ARTICLE

The Internet of Things as A Tool to Improve Environmental Taxation within the EU: A Case Study on the Design of Annual Road and Motor Vehicle Taxes

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Technology is essential for the transition towards climate neutrality not only in technical aspects (better and more efficient capture, energy storage, or carbon use) but also as an important tool in taxation. The progressive implementation of the Internet of Things' (IOT) technology can contribute to achieving the proposed objectives of the European Union's (EU's) environmental agenda. Its capacity to monitor and record real-time emissions creates the possibility of determining the exact amount of emissions that a vehicle emits during the year. Its implementation for tax purposes can revolutionize the design of the taxable event and the quantifying elements of certain environmental taxes, particularly those related to taxing pollutant emissions from motor vehicles in order to ensure more compliance with the pollutant pays principle.

Keywords: Internet of things, IoT, real-time monitoring, environmental taxation, pollutant emissions, polluter pays principle, annual motor vehicle taxes, annual road taxes, car taxes.

1 Introduction

The Internet of Things (also known as the IoT) is a booming technology that will increasingly experience expansion and widespread use as connectivity capabilities enable real-time information exchanges. The European Union (EU) recognized that technology is essential for achieving the climate neutrality goals of the European Green Deal. A specific type is mentioned as an essential tool to achieve this objective: 'artificial intelligence, 5G networks, cloud and edge computing and the internet of things'.[1]In this context, the Green Deal highlights that 'digitalisation [...] brings new opportunities for remote monitoring of air and water pollution or monitoring and optimising the way energy and natural resources are used'.[2] The IOT is a technology that could support developing and executing such environmental undertakings, and its capacity to monitor pollutant emissions[3] makes it an interesting tool for tax purposes.

The primary objective of this article and its content is focused on exploring whether the IOT could be a viable instrument for supporting the implementation of the polluter pays principle within environmental taxation. For this reason, it provides a case study centred on the application of such technology in annual motor vehicle and road taxes. Those that are levied across the EU Member States have experienced the progressive introduction of a green element in calculating its tax bases, as the reader will observe further in this research. Therefore, the article's specific aim is to analyse whether such technology could be used to adjust or even redesign those annual road taxes that already contain an environmental element to calculate their tax bases and tax liabilities in order to make them more compliant with the environmental tax principle of polluter pays principle.

This article is divided into seven parts. Section I introduces the content and purpose of the article. Section II presents the EU's agenda for environmental purposes and its enhancement of technology for such a commitment. Section III develops what the technology of the IOT is and how it works. Section IV introduces the reader to its current regulatory framework within the EU. The goal is to provide the necessary background information to allow a better understanding about how much regulatory latitude exists within the EU and its Member States to

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1 European Commission, *Communication from the Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of the Regions The European Green Deal*, COM(2019) 640 final 11 Dec. 2019, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640&from=EN (accessed 15 Apr. 2024)

2 *Ibid.*

3 For the purposes of this article, pollutant emissions refer to those air-polluting substances derived from the combustion of fossil fuels. It refers to mainly emissions of carbon dioxide (CO2), particulate matters (PM), nitrogen oxides (NOx), or ammonia (NH3) among others.

legislate its use for tax purposes. Section V reflects on the potential application of the IOT on environmental taxation and focuses particularly on annual motor vehicle taxes and road taxes within the EU. The section aims to demonstrate how introducing IOT devices that monitor real-time emissions could improve the design of such taxes to ensure better adherence with the polluter pays principle. Finally, section vi explains how to optimize the structures and the method of quantification of the tax liability of the described taxes in section iv in order to improve and refine its accuracy. Section VII concludes the article.

2 Towards an ecologic and digital transition within the EU: The European Green Deal

Articles 11, 191, and 193 of the Treaty on the Functioning of the European Union (TFEU) regulate the legal bases of the Union's environmental policy, making the fight against climate change and environmental degradation a EU objective *per se* and a common challenge for all Member States. The origins date back to the Paris European Council of 1972 when the importance of developing a community environmental policy to improve the quality of life and living standards was emphasized for the first time.[4] Such policy materialized a year later as the programme of action of the European Communities on the environment[5] and finally developed in the Single European Act of 1987.[6] Later, the Treaty of Maastricht of 1993 made environmental protection a policy area of the Union.[7] Finally, the Lisbon Treaty of 2009 consolidated it when the fight against climate change was introduced into the TFEU as a specific legal obligation.

In 2019, the European Commission presented the European Green Deal[8] which is guidance for making the EU economy more sustainable and placing the 'well-being of citizens at the centre of economic policy'.[9] The Green Deal is part of the commission's strategy to implement the 2030 Agenda and the UN Sustainable Development Goals[10] to respond to global warming and climate change challenges. The main objective is to reduce greenhouse gas emissions by 50% by 2030 and make Europe the first climate-neutral continent by 2050.[11] A broad variety of measures is required for such an ambitious objective. The most noteworthy include the Climate Law,[12] the revision of the Energy Taxation Directive,[13] the extension of the EU Emissions Trading System (ETS), or the proposal for a regulation of carbon border adjustment measures (CBAM) with the aim to prevent the risk of carbon leakage and ensure the EU's climate leadership.[14]

Besides these measures, the Green Deal highlights technology's general relevance for the transition to climate neutrality. Among all of the types, it mainly refers to digital technologies, such as artificial intelligence, 5G networks, cloud computing, or the IOT as effective tools to enhance environmental policies. Furthermore, it states that 'digitalisation […] brings new opportunities for remote monitoring of air and water pollution or monitoring and optimising the way energy and natural resources are used'.[15] The IOT is the ideal technology to accomplish such purposes.

3 The basics of the IOT: A technology to consider for tax purposes

The term IOT was first used in 1999 by Kevin Ashton[16] who is a digital technology pioneer who intended to describe a system that connects computers to the physical

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4 *See* Point 3 and 8, Statement from the Paris Summit (19 to 21 Oct. 1972), Bulletin of the European Communities (10 Oct. 1972), 14–26, http://www.cvce.eu/obj/statement_from_the_paris_summit_19_to_21_october_1972-en-b1dd3d57-5f31-4796-85c3-cfd2210d6901.html (accessed 15 Apr. 2024)

5 Declaration of the Council of the European Communities and of the representatives of the Governments of the Member States meeting in the Council of 22 Nov. 1973 on the Programme of action of the European Communities on the environment, Official Journal C 112, 20 Dec. 1973, 0001–0002.

6 Article 25 incorporates Part 3 of the Treaty establishing the European Economic Community, adding a Title VII entirely devoted to the Environment (*see* Single European Act OJ L 169 (29 Jun. 1987), https://eur-lex.europa.eu/legal-content/ES/TXT/PDF/?uri=CELEX:11986U/TXT&from=ES (accessed 15 Apr. 2024)

7 The Treaty on European Union provides in Art. 3.k) for establishing a standard policy on the Environment. *See* Treaty on European Union, OJ C 191, 29 Jul. 1992, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:11992M/TXT&from=EN (accessed 15 Apr. 2024)

8 European Commission, *supra* n. 1.

9 Mart van Hulten, *The Green Deal Consultations: Well-Being Aims and Tax Related Reforms*, 6 EC Tax Rev. 267 (2020), doi: 10.54648/ECTA2020054 (accessed 15 Apr. 2024)

10 United Nations, *The 17 Goals*, Department of Economic and Social Affairs, https://sdgs.un.org/goals (accessed 15 Apr. 2024)

11 *See* Marta Villar Ezcurra & Jerónimo Maillo González-Orús, *Environmental Governance Through Tax Law in the European Union. Blue Planet Law* 173–186 (In: Maria da Gloria Garcia & António Cortês eds, Springer, Cham 2023).

12 Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 Jun. 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'), PE/27/2021/REV/1, *OJ L 243,* 9 Jul. 2021, at 1–17.

13 This measure is particularly relevant as the current directive is not suitable for addressing the climate change challenges. *See* Marina Bisogno, *Twenty Years After the Adoption of the Energy Taxation Directive, Is Its Reform in a Greener Sense Just an Illusion?,* 51(10) Intertax 697–702 (2023), doi: 10.54648/TAXI2023058 (accessed 15 Apr. 2024)

14 Alice Pirlot, *Carbon Border Adjustment Measures: A Straightforward Multi-Purpose Climate Change Instrument?*, 34(1) J. Envtl. L. 25–52 (2022), doi: 10.1093/jel/eqab028 (accessed 15 Apr. 2024)

15 *Supra* n. 7.

16 Kevin Ashton, *That 'Internet of Things' Thing*, RFID Journal (22 Jun. 2009), https://www.rfidjournal.com/that-internet-of-things-thing (accessed 15 Apr. 2024)

world through sensors.[17] Even though there is no official definition of it, technology experts attempted to provide one. For instance, according to Bunz and Meikle,[18] the IOT describes the multiple uses and processes resulting from giving a network address to a 'thing' or device equipped with sensors. The combination of these three factors, i.e., network (Internet), sensors, and devices, gives them several abilities such as observing, speaking, or tracking. Nevertheless, Watts stated[19] that the IOT (sometimes also referred to as the Internet of Everything) is an architecture capable of handling information from a global network where people can interact through objects. Despite the different focuses of both definitions, they denote that the main idiosyncratic trait of this technology is how the combination of a network, sensors, and devices allows computers to receive information about the physical world through regular objects. Since its origins in the 1980s,[20] the IOT has advanced substantially, and it can now be found in electronic devices, watches, lights, and even textiles.[21] This significant progression in the connectivity of ordinary objects has allowed creating a complete network of interconnected devices. Today, vehicles, buildings, and cities full of different devices, sensors, and software can be found that are capable of collecting and exchanging data and are often referred to with the adjective 'smart'.[22]

How does the IOT work? What is known as its architecture is divided into four phases. The first is wireless sensors and actuators that measure and collect data. The second includes systems for aggregating sensor data and converting analogue to digital data. In this phase, the raw data, i.e., the analogue data gathered during the first phase, is converted into digital data. This is subsequently formatted so that it can be sent to a processor (i.e., computer) via an Internet gateway over a network (wireless or wired). The connectivity that allows data transmission can be through different types of connection without altering the IOT' definition, such as a 3G, 4G, and 5G connection to a Wi-Fi, Bluetooth,[23] or radio frequency identification system (RFID).[24] The important thing about it is to provide the mechanism with a suitable gateway with sufficient data transmission capacity that is adapted to the needs of each environment. In the third phase, data are analysed and processed to reduce their volume to what is strictly necessary for the purposes for which they have been collected. Finally, the polished data are sent to a data centre (the cloud) which is analysed, managed, and stored in the fourth phase in which a computer system analyses, classifies, and secures data storage.[25] Therefore, data nourishes the IOT devices that can extract raw analogical information and process it into digital information in real-time.[26] Such capacity makes it a valuable tool to monitor and analyse information in diverse fields. It has proven to be effective for innovating services, applications, and improving products.[27] It provides greater efficiency in the logistics process and facilitates closely monitoring the production or supply chain, particularly when combining it with other technologies.[28]

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[17] Avnet Silica, *Interview with Kevin Ashton – Inventor of IoT: Is Driven by the Users*, Avnet Silica (11 Feb. 2018), https://my.avnet.com/silica/resources/article/interview-with-iot-inventor-kevin-ashton-iot-is-driven-by-the-users/ (accessed 15 Apr. 2024)

[18] Mercedes Bunz & Graham Meikle, *The Internet of Things* (Polity Press 2018).

[19] Atslands Rego da Rocha, Flávio R. C. Sousa & Andrei Bosco Bezerra Torres*, Internet of Things: Architectures, Technologies and Applications in 4 Internet of Things (iot): Applications, Technology, and Privacy Issues. Internet Theory, Technology and Applications* 56 (Silvia Watts ed., Nova Science Publishers 2016).

[20] In 1982, a group of students at Carnegie Mellon University (Pittsburgh, Pennsylvania) connected the ARPANET to a Coca-Cola vending machine to find out if there were cold bottles and cans available. This experiment was the precursor to the Internet of Things because ARPANET cannot be considered as the Internet itself. {*See* Janet Abbate, *Inventing the Internet* 133 (The MIT Press 1999), *see* Paul E. Ceruzzi, *Computing: A Concise History* 121 (The MIT Press Essential Knowledge series 2012); *see* Jordan Teicher, *The little-known Story of the first IoT device* IBM (7 Feb. 2018), https://www.ibm.com/blogs/industries/little-known-story-first-iot-device/} (accessed 15 Apr. 2024). Some years later, in 1989, Dan Lynch connected a toaster to the already developed Internet to control its switching on and off and the precise time to eject the toast automatically. This device was classified as the first proper Internet of Things device in history. {*See* John Romkey, *Toast of the IoT: The 1990 Interop Internet Toaster,* 6(1) IEEE Consumer Electronics Mag. 116–119 (2017), doi: 10.1109/MCE.2016.2614740}.

[21] *See* Tiago M. Fernández-Caramés & Paula Fraga-Lamas, *Towards the Internet of Smart Clothing: A Review on IoT Wearables and Garments for Creating Intelligent Connected E-Textiles,* 7(12) Electronics 405–444 (2018), doi: 10.3390/electronics7120405 (accessed 15 Apr. 2024) They present a multitude of examples of smart clothing and textile accessories that are used for different purposes from clothing for athletes that monitors their physical condition to prevent injuries to wearing apparel for people with a visual disability to improve their mobility and enable them to be more independent and garments for weight loss that control the metabolic parameters of those who wear it.

[22] Throsten Kramp, Rob van Kranenburg & Sebastian Lange, *Introduction to the Internet of Things. Enabling Things to Talk* 1–10 (Alessandro Bassi et al. eds, Springer 2013), https://doi.org/10.1007/978-3-642-40403-0_1 (accessed 15 Apr. 2024)

[23] *See* Kuor-Hsin Chang, *Bluetooth: A Viable Solution for IoT? {Industry Perspectives},* 21 IEEE Wireless Communications 6–7, (2014), doi: 10.1109/MWC.2014.7000963 (accessed 15 Apr. 2024) 4A Shahid Raza et al., *Building the Internet of Things with Bluetooth Smart*, 57 Ad Hoc Networks 19–31 (2017), doi: 10.1016/j.adhoc.2016.08.012 (accessed 15 Apr. 2024)

[24] *See Supra* n. 15.

[25] For a more detailed explanation of Internet of Things' architecture and technology used, *see* Debasis Bandyopadhyay, Jaydip Sen, *Internet of Things: Applications and Challenges in Technology and Standardisation*, 58 Wireless Pers. Comm. 49–69 (2011), doi: 10.1007/s11277-011-0288-5 (accessed 15 Apr. 2024)

[26] *See* Milan Milenkovic, *Internet of Things: Concepts and System Design* (Springer 2020).

[27] *See* a diversity of services, improvements of products, and potential applications that the Internet of Things can have in 7A Khalid Elgazzar et al., *Revisiting the Internet of Things: New Trends, Opportunities and Grand Challenges*, 1 Frontiers in the Internet of Things, 1–18 (2022), https://www.frontiersin.org/articles/10.3389/friot.2022.1073780, doi: 10.3389/friot.2022.1073780 (accessed 15 Apr. 2024)

[28] *See* 4A Alexandra Lagorio et al., *5G in Logistics 4.0: Potential Applications and Challenges*, 217 Procedia Comp. Sci. 651, at 650–659 (2023), doi: 10.1016/j.procs.2022.12.261 (accessed 15 Apr. 2024) It was already foreseen more than ten years ago by Margherita Forcolin, Enrico Fracasso, Francesco Tumanischvili, Paola Lupieri, *EURIDICE – IoT Applied to Logistics Using the Intelligent Cargo Concept*, 17th International Conference on Concurrent Enterprising, Aachen, Germany 20 Jun. – 2011 22 Jun. 2011, 1–9 (2011).

It is also beneficial for improving the consumption of resources and energy.[29]

The number of fields where the IOT shows significant practicality contributes to an exponential increase in the number of devices in place. In this context, an example to comprehend the dimension that this technology is taking is that the number of IOT devices has increased from 1.8 million devices in use in 2013 to approximately twenty billion today. Moreover, it is expected to reach fifty billion devices in the following years and generate 79.4 zettabytes (79.4 trillion gigabytes) of data.[30] To be concise, with the expansion of the IOT in all fields of everyday life and among all of the expected zettabytes of data generated and treated by all of the different devices, it is not unreasonable to expect that there might be potentially relevant helpful information for tax purposes.[31] For instance, the IOT has proven exceptionally efficient in real-time emissions monitoring,[32] hence, it can directly or indirectly be used for environmental tax purposes.

In a past scenario that did not contemplate the existence of such technology, it was understandable to design a tax that did not consider actual pollution levels since there was no way to accurately monitor them. However, currently having this technology available and taking into account how useful it is for systematically tracking real-time emissions, two questions arise. The first is whether this particular ability can be helpful for environmental tax purposes, and the second is if it can be a relevant technology to influence the design of certain elements of those taxes. One example is the method to calculate the tax base and/or the tax liability to make them more compliant with the environmental tax principles, particularly the polluter pays principle.

4 IOT-generated data relevant for tax purposes: A still unregulated field within the EU

There are still deficiencies in the primary stage of regulating the IOT within the EU legal framework for tax purposes. The European Commission has been a frontrunner in claiming a common standard policy to ensure its correct use and applications for the common good.[33] It has recognized both the possibilities this technology presents and the risks that could impinge on the IOT. However, tangible proposals of regulations did not arrive until the presentation of the EU strategy for data[34] in 2020. It presented some key measures for making the use and availability of data more in accordance with the EU rules and values, among which are the proposals for the Data Governance Act[35] and the Data Act.[36] Both proposals of EU Regulations intend to harmonize rules to strengthen data-sharing mechanisms across the EU and guarantee fair access to data and its use. Nevertheless, none of them directly regulate the use of the information extracted by the IOT devices for tax purposes.

A more comprehensive examination of the Data Act proposal clarifies that public sector bodies cannot freely access or request it to data generated by IOT devices unless there is an exceptional need for the reason of public interest.[37] However, this reason does not cover the use of IOT-generated data for taxation purposes or the capacity of tax and customs authorities to request access to such data. Indeed, the proposal of the regulation dissociates itself from regulating the entities' capacity as public sector bodies to collect, share, access, and use data generated by IOT devices.[38]

The proposed Data Act leaves a regulatory margin of freedom to the responsible bodies for taxation and customs at both the Union and Member States' levels to regulate it at their convenience. Therefore, the strict requirements for public

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29 *See* Leszek Marek & Jarosław Woźniczka, *The Internet of Things as a Customer Experience To ol*, 3(3) Jagiellonian J. Mgmt. 163–176 (2017) doi: 10.4467/2450114XJJM.17.011.9562 (accessed 15 Apr. 2024)

30 *See* European Commission, *Rolling Plan for ICT Standardisation* (European Commission 2023), https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/internet-things-rp2023 (accessed 15 Apr. 2024)

31 *See* 5A Álvaro Antón Antón et al., *The Internet of Things in Tax Law,* 182 Crónica Tributaria 151–205 (2021), doi: 10.47092/CT.22.1.5 (accessed 15 Apr. 2024)

32 Some examples of Co2 monitoring emissions can be found in 7A He Zhang, Jianxun Zhang, Rui Wang et al., *Smart Carbon Monitoring Platform Under IoT-Cloud Architecture for Small Cities in B5G,* Wireless Network (2021), doi: 10.1007/s11276-021-02756-2 (accessed 15 Apr. 2024); or Newlin Rajkumar, Sruthi M. S, & Dr V. Venkatesa Kumar, *IoT Based Smart System for Controlling Co2 Emission*, 2(2), Int'l J. Sci. Res. Comp. Sci., Eng'g & Info. Tech. 284–288 (2017); or Prabhu Ramaswamy, *IoT Smart Parking System for Reducing Greenhouse Gas Emission. In 2016 International Conference on Recent Trends in Information Technology* (ICRTIT) 1–6 Apr. 2016).

33 Already in 2009 when the term 'Internet of Things' was known mainly among groups of technology experts, the European Commission began to present its concerns about the applications and challenges of this novel technology (*see* Rolf H. Weber, *Internet of Things – New Security and Privacy Challenges*, 26(1) Comp. L. & Sec. Rev. 23–30 (2010), doi: 10.1016/j.clsr.2009.11.008) (accessed 15 Apr. 2024). Such concerns leaned towards the development of the first policy approach towards the Internet of Things in the EU. *See* European Commission, *Communication from the Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of the Regions*: *Internet of Things – An action plan for Europe,* COM(2009) 278 final 18 Jun. 2009, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0278:FIN:EN:PDF (accessed 15 Apr. 2024)

34 *See* European Commission, *Communication from the Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of the Region: A European Strategy for data*, COM(2020) 66 final (19 Feb. 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066 (accessed 15 Apr. 2024)

35 European Commission, *Proposal for a Regulation of the European Parliament and the Council on a European data governance (Data Governance Act)*, COM(2020) 767 final 2020/0340 (COD) (25 Nov. 2020), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0767 (accessed 15 Apr. 2024)

36 European Commission, *Proposal for a Regulation of the European Parliament and the Council on harmonised rules on fair access to and use of data (Data Act)*, COM(2022) 68 final 2022/0047 (COD) (23 Feb. 2022), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022PC0068 (accessed 15 Apr. 2024)

37 *See supra* n. 35, Art. 1.2(d), at 38.

38 *See ibid.*, Art. 1.4, at 38.

bodies to properly access and utilize IOT generated data do not apply to that area of taxation and customs or their sectorial legislation.[39] On the contrary, it is expressly excluded[40] which means that Member States have a large legislative margin unless the commission dares to regulate the IOT for tax purposes with a mainly new regulation or directive. They are still granted discretion to decide the most convenient way to regulate this and up to what extent the data that these devices are generating is particularly relevant for tax purposes.

5 IOT on environmental taxation: Room for improvement

Considering the regulatory capacity that is still available to regulate its use for tax purposes, this section aims to present a case study to show a potential regulation of the IOT for tax purposes. Particularly, it shows how the it could help improve the design of a particular type of environmental taxes. This section takes into account its development for the automotive field and the refinement achieved by monitoring the actual pollution released into the atmosphere for individual vehicles.[41] It analyses how this technology's usefulness and precision can be materialized for monitoring emissions on those motor vehicle taxes that have introduced an environmental element into their calculation. For this reason, subsection 5.1 will examine certain annual road taxes or annual motor vehicle taxes that take into account the emissions of greenhouse gas effects in the calculation of their tax base and tax liability[42] but do not consider the genuine amount of pollutant emissions. Thus, subsection 5.2 will show what would occur if an IOT device was used to help calculate annual road/motor vehicle taxes. The objective is to demonstrate how governmental entities might take advantage of this technology to align the design of environmental taxes more in accordance with environmental tax principles.

5.1 *Annual Road and Motor Vehicles Taxes in the EU and Their Current Calculation Method*

During the last decades, some EU Member States (not all, but some of them) have progressively incorporated a green element in the tax base or tax liability of their annual road and motor vehicle taxes to make them compliant with the polluter pays principle.[43] The intention of doing so is to tax those taxpayers responsible for contributing to damaging the environment which happens every time a vehicle with an engine that runs on fossil fuels is operated on the roads. It is an ex-post measure that applies once a polluting activity has been carried out and its effects are known.

Taxes levied on emissions intend to dissuade and prevent their release into the atmosphere. Taxes on CO2 and other pollutant emissions are divided into those that indirectly tax them such as taxes on production and consumption (carbon taxes)[44] and those that directly tax them (i.e., all fees, charges, or taxes on emissions or atmospheric pollution). This last group of taxes that includes pollutant gases as part of the elements used to calculate the tax base comprises those annual road taxes or motor vehicle taxes within the EU Member States that decided to add this environmental tax element.

Although many taxes levied on pollutant gases calculate their tax base based on 'measured and estimated' emissions,[45] the main question is how the measurements are made. For this reason, a comparative study of the elements that integrate the taxable base of different EU Member States' annual motor vehicle and road taxes is necessary to examine how tax bases and tax liabilities are calculated and whether there are any improvable elements.

From the table's information, it is clear that the scope of annual road or motor vehicle taxes differs from state to state across the EU. Even though similar elements are taken to integrate the taxable bases of the analysed

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[39] *See ibid.,* Arts 17–22, at 49–52.

[40] Recital 60 of the Preamble enhances that for the exercise of their tasks such as 'the collection of data for taxation or customs purposes public sector bodies and Union institutions, agencies and bodies should rely on their powers under sectoral legislation. This Regulation accordingly does not affect instruments for the sharing, access and use of data in those areas'. *See supra* n. 35, at 30.

[41] Numerous technical studies support the viability of recording the emission of gases and polluting particles through Internet of Things devices in real-time and with high precision. Among them, *see* Souvik Manna, Suman Sankar Bhunia & Nandini Mukherjee, *Vehicular Pollution Monitoring Using IoT*, International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014), 1–5 (2014) doi: 10.1109/ICRAIE.2014.6909157 (accessed 15 Apr. 2024): Shahane, Prachi & Preeti Godabole, *Real-Time Monitoring of CO2 Emissions in Vehicles Using Cognitive IOT*, 5 Int'l J. Sci. & Res. 758–761(2016), doi: 10.21275/v5i3.NOV161965 (accessed 15 Apr. 2024); Tsventan Tsokov & Dessislava Petrova-Antonova, *Monitoring and Control of Vehicles' Carbon Emissions. Software Technologies* 229–243 (Enrique Cabello et al. eds, Springer 2018) or 4A Aayushi Gautam et al., *Vehicle Pollution Monitoring, Control and Challan System Using MQ2 Sensor Based on Internet of Things*, 116(2) Wireless Personal Communications 1071–1085 (2021), doi: 10.1007/S11277-019-06936-4 (accessed 15 Apr. 2024)

[42] Annual road and motor vehicle taxes are directly levied on the ownership of motorized vehicles that are suitable for circulating on public roads. *See* the table below for extensive examples of annual road and motor vehicle taxes with examples of elements integrated into the calculation of either their tax bases or their tax liabilities.

[43] *See* OECD, *Recommendation of the Council on Guiding Principles concerning International Economic Aspects of Environmental Policies, C (72)128*, (OECD 1972). *See also* Alice Pirlot, *Exploring the Impact of European Union Law on Energy & Environmental Taxation*, Research Handbook on European Union Tax Law 359–388 (Christina HJI Panayi et al. eds, Edward Elgar Publishing Limited 2020).

[44] *See* footnotes 6 and 7 at Iñaki Bilbao Estrada & Pasquale Pistone, *Global CO2 Taxes*, 41(1) Intertax 3, at 2–14 (2013), doi: 10.54648/TAXI2013001 (accessed 15 Apr. 2024)

[45] European Commission, *Environmental Taxes: A Statistical Guide 2013 Edition* 13 (Eurostat, Publications Office 2013), https://data.europa.eu/doi/10.2785/47492 (accessed 15 Apr. 2024)

Table 1 EU motor vehicle taxes and road taxes contemplating pollutant emissions[46]

COUNTRY	ELEMENTS TO CALCULATE THE TAX
BELGIUM	Cubic centimetres (cc), CO2 emissions, type of fuel, and standard of emissions[47]
DENMARK	Vehicles registered between 1 July 1997 and 18 March 2009: payment based on the weight of the vehicle.Vehicles registered between 1 July 1997 and 30 June 2021: vehicle weight + mileage x litres of fuel.Vehicles registered after 1 July 2021: grCo2/km according to standard of emissions[48]
FINLAND	Type of vehicle + Weight>2,500kg + Annual emissions of CO2gr/km 0 a >400gr/km[49]
FRANCE	Annual Emissions of CO2gr/km >123 to >225gr/m[50]
GERMANY	Vehicles registered >2009 + cubic centimetres (cc) + annual emissions of CO2[51]
GREECE	Year of register of the vehicle + type of vehicle + CC For vehicles registered after 2021 = Co2, emissions are taken into account 0 to >281gr/m[52]
IRELAND	Year of register of the vehicle + type of vehicle + Annual emissions of CO2gr/km 0 to >225gr/m[53]
ITALY	Power (Kw) + region coefficient + Annual CO2gr/km emissions + vehicle age[54]
LATVIA	Year of register of the vehicle + CC+ Annual emissions of CO2gr/km 50gr/Km to >401gr/m[55]
LUXEMBURG	CC + fuel type + Annual emissions of CO2gr/km 115gr/Km to >170gr/m[56]
MALTA	Type of vehicle + age of the vehicle+ type of fuel + CC + Annual emissions of CO2gr/km 0gr/Km to >250gr/Km. Diesel vehicles take PM into account[57]
NETHERLANDS	Weight, type of fuel (petrol, diesel, LPG), and CO2 emissions (there is only a special CO2 regime for passenger cars that emit less than 50 g/km)[58]
PORTUGAL	Type of vehicle + date of register + CC+ type of fuel + Annual emissions of CO2gr/km 120gr/Km to >260gr/Km[59]

Notes

46 This table only contemplates those EU Member States that include some pollutant emissions as an element integrating the tax base of the tax liability. However, it does not consider the rest of the Member States that do not include such an element to calculate their road taxes.

47 Vlaanderen, *Tarief personenauto, auto voor dubbel gebruik en minibus*, https://www.vlaanderen.be/tarief-personenauto-auto-voor-dubbel-gebruik-en-minibus (accessed 15 Apr. 2024)

48 The Danish Motor Vehicle Agency, *periodic taxes,* https://motorst.dk/en-us/individuals/vehicle-taxes/periodic-taxes (accessed 15 Apr. 2024)

49 Vero skatt, *Car tax*, https://www.vero.fi/en/individuals/vehicles/car_tax/ (accessed 15 Apr. 2024) and Finlex, *Ajoneuvoverolaki,* https://www.finlex.fi/fi/laki/ajantasa/2003/20031281 (accessed 15 Apr. 2024)

50 Ministère de l'économie des finances et de la souveraineté industrielle et numérique, *Comment fonctionne la taxe malus sur les véhicules polluants ?,* https://www.economie.gouv.fr/cedef/malus-vehicules-polluants (accessed 15 Apr. 2024)

51 Bundesministerium der Finanzen, *Kfz-Steuer-Rechner*, https://www.bundesfinanzministerium.de/Web/DE/Service/Apps_Rechner/KfzRechner/KfzSteuerrechner.htmlen (accessed 15 Apr. 2024)

52 Government of Greece, *Annual Road Tax for Private Cars*, https://www.gov.gr/en/sdg/vehicles/taking-motor-vehicle-temporarily-or-permanently/road-tax/annual-road-tax-for-private-cars (accessed 15 Apr. 2024)

53 Citizens Information Ireland, *Motor Tax*, https://www.citizensinformation.ie/en/travel-and-recreation/motoring/motor-tax-and-insurance/ (accessed 15 Apr. 2024)

54 Automobile Club d'Italia, *Guida al bollo auto*, https://www.aci.it/i-servizi/guide-utili/guida-al-bollo-auto.html (accessed 15 Apr. 2024)

55 State Revenue Service, *Vehicle Operation Tax*, https://www.vid.gov.lv/en/vehicle-operation-tax (accessed 15 Apr. 2024)

56 Portal des Dounaes et accises, *Taxes sur les véhicles routiers*, https://douanes.public.lu/fr/vehicules/taxe-vehicules-automoteurs.html (accessed 15 Apr. 2024)

57 Land Transport Directorate, *Annual Circulation license Fees,* https://www.transport.gov.mt/include/filestreaming.asp?fileid=5992 (accessed 15 Apr. 2024)

58 Netherlands Enterprise Agency, RVO, *Motor vehicle tax (mrb),* https://business.gov.nl/regulation/motor-vehicle-tax/#art:foreign-number-plate (accessed 15 Apr. 2024)

59 e-Portugal.gov.tp, *Pagar o Imposto Único de Circulação (IUC)*, https://eportugal.gov.pt/servicos/pagar-o-imposto-unico-de-circulacao-iuc- (accessed 15 Apr. 2024)

COUNTRY	ELEMENTS TO CALCULATE THE TAX
SPAIN[60] (REGION OF CATALONIA)	Either annual emission of CO2 gr/km 95gr/km > 140gr/km + tariff or type of vehicle (including hybrid vehicles) + type of fossil fuel + coefficients on: vehicle's cubic capacity, power of the vehicle, weight and age of the vehicle + tariff[61]
SWEDEN	Tariff + CO2 emissions + type of fuel[62]

Source: Table elaborated by the author based on the information duly indicated in the corresponding footnotes in each box.

taxes, not all countries use the same elements but do share two common ones. First, none of them integrate common pollutants from vehicles such as nitrogen oxides (NOx) or particulate matter (PM). Second, a common criterion in all of them is the way annual emissions of CO2 are measured. All of these taxes are based on the number of emissions stated in the vehicle's certificate of conformity (CoC).[63] The way to measure this follows some particular standards of emissions based either on the New European Driving Cycle (NEDC)[64] or the Worldwide Harmonized Light Vehicle Test Procedure (WLTP).[65] They are the mandatory tests that manufacturers must undergo as part of the European whole vehicle type approval system (WVTA).[66] The NECD test was a procedure used to measure vehicle CO2 emissions and fuel consumption. The WLTP test replaced the NEDC for vehicles approved for sale in Europe after September 2018. Comparing it to the NEDC, there are substantial changes in the test procedure to make it more precise and reliable regarding the measurement of CO2 emissions.[67]

5.2 *General Issues in the Taxation of Emissions for Annual Road and Motor Vehicle Taxes*

The main issue of the road and motor vehicle taxes described above is that the vehicle owners are not taxed on the actual amount of emissions but on the amounts stated in the vehicle's CoC. The key to any environmental taxes on emissions is the measurement of those emissions, i.e., the element causing environmental damage to be minimized.[68] However, the main problem with these taxes is that the measurement elements used to calculate their taxable bases and tax liabilities are not accurate. In the early 2000s, Herrera Molina noticed the difficulty of precisely measuring the emissions of pollutant gases and how this could lead to establishing alternative methods such as objective estimation or indirect estimation methods to determine the tax base.[69] The difficulty in controlling and monitoring actual pollutant emissions necessitated using alternative quantification methods such as relying on the unchanging amounts of the CoC.

Notes

[60] Spain's current annual motor vehicle tax does not contemplate the amount of emissions of the vehicle as part of the tax base or for calculating the tax rate (*see* Art. 95 of the *Real Decreto Legislativo 2/2004, de 5 de marzo, por el que se aprueba el texto refundido de la Ley Reguladora de las haciendas Locales*, BOE-A-2004-4214, 09 Mar. 2004). Therefore, this lack of regulation at the state level affords opportunities for creating new taxes on motor vehicles' emissions. This is what the Autonomous Community of Catalonia d*id.* Using its legislative powers, it enacted a new regional annual tax on carbon dioxide emissions from motor vehicles. (*SeeLlei 16/2017, de l' 1 d' agost, del canvi climàtic*, 7426 DOGC, CVE-DOGC-A-17213111-2017, 03 Aug. 2017.).

[61] *See* all the taxable base formulas and tax liability in Art. 43bis and Art. 44 of Law 16/2017 *supra* n. 60.

[62] Transport styrelsen, *Malus – for high emission vehicles,* https://www.transportstyrelsen.se/en/road/Vehicles/bonus-malus/malus/#:~:text=grams%20per%20kilometre.-,For%20vehicles%20that%20are%20put%20into%20use%20and%20become%20taxable,than%20125%20grams%20per%20kilometre (accessed 15 Apr. 2024)

[63] 'A certificate of conformity is a statement by the manufacturer that the vehicle conforms to EU type-approval requirements. EU countries cannot refuse to register vehicles if they are accompanied by a valid CoC that proves their compliance with EU law'. (European Commission, *Technical harmonisation in the EU*, https://single-market-economy.ec.europa.eu/sectors/automotive-industry/technical-harmonisation/technical-harmonisation-eu_en) (accessed 15 Apr. 2024)

[64] Commission Regulation (EC) No 692/2008 of 18 Jul. 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles concerning emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, OJ L 199, 679–707 (28 Jul. 2008).

[65] Commission Regulation (EU) 2017/1151 of 1 Jun. 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles concerning emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Commission Regulation (EC) No 692/2008, OJ L 199, 1–136 (28 Jul. 2008).

[66] Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC, OJ L 151, 1–218, (14 Jun. 2018).

[67] For practical and visual information about the changes and updates in the measurements of CO2 emissions between the NEDC and WLTP, *see* WLTP Facts, *From NEDC to WLTP: What will Change?,* https://www.wltpfacts.eu/from-nedc-to-wltp-change/ (accessed 15 Apr. 2024)

[68] European Commission, *supra* n. 45 at 10–11.

[69] Pedro Manuel Herrera Molina, *Derecho tributario ambiental* 74 (Marcial Pons 2000).

Although the measurement system during the test of the vehicles has become more accurate when comparing the NEDC system with the new WLTP procedure and criteria,[70] the critical point is that these measurements obtained during the tests are mainly an average assigned to each vehicle model. To be concise, when paying these annual road taxes that include the amount of CO2 emissions, taxpayers are being taxed based primarily on the model of the vehicle they own as based on the WPLT standard. There are no specific measurements of the amount of emissions that each vehicle releases into the atmosphere every time it is used, and this is the main problem. Taxpayers are not paying for the genuine amount but only an estimation

Even though the objective of an annual motor vehicle tax is to tax the ownership of the motorized vehicles that taxpayers use on public roads in order to keep them in good condition, the transport sector generates different externalities, among which are the effects of pollution caused by their emissions. However, such externalities, as the OECD's Working Group on Transport states, 'occur not at the point of purchase of the vehicle or even the fuel, but at the point of use'.[71] Consequently, adding CO2 emissions as one more element for calculating annual road/motor vehicle taxes in some Member States intends to internalize the external costs of pollution caused by using vehicles. However, the amount of CO2 emissions comes from the CoC of the vehicle assigned to each vehicle model based on the NEDC or WPLT test.

Thus, the main outcome of using these standards as elements of the tax base implies that drivers who do not use their car regularly ultimately pay the same amount of taxes as taxpayers who do. If the polluter pays principle is followed as the fundament to internalize such externality, owning a vehicle does not guarantee that it is used and pollutes.[72] Situations may arise in which the vehicle owner uses it on very few or limited occasions and, despite not polluting or polluting very little, must still pay the same annual road/ motor vehicle tax as the owner who uses the same vehicle model daily. This can lead to situations where the polluter pays principle is not applied accordingly to its purpose because those who pollute more are not paying more according to the level of negative externality that they are causing. Moreover, as highlighted in section 5.1, the annual road/ motor vehicle taxes do not include other externalities besides CO2 emissions. No NOx, PM, or any other pollutant gases are considered.

In the face of this situation, the questions that arise are: Do we have the technology to make precise measurements of the real emissions of each vehicle? Could other pollutant agents, such as NOx and PM, also be measured and included in the tax base? Could the methods that quantify the tax base and the tax liability be improved?[73] The IOT could provide a positive answer to all of these questions. Would it be feasible from a management perspective? The following section analyses these questions.

6 Proposals of improvement: Annual motor vehicles taxes in the light of the IOT

As explained in the section above, road or motor vehicle taxes have progressively incorporated the taxation of CO2 emissions by vehicles. However, they have several deficiencies that could be improved. These might occur with technology by using devices and sensors that monitor emissions and can collect, process, and exchange accurate data in real-time. Introducing those that monitor real-time CO2 emissions (and other pollutant particles and gasses) can also be used for tax purposes to improve the design of environmental taxes. This section aims to demonstrate how the annual road and motor vehicle taxes that contemplate CO2 emissions could be redesigned to align with the reality of the taxpayers who pay them while better meeting their environmental protection objective.

6.1 *The Taxable Event: Ownership Taxation v. Taxation of Actual Emissions*

The IOT can potentially enable completely redesigning the current environmental taxes on vehicles. Thus far, the taxable event of these was the ownership of the vehicle, and the way to calculate the taxable base included a fix standard amount of emissions. Now, due to the IOT, even though the taxable event can remain the same, i.e., the ownership of a pollutant vehicle, the taxable base could be calculated taking into account the actual amount of emissions emitted annually by that vehicle. Therefore, with this technology, the design of such environmental taxes could comply with what Herrera Molina insisted on more than twenty years ago: 'The

Notes

70 Additionally, it is important to take into account the new and updated criteria regarding the CO2 emission standards established by Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 Apr. 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011OJ L 111, 13–53, 25 Apr. 2019, and Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 Jun. 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC, OJ L 198, 202–240 (25 Jul. 2019).

71 OECD – Working Group on Transport, *The scope for CO2-based differentiation in motor vehicle taxes. In equilibrium and in the context of the current global recession, ENV/EPOC/WPNEP/T(2009)1/FINAL*, 11 (OECD 2009).

72 *See* Stefan Ambec & Lars Ehlers, *Regulation via the Polluter-pays Principle*, 126(593) The Econ. J. 884–906 (2016), doi: 10.1111/ecoj.12184 (accessed 15 Apr. 2024)

73 *See* Federica Pitrone, *Defining 'Environmental Taxes': Input from the Court of Justice of the European Union*, 69(1) Bull. Int'l Tax'n 62, 58–64 (2014), doi: 10.59403/3mz5s8t (accessed 15 Apr. 2024)

configuration of the environmental tax should be closely related to the origin of the pollution that one wishes to combat'.[74]

In a past scenario that did not contemplate the existence of technology such as the IOT, it was understandable to design a tax to be levied on the owners of polluting vehicles regardless of whether they used it. There was no method to accurately discern and monitor whether and how often they performed the negative externality of emitting pollutant gases and particles into the atmosphere. However, the possibility currently exists of introducing a vehicle pollution monitoring system that can detect and measure various types of pollutant gases with precisions on a real-time basis.[75] Consequently, with this, the design of annual road/motor vehicle taxes that aim to include a green element (i.e., the amount of emissions) could improve.

This suggestion adheres to the same approach that the European Commission intends to apply with the new EURO7 standards.[76] The proposal is to introduce on-board monitoring systems 'to monitor and control the emission behaviour of the vehicles continuously via an on-board monitoring (OBM) system {besides warning} the user to perform repairs of the engine or the pollution control systems when these are needed'[77] as the sensors installed in vehicles have already been able to do up to today. According to Article 3, point 38 of the proposal the OBM is a system capable of detecting emission exceedances by employing information stored in the vehicle and communicating it via the on-board diagnostic system (OBD) port and over a network. The OBD is a system connected to an engine capable of communicating engine information off-board.[78] However, this network of devices is also connected to another on-board system. The on-board fuel and energy consumption monitoring device (OBMFC) will monitor the parameters of the vehicle's energy and fuel consumption.[79]

The new OBM, OBS, and OBMFC are IOT devices. The OBM and the OBMFC systems installed in vehicles will be capable of registering the magnitude and duration of all emission exceedances as well as fuel and energy consumption and recording and communicate and notify the emissions data via the OBD.[80] Their sensors are intended to be programmed to monitor primarily the emissions of CO2, NOx, PM, and even ammonia (NH3) on a real-time basis and alert the driver when there is an anomaly (primarily an excess) in them.[81]

Accordingly, if it is possible to collect real-time data on the pollution caused by individual motor vehicles by utilizing sensors and devices connected to the Internet, they could alert the driver regarding the exceedance of the levels of emissions and maintain an accurate record. It could also be possible to monitor and record all of them and not only the exceedances. Automobile manufacturers could install these devices that would provide more than just detailed information to the driver; they could determine the exact number of times the vehicle is used and provide an accurate amount of CO2, NOx, PM, or NH3 emitted per journey on a yearly basis. This would enable moving from an annual road/motor vehicle tax with an environmental component based on the ownership of a particular type of vehicle to a tax on actual emissions.

6.2 *A More Realistic Calculation of the Tax Base*

The tax bases of the annual road/motor vehicle taxes described above in section 5.2 include the CO2 emissions per kilometre stated in the vehicle's official certificate issued by the manufacturer or importer.[82] As already explained, these official emission amounts are obtained from the standard methods of measurement established by the European regulations specifically carried out by the NEDC and the WLTP tests[83] and are expressed in grams per kilometre. Then, they are usually multiplied by a coefficient to derive at the tax liability. In all of the cases described above, the structures of the tax rates follow a progressive scale that begins from a minimum of emissions and reaching a marginal number. In most cases, the coefficients are applied to brackets of emissions either in grams[84] or, in other cases, the

Notes

74 Pedro Manuel Herrera Molina, *supra* n. 69, at. 54. (Translation made by the author of this article).

75 Some of them are indicated *supra* n. 40.

76 *See* European Commission, Proposal for a Regulation of the European Parliament and of the Council on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles concerning their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009, COM(2022) 586 final, 2022/0365 (COD), 10 Nov. 2022).

77 *See* Recital 15 of *ibid.*, at 19.

78 Article 3, point 49, of Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC L 151, 13, 1–204.

79 *See* Art. 3, point 39 of, *supra* n. 76.

80 *See* Art. 6.6 and Art. 6.7 of *supra* n. 76.

81 *See* Art. 1.1 and 1.2 of *supra* n. 76 and *also see* 10A Vicente Franco et al., *On-Board Monitoring of Emissions in the Future Euro 7 Standard*, SAE Technical Paper 2023–24-0111 (2023), Doi: 10.4271/2023-24-0111 (accessed 15 Apr. 2024)

82 *See supra* n. 63.

83 *See supra* n. 64 and 65.

84 *See supra* n. 47, 48, 50, 51, 52, 53, 54, 55, 57, 58, 59, 60, 61 and 62.

progressivity is more exacerbated by increasing the coefficient per gram emitted.[85] However, the way the emissions are calculated and, consequently, how this is accomplished for the annual road/motor vehicle taxes do not reflect the reality of the emissions of each taxpayer.

Endowed with sufficient software capacity, devices of the IOT could be able to store data each time the vehicle is used. This way, they could provide reliable and accurate total pollutant emissions during a fiscal year or at least an average of emissions per vehicle per kilometre. Following the same approach as the OBD and OBM systems regarding their cybersecurity systems[86] and anti-tampering measures,[87] avoiding manipulations of the pollution control systems could be plausible. Once the information is transmitted for storage, a blockchain mechanism could guarantee the validity of the data regarding each trip.[88]

With this information, there would not need to be an exhaustive revision of the current legislation since the same manners of calculating the taxes could still be valid with the same progressive coefficients, brackets, and scales. The only necessary legislative change would be the amount of pollutant emissions used. Instead of taking the current emissions stated in the CoC, it would be each vehicle owner's actual annual emissions. This way, each taxpayer would be subject to the taxable event for their actual measurements taking the same units of grams per kilometre.

Moreover, annual road/motor vehicle taxes that want to introduce this environmental tax element instead of focusing only on the CO2 emissions could extend the variable environmental tax element of their tax bases to other equally pollutant elements. Taking advantage of the Euro7 OBD's foreseen capacity to also monitor the real amount of NOx, PM, and even ammonia (NH3) emissions, all or some of these elements could be taken into account, and they could even dispense with the amount of actual CO2 emissions. These can be easily taxed with an excise carbon tax on fuels.[89] In cases when states apply such a carbon tax, it could lead to double taxation if they also tax the same amount of CO2 emissions as part of the annual road/motor vehicle taxes. For this reason, it would make more sense to apply the IOT to monitor the actual amount of NOx, PM, and NH3 emissions and include them in the annual road/motor vehicle taxes.

6.3.1 *Viable Tax Management: Singapore's ERP 2.0 System as an Example*

While redesigning the taxable event, the tax base, and the calculation of the liability is relatively easy to carry out, tax management becomes a more complex question. If an IOT device is used, the data collected would be stored in a database located in an external server (cloud) to which the vehicle owner would have access. This already presents two different questions. How would the data be transmitted for its analysis and storage? Who would be entitled to access those data?

As foreseen for the OBD system, the devices can transmit information via the OBD port and over a network[90] which entails that wireless technology will play an important role. However, suppose a step further is required, and the OBD aims to store all of the data regarding a car's emissions for tax purposes. In that case, it requires robust and reliable connectivity between the IOT device and the data receptor. A potential solution is to store it in the integrated software in the vehicle and ensure at least one backup for the database.[91] However, the most difficult question is whether it is plausible to grant connectivity with a remote server (cloud) which would be the company providing this service to store and process the data. The most logical answer is the entity responsible for installing the IOT device, yet it would all depend on what is best to ensure good operability. As a comparative example regarding the management of an OBD system, there is the already designed and about to implemented Singaporean Land Transport Authority (LTA) On-Board Units (OBU) for the Next-Generation Electronic Road Pricing (ERP) System.[92]

Singapore implemented the first ever congestion charge[93] primarily aiming to reduce the number of private vehicles accessing certain city areas as traffic congestion

Notes

85 This is the case in Finland and Luxembourg. *See supra* n. 49 and 56.

86 *See supra* n. 80, Art. 4.9, at 28 and UN Regulation No 155, Uniform provisions concerning the approval of vehicles regarding cybersecurity and cybersecurity management system OJ L 82, 30–59 (9 Mar. 2021).

87 *See* Recital 15 and Art. 7.2 in *supra* n. 80, at 19 and 31.

88 Blockchain technology has been extensively tested, especially in the area of customs, to guarantee the fidelity of the gathered data and be able to impede tampering with it. For example, *see* Yotaro Okazaki, *Unveiling the Potential of Blockchain for Customs*, 45 WCO Research Paper Jun. 2018, https://www.wcoomd.org/-/media/wco/public/global/pdf/topics/research/research-paper-series/45_yotaro_okazaki_unveiling_the_potential_of_blockchain_for_customs.pdf (accessed 15 Apr. 2024)

89 Alice Pirlot, *Section 95 and Schedule 12: Carbon Emissions Tax; Section 96: Charge for Allocating Allowances under Emissions Reduction Trading Scheme*, 4 Brit. Tax Rev. 491, at 490–497 (2020).

90 *See supra* n. 80 and the EU Regulation of *supra* n. 82.

91 ACKO, *Connected Cars: What is it? Features and Benefits* (22 Sep. 2020), https://www.acko.com/car-guide/connected-cars-features-benefits/#:~:text=Usually%2C%20such%20vehicles%20connect%20to,with%20any%20external%20device%2Fservices (accessed 15 Apr. 2024)

92 *See* Land Transport Authority, *Joint News Release by the Land Transport Authority (LTA), NCS Pte Ltd & MHI Asia Pacific Pte Ltd – Installation of On-Board Units for Next-Generation ERP System Delayed to 2023 Due to Global Microchip Shortage* (17 Nov. 2021), https://www.lta.gov.sg/content/ltagov/en/newsroom/2021/11/news-releases/installation-of-obu-for-next-generation-erp-system-delayed.html (accessed 15 Apr. 2024)

93 *See* Peter L. Watson & Edward P. Holland. *Congestion Pricing-The Example of Singapore*, 42(248) Ekistics 14–18 (1976).

was slowly underpinning Singapore's economic welfare.[94] The congestion charge scheme evolved due to technology,[95] and the latter has also been the reason for replacing the current congestion charge system, known as the ERP system, with a next-generation ERP system supported by the Global Navigation Satellite System (GNSS) technology.[96] Since 2021, progressively, all vehicles in Singapore have had to install the new OBUs and, as the LTA states, 'central to the new system is a new vehicle on-board unit (OBU), which can provide value-added services for motorists, such as advance alerts on charging locations and real-time traffic information'.[97] This new system is ultimately coordinated and managed by a central computer system (CCS) that receives and transmits information from and to the vehicle units.[98] The GNSS-based ERP was designed and developed by Mitsubishi Heavy Industries, Ltd (MHI), its subsidiaries, and NCS Pte Ltd, a wholly-owned company of the Singtel Group.[99] However, the companies had to deliver the project to the LTA of Singapore that manages the data collected from users by the next-generation ERP.

Furthermore, the LTA guarantees that they 'will only use anonymised or aggregated data for traffic management and transport planning purposes. Vehicle-specific data will be used only for payment, charges and enforcement, such as against non-payment of ERP charges'.[100] In the same manner as the European OBD system, Singapore's LTA will implement a robust security system to avoid unauthorized access and improper use of the data.[101]

In summary, although the providers for the entire service and its connectivity are the companies awarded the project, the congestion charge's data management belongs to the competent authority, i.e., the LTA. In the case of the potential use of the European OBD for environmental tax purposes, there is no need for such a complex and interconnected system. Nevertheless, competent tax authorities should grant easy access to the data, and several options exist.

If the annual road/motor vehicle tax is designed to be declared in a self-assessment mode, then access to the data by the tax authorities would only be needed in the event of its revision. On the contrary, if the tax is designed in settlement mode, either the introduction of an annual information obligation by the taxpayer or by the company managing the database or direct access by the tax authorities to this database located in a cloud would be necessary. Even though the first option is less complex, easy access to the information should be necessary in both cases. This means transmitting the information in a standardized file format from the vehicle's internal software to the taxpayer or the competent tax authorities is necessary. The easiest way is via the Bluetooth connection between the automobile and a smartphone, but then taxpayers must rely on the latter. How to provide this connection reliably and securely so that the information is not manipulated is the most complex part that necessitates a critical, separate study.

7 Conclusions

The overarching objective of this study has been to analyse whether the IOT could be used for taxation purposes, more specifically for environmental tax purposes, to achieve an enhanced level of respect for the polluter pays principle. For this reason, the study intended to not only answer the question from a general perspective but also to materialize the application of this technology through an empirical case study on the application of the IOT on a particular type of tax, i.e., annual road and motor vehicle taxes. The main conclusions are:

FIRST – The capacity of the IOT to monitor the real amount of emissions besides CO2 could help eliminate the taxation of those from annual/motor vehicle taxes and focus the environmental element on other pollutant agents. With the proper programming, these new OBM devices and systems could record all of the indicated emissions in real-time. By maintaining an accurate record of the number of times the vehicle is used and the amount of pollutant emissions (either NOx, PM, or NO3) emitted per journey, this information could be used for taxation purposes to end the design of annual road/motor vehicle taxes based on ownership. Furthermore, if a state already

Notes

[94] This was announced by the Singaporean newspaper *The Strait Times. See* Newspaper SG, *Traffic jams: Govt gets tough*, The Straits Times 6 (17 May 1975).https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19750517-1.2.28 (accessed 15 Apr. 2024)

[95] *See* Sock-Yong Phang & Rex S. Toh, *Road Congestion Pricing in Singapore: 1975–2003*, 43(2) Transportation J. 16–25 (2004).

[96] Land Transportation Authority, *ERP 2.0 On-Board Unit Installation Extended to New Vehicles and Existing Motorcycles from 1 May 2024,* News Releases (28 Mar. 2024) https://www.lta.gov.sg/content/ltagov/en/newsroom/2024/3/news-releases/on-board_unit_installation_extended.html (accessed 15 Apr. 2024)

[97] *Supra* n. 96. Indeed, due to these smart devices that will monitor the vehicle in real-time in addition to being used to pay for the corresponding trips, they will also provide drivers with real-time information on road traffic conditions. They will also be able to warn the driver when entering areas requiring special attention such as when schools or silver zones (reduced speed zones) are nearby. Moreover, they will incorporate a system to manage payments for public parking and therefore replace the analogue system of paper tickets and receipts.

[98] *See* 6A Ryota Hiura et al., *System Evaluation Test of Global Navigation Satellite System-Based Road Pricing System*, 50(4) Mitsubishi Heavy Indus. Tech. Rev. 17, at 15–21 (2013) *See* 5A Hidekazu Ohno, Tohru Suzuki et al, *Development of the Next Generation Road Pricing System with GPS Technology* 44(2) Mitsubishi Heavy Indus. Tech. Rev. 1–5 (2007).

[99] *See* MHI, MHI and NCS Win Singapore's Next-generation Electronic Road Pricing System Project (MHI 9 Mar. 2016), https://www.mhi.com/news/1603091964.html (accessed 15 Apr. 2024)

[100] *See* Land Transport Authority, *Oral Reply by Senior Minister of State for Transport Dr Amy Khor to Parliamentary Question on ERP 2.0* (6 Nov. 2023), https://www.mot.gov.sg/news/details/oral-reply-by-senior-minister-of-state-for-transport-dr-amy-khor-to-parliamentary-question-on-erp-2.0 (accessed 15 Apr. 2024)

[101] *Supra* n. 95.

taxed the exact amounts of CO_2 emissions through an excise carbon tax on fuels, it would not be necessary to include that as part of the tax base of annual road/motor vehicle taxes thereby avoiding potential double taxation.

SECOND – The IOT could change how current environmental taxes are conceived and designed. It would allow changing the way the tax base and the tax liability are calculated. Such technology could help comply with the true purpose of an environmental tax, i.e., to tax the source of pollution. Therefore, it would allow to effectively tax each taxpayer according to the total amount of pollutant emissions emitted on an annual basis. The IOT could make environmental taxes much fairer and more respectful of the pollutant pays principle.

THIRD – Implementing the IOT for tax purposes is still in its infancy and does not have an overabundance of practical references due to its novelty and lack of regulation for taxation purposes. Besides using it for environmental tax purposes, there are a plethora of scenarios and possibilities to apply it within the taxation field, and many questions still to be answered and worth studying. Could its capacity to monitor any analogical data in real-time be used to limit (or even terminate) the application of objective estimation methods or indirect estimation methods for calculating the taxable base of personal and/or corporate income tax? Could the IOT alone or with other technology, such as blockchain, help solve VAT and customs issues related to traceability or missing trader fraud? Can the data gathered by such devices be used as a proving element for tax procedures? If so, what would be the impact on taxpayer rights? These questions indicate that it is a technology worth studying for tax purposes, thus, researchers, policymakers, and governmental bodies should consider it more seriously. It is necessary to begin having clear policies and regulations on the limits regarding its use and implementation for this within the EU.