transaction costs arising from designing and implementing these instruments. Then, it applies Blockchain smart contracts to TPS and argues the benefits of using these technologies in reducing their policy-related transaction costs.

2. Tradable Permit Schemes (TPS)

While different MBIs share some common characteristics, they may have different approaches to achieve their objectives. These instruments have been classified into various categories. Whitten et al. (2003), for example, suggest three types of MBIs, namely, price-based instruments, rights-based instruments, and market friction instruments. The price-based instruments aim at commodifying the environment through imposing taxes or subsidies. The quantity-based instruments target a fixed quantity or level of outcome and endeavour to align private interests with social interests through placing quantitative restrictions and creating markets for tradable permits in property rights (Clinch and O'Neill, 2010). The market friction instruments, on the other hand, aim to stimulate markets to produce the desired outcome and improve the efficiency of the existing markets, through reducing transaction costs and improving information flows (Whitten et al., 2003, Lockie, 2013).

TPS, which are the focus of this paper, fall within the quantity-based category. These instruments use a cap and trade system. The rationale behind the cap and trade mechanism is creating artificial scarcity in order to efficiently and sustainably manage environmental resources (Pirard, 2012). They create a new market for a particular environmental resource or an environmental problem to achieve their objectives. For example, in the case of emissions, the regulatory authorities determine an acceptable level of emission, which can be called as an absolute emissions cap. Consequently, the cap will be divided into a number of permits or allowances, and they will be allocated to the firms participating in the scheme. Then, in the new market for permits, users are free to trade allowances in an effort to obtain the lowest cost of compliance for themselves. Therefore, any desired level of emissions reduction can be achieved at least cost (Hahn and Stavins, 1992). Also, TPS provide agents with incentives to develop and adopt cheaper and more efficient ways of reducing the future costs of achieving targets. As they attempt to avoid paying the price per unit of pollution, such incentives encourage firms to invest in research and technologies to reduce abatement costs over time (Milliman and Prince, 1989, Jaffe and Stavins, 1995, Malueg, 1989).

3. Transaction Costs and Tradable Permit Schemes (TPS)

The concept of transaction costs first introduced as simply 'the cost of using the price mechanism' by Nobel Laureate Ronald Coase (1937). Transaction costs are generally defined as the costs involved in a transaction over and above production costs (Nilsson and Sundqvist, 2007, Shahab and Viallon, 2019). These costs include, for example, the costs of gathering information, contracting, negotiating, and evaluating alternative options. Transaction costs arise due to the existence of information uncertainties and because of the actions that actors must take to manage for these uncertainties (Williamson, 1998). Complexity and uncertainty surrounding the design and implementation of policy instruments can increase transaction costs leading to lower levels of policy efficiency. In addition, transaction costs can have a considerable impact on the equity of policy instruments as such costs are often distributed unevenly among parties involved. Given the considerable impact of transaction costs on policy outcome, decision makers and policy researchers need to take account of these costs when designing, implementing, and analysing policy instruments (Shahab et al., 2018c, 2019a, 2019b). High transaction costs might not only reduce efficiency, but also hinder interested actors from participating in policy instruments.

Many researchers have discussed the transaction costs of TPS from both theoretical and empirical perspectives. Stavins (1995) and Tietenberg (2006) theoretically argue that the presence of policy-related transaction costs might compromise the potential cost savings from the trading schemes. Empirically, Kerr and Maré (2008) show that the existence of transaction costs contributed to efficiency losses of 10–20% of the tradable permit market created during the US lead phasedown. Gangadharan (2000) finds that transaction costs had a considerable influence on the choice to participate in the Regional Clean Air Incentives Market (RECLAIM); without such costs the probability of trading was claimed to increase by 12–32%. In an effort to measure the transaction costs for firms in the EU ETS, Jaraite et al. (2010) find that the average transaction costs were €0.05 per tonne for the largest firms, while the average transaction costs were €2.02 for small firms, comprising over 18% of the allowance price of the time. In the context of TDR programmes in the US state of Maryland, Shahab et al. (2018a) estimated that the total transaction costs range from 13% to 21% of total TDR costs per transaction. These transaction costs arise from various activities, including, *inter alia*, finding a TDR seller/buyer, hiring a broker and paying a brokerage fee, negotiating a TDR price, and preparing a contract (Shahab et al., 2018b).

4. Reducing Transaction Costs of Tradable Permit Schemes Using Blockchain Smart Contracts

Smart contracts, which are part of Blockchain technology, are computer protocols that are meant to facilitate digital verification, enforcement, and recording of contracts by automatically generating transactions once certain conditions for contracts are met (Allam, 2018). According to Iansiti and Lakhani (2017), smart contracts are self-executing contracts that rely on the power of Blockchain technology to digitally facilitate performance of a contract in a more transparent and credible manner; hence, negating the need for a third party. By far, smart contracts supersedes the traditional contracts in various forms and more so in respect to credibility, security, transparency, traceability, irreversibility, distributable, and immutability amongst many other characteristics that are enabled by the Blockchain technology (Lauslahti et al., 2017). Sadiku (2018) adds that smart contracts are self-sufficient and conditional in nature. With traditional contracts, parties involved have to contend with extra transaction costs like those linked to the necessity of a third party to verify and enforce the contracts. However, with smart contracts, such issues are addressed during the coding of the smart contract programme, and the self-executing character of these contracts cement this notion (Allam and Jones, 2019). Giancaspro (2017) discusses that the self-execution quality is programmed to allow for reduced human errors and duplicity and to foster speed at which transactions are processed.

There are several potential benefits accruable when the implementation of TPS is backed by the use of smart contracts running on the Blockchain technology. We focus on the downward effects that they potentially have on the TPS policy-related transaction costs here. One of the main benefits of using smart contracts in this regards is their ability to increase the amount of relevant information available to interested actors. By increasing the availability of up-to-date and accurate information, smart contracts can decrease the uncertainties surrounding permit trades and as a result reduce transaction costs. Permit trading can be a complex process (Pop et al., 2018), particularly when permits are not well defined and made to apply to various contexts and jurisdictions. Smart contracts can reduce such complexities due to the possibility of using a singular platform to treat contractual agreements. In addition, through allocating information where necessary, filtering it, and reducing the overload of information, smart contracts enable actors to avoid and skip extra and irrelevant information more easily, compared to the traditional contracts. The use of smart contracts can also limit opportunistic behaviours by codifying parties' responsibilities and obligations and eliminating the need for and the costs of external enforcement (Vatiero, 2018). This is important given the fear of fraud and insecurity has the potential to considerably increase transaction costs (Karamitsos et al., 2018). These contracts increase transparency of the market for permits (Romano and Schmid, 2017), leading to higher levels of trusts and reduced transaction costs. Such quality allows actors to save on time-related costs as well as the direct monetary costs pertaining to the involvement of third parties and legal fees.

Information asymmetries among interested parties are one of the influencing factors in the magnitude and distribution of transaction costs in exchanges in general, and TPS transactions in particular. Smart contracts facilitate information flow and help correcting information asymmetries. By promoting the availability of sufficient information, they limit security issues and fraudulent activities that are eminent when information is scarce or non-transparent. These contracts store information in a distributable and verified database, whilst offering the ability to self-execute. Smart contracts facilitate the linkage between buyers and sellers leading to a higher level of trading quality. Buyers and sellers of permits can easily find each other on Blockchain platforms and negotiate on a price or on any other contractual requirements. Relying on their conditional based principles, smart contracts enhance the interactions between sellers and buyers since they can agree on terms and conditions without requiring a third party. These smart contracts are equipped with the functionalities of self-execution irrespective of time and jurisdiction constraints (Kim and Laskowski, 2018), within which transactions can be viewed by both parties in real-time. It is worth noting that the costs involved in establishing Blockchain supported schemes are higher, compared to those using traditional contracts. However, the automation of these technologies decreases the costs of administration, reporting, and execution (Fu et al., 2018). The high initial set-up costs, which include those paid to programmers and hiring ICT experts to oversee smooth application of the programmes, are due to the newness of this technology. However, these costs are expected to stabilise over time. Another limitation on integrating Blockchain smart contracts into the implementation of TPS is the lack of universally agreed protocols and standards on the use and development of these technologies. As a result, a singular platform where numerous Blockchain transactions can operate has not yet been developed. However, in the context of consensus on the need for market regulation surrounding Blockchain technology and the increasing interest in this technology, it is anticipated this will shortly be developed.

5. Summary and Conclusions

As market-based policy instruments, tradable permit schemes are introduced as an alternative to traditional regulatory instruments. These schemes aim to achieve a specified level of outcome through placing quantitative restrictions and creating markets for tradable permits. In essence, TPS are designed to assist in defining property rights and establishing a property rights market, which can replace direct forms of public intervention in order to internalise externalities and cope with market failures. The proponents of these alternative instruments claim that, in theory, they lead to similarly effective policy outcomes but with higher levels of efficiency. However, in practice, some researchers argue that the design and implementation of these policy instruments are associated with high transaction costs, resulting in reduced policy efficiency. Such transaction costs mainly arise due to the uncertainties, complexities, and information asymmetries surrounding TPS transactions, such as finding a permit buyer/seller, collecting accurate information, negotiating a price for permits, preparing a contract, and hiring intermediaries.

In this paper, we explored the potential of using smart contracts, supported by Blockchain technology, in implementing TPS in order to reduce their associated transaction costs. We argued that the characteristics of Blockchain smart contracts which include decentralisation, transparency, automation, and immutability, have the potential to contribute to the design and implementation of TPS. The use of Blockchain smart contracts can reduce policy-related transaction costs in TPS through: I) increasing the amount of relevant information available to parties involved; access to adequate and reliable amount of information decreases uncertainties in the market and has a downward effect on the time and effort the parties have to invest in each transaction; II) reducing the amount of irrelevant information available to parties involved; smart contracts enable actors to refine data sets into what they need, without including other data that can be repetitive and irrelevant. This ability to easily filter and process the accessible data can lower the time and effort actors require to put in the information collection processes, whilst reducing the level of complexities; III) correcting information asymmetries among the actors involved; providing reliable information for the actors involved in an equal, timely, and transparent manner can reduce the potential for rent-seeking behaviours and opportunism; IV) reducing the need for the involvement of intermediaries, since smart contracts have the potential to negate not only the need for information providers and brokers, but also the necessity of a third party to verify the contracts; and V) providing platforms where permit buyers and sellers can easily find each other and negotiate contracts. Despite these benefits it is important to take the transaction costs of establishing these smart contracts in TPS into account, since such transaction costs are higher than those of the traditional contracts. More research is needed to identify the broader costs and benefits of integrating Blockchain smart contracts into TPS design and implementation.

6. References

ALLAM, Z. 2018. On Smart Contracts and Organisational Performance: A Review of Smart Contracts through the Blockchain Technology. *Review of Economic and Business Studies,* 11**,** 137-156.

ALLAM, Z. & JONES, D. S. 2019. The Potential of Blockchain within Air Rights Development as a Prevention Measure against Urban Sprawl. *Urban Science,* 3**,** 38.

BAUMOL, W. J. & OATES, W. E. 1988. *The Theory of Environmental Policy,* Cambridge, Cambridge University Press.

BENNETT, R. M., PICKERING, M. & SARGENT, J. 2019. Transformations, transitions, or tall tales? A global review of the uptake and impact of NoSQL, blockchain, and big data analytics on the land administration sector. *Land Use Policy,* 83**,** 435-448.

CHANG, S. E., CHEN, Y.-C. & LU, M.-F. 2019. Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process. *Technological Forecasting and Social Change,* 144**,** 1-11.

CLINCH, J. P. & O'NEILL, E. 2010. Assessing the Relative Merits of Development Charges and Transferable Development Rights in an Uncertain World. *Urban Studies,* 47**,** 891-911.

COASE, R. H. 1937. The Nature of the Firm. *Economica,* 4**,** 386-405.

FU, B., SHU, Z. & LIU, X. 2018. Blockchain Enhanced Emission Trading Framework in Fashion Apparel Manufacturing Industry. *Sustainability,* 10**,** 1105.

GANGADHARAN, L. 2000. Transaction Costs in Pollution Markets: An Empirical Study. *Land Economics,* 76**,** 601-614.

GIANCASPRO, M. 2017. Is a 'smart contract' really a smart idea? Insights from a legal perspective. *Computer Law & Security Review,* 33**,** 825-835.

HAHN, R. W. & STAVINS, R. N. 1992. Economic Incentives for Environmental Protection: Integrating Theory and Practice. *The American Economic Review,* 82**,** 464-468.

HANLEY, N., SHOGREN, J. & WHITE, B. 2013. *Introduction to Environmental Economics,* Oxford, Oxford University Press.

HEINDL, P. 2017. The impact of administrative transaction costs in the EU emissions trading system. *Climate Policy,* 17**,** 314-329.

IANSITI, M. & LAKHANI, K. R. 2017. The Truth About Blockchain. *Harvard Business Review*.

JAFFE, A. B. & STAVINS, R. N. 1995. Dynamic Incentives of Environmental Regulations: The Effects of Alternative Policy Instruments on Technology Diffusion. *Journal of Environmental Economics and Management,* 29**,** S43-S63.

JARAITE, J., CONVERY, F. & DI MARIA, C. 2010. Transaction costs for firms in the EU ETS: lessons from Ireland. *Climate Policy,* 10**,** 190-215.

KARAMITSOS, I., PAPADAKI, M. & AL-BARGHUTHI, N. B. 2018. Design of the Blockchain Smart Contract: A Use Case for Real Estate. *Journal of Information Security,* 9**,** 177-190.

KERR, S. & MARÉ, D. C. 2008. Transaction Costs and Tradable Permit Markets: The United States Lead Phasedown. Wellington, New Zealand: Motu Economic and Public Policy Research Trust.

KIM, H. & LASKOWSKI, M. 2018. *A Perspective on Blockchain Smart Contracts: Reducing Uncertainty and Complexity in Value Exchange,* Toronto, Canada, Schulich School of Business, York University.

LAUSLAHTI, K., MATTILA, J. & SEPPÄLÄ, T. 2017. Smart contracts - how will blockchain technology affect contractual practices? *ETLA*.

LOCKIE, S. 2013. Market Instruments, Ecosystem Services, and Property Rights: Assumptions and Conditions for Sustained Social and Ecological Benefits. *Land Use Policy,* 31**,** 90-98.

MALUEG, D. A. 1989. Emission Credit Trading and The Incentive to Adopt New Pollution Abatement Technology. *Journal of Environmental Economics and Management,* 16**,** 52-57.

MILLIMAN, S. R. & PRINCE, R. 1989. Firm Incentives to Promote Technological Change in Pollution Control. *Journal of Environmental Economics and Management,* 17**,** 247-265.

NILSSON, M. & SUNDQVIST, T. 2007. Using The Market at a Cost: How the Introduction of Green Certificates in Sweden Led to Market Inefficiencies. *Utilities Policy,* 15**,** 49-59.

OATES, W. E., PORTNEY, P. R. & MCGARTLAND, A. M. 1989. The Net Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting. *The American Economic Review,* 79**,** 1233-1242.

OECD 1994. *Applying Economic Instruments to Environmental Policies in OECD and Dynamic Non-Member Countries,* Paris, OECD Documents.

PIRARD, R. 2012. Market-based Instruments for Biodiversity and Ecosystem Services: A Lexicon. *Environmental Science & Policy,* 19–20**,** 59-68.

POP, C., CIOARA, T., ANTAL, M., ANGHEL, I., SALOMIE, I. & BERTONCINI, M. 2018. Blockchain Based Decentralized Management of Demand Response Programs in Smart Energy Grids. *Sensors,* 162**,** 1-21.

ROMANO, D. & SCHMID, G. 2017. Beyond Bitcoin: A Critical Look at Blockchain-Based Systems. *Cryptography,* 1**,** 1-15.

SADIKU, M. N. O. E., K.G.; MUSA, S.M. 2018. Smart contracts: A primer. *Journal of Scientific and Engineering Research,* 5**,** 538-541.

SHAHAB, S., CLINCH, J. P. & O'NEILL, E. 2018a. Estimates of Transaction Costs in Transfer of Development Rights Programs. *Journal of the American Planning Association,* 84**,** 61-75.

SHAHAB, S., CLINCH, J. P. & O'NEILL, E. 2018b. Timing and distributional aspects of transaction costs in Transferable Development Rights programmes. *Habitat International,* 75**,** 131-138.

SHAHAB, S., CLINCH, J. P. & O'NEILL, E. 2019a. An Analysis of the Factors Influencing Transaction Costs in Transferable Development Rights Programmes. *Ecological Economics,* 156**,** 409-419.

SHAHAB, S., CLINCH, J. P. & O’NEILL, E. 2018c. Accounting for Transaction Costs in Planning Policy Evaluation. *Land Use Policy,* 70**,** 263–272.

SHAHAB, S., CLINCH, J. P. & O’NEILL, E. 2019b. Impact-based planning evaluation: Advancing normative criteria for policy analysis. *Environment and Planning B: Urban Analytics and City Science,* 46**,** 534-550.

SHAHAB, S. & VIALLON, F. X. 2019. A Transaction-cost Analysis of Swiss Land Improvement Syndicates. *Town Planning Review,* 90**,** 545-565.

STAVINS, R. N. 1995. Transaction Costs and Tradeable Permits. *Journal of Environmental Economics and Management,* 29**,** 133-148.

STAVINS, R. N. 2001. Experience with Market-Based Environmental Policy Instruments. *Resources for the Future*.

TIETENBERG, T. H. 2006. *Emissions Trading: Principles and Practice,* Washington, DC, Resources for the Future.

VATIERO, M. 2018. Smart contracts and transaction costs. *Discussion Papers.* Pisa, Italy: Dipartimento di Economia e Management (DEM), University of Pisa.

WHITTEN, S., VAN BUEREN, M. & COLLINS, D. An Overview of Market-Based Instruments and Environmental Policy in Australia. AARES Symposium, 2003.

WILLIAMSON, O. E. 1998. Transaction Cost Economics: How It Works; Where It is Headed. *De Economist,* 146**,** 23-58.