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Economics For Environmental Management: A Practical Approach Towards Circular Economy

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Master in Economics

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Resumo

Economia Circular tem o potencial de ser uma solução para os atuais problemas ambientais, ao incorporar materiais e produtos finais que podem ser reutilizados e/ou reciclados. Porém, o atual mercado não é capaz de alcançar esta solução por si mesmo, requerendo intervenção do estado e/ou governo. Este estudo recolhe algumas das políticas mais recomendadas na literatura atual, que vão desde ajudar a divulgar informação clara sobre a economia circular, promover colaborações entre empresas, ou até implementação de leis. Mudanças no mercado também podem ser causadas usando políticas fiscais e financeiras, tais como aumentar taxas indiretas aos desperdícios e poluição, aumentar taxas diretas a produções lineares não otimizadas, fornecer incentivos positivos a empresas que tentem transformar a sua produção num sistema circular. Todavia, para implementar estas políticas, é necessário adaptá-las a cada ponto específico na cadeia de produção, considerar propriedades/diversidade das empresas locais, e as possíveis respostas comportamentais dos agentes face aos incentivos. Esta dissertação também demonstra como usar os básicos da economia para tentar quantificar, no geral, quanto deve ser o valor do incentivo ou taxa, para que o mercado mude em favor da Economia Circular. Modelos econométricos com dados reais provam que seja incentivos ou taxas são ferramentas de intervenção governamental que significativamente promovem o desenvolvimento sustentável. Não obstante, Economia Circular também tem os seus limites e riscos, por isso é pertinente calcular o seu custo de implementação para determinar se realmente é a solução correta para cada situação em específico.

Palavras-chave: Economia Circular, meio ambiente, taxas, incentivos, políticas governamentais, comportamento dos agentes económicos.

Códigos da classificação JEL:

C19: Métodos Econométricos e Estatísticos: Outro

D04: Política Microeconómica: Formulação, Implementação, e Avaliação

H32: Políticas Fiscais e Comportamento de Agentes Económicos: Empresas

Abstract

Circular Economy has the potential of being a solution to face current environmental problems, by incorporating reusage and recycling of production materials and/or the final product. However, the current markets seem unable to fully tap into this type of solution on their own, requiring state and/or governmental intervention. This study gathers some of the most recommended policies from current literature, which range from helping to disseminate clear information about Circular Economy, promoting collaborations between firms, to the implementation of stricter laws. Shifts in the market may also be done by financial and fiscal policy means, such as increasing indirect taxes for wastes and pollution, increasing taxes on unoptimized linear production methods, granting positive incentives to firms trying to turn their production into a circular system. Nevertheless, to implement these policies, it is crucial to consider adapting them at each specific point of the production chain, considering the local firm properties/diversity, and how agents behave in response to such incentives. This dissertation also demonstrates how to use basic economics, to attempt a general quantification of how much an incentive or tax should be, as to support a market shift towards Circular Economy. Econometric models using real data prove that both incentives and taxes are significant governmental intervention tools that improve development towards sustainability. Nonetheless, Circular Economy also has limits and risks, therefore, assessing the costs of implementing it is crucial for determining if it is the correct solution for each specific situation.

Keywords: Circular Economy, environment, taxes, incentives, governmental policy, behavior of economic agents.

Codes from the JEL classification:

C19: Econometric and Statistical Methods: Other

D04: Microeconomic Policy: Formulation, Implementation, and Evaluation

H32: Fiscal Policies and Behavior of Economic Agents: Firm

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1. Introduction

At the time this study was started, the economic consequences of the Covid19 pandemic crisis were a new focus of investigation, as this was an unprecedented type of crisis which decreased or fully stopped production and trade procedures, in order to protect public health. During 2022 however, the conflict between Russian and the Ukraine, to which the United Nations responded with sanctions towards Russia, making an embargo towards Russian oil/natural gas, eventually caused an increase on the prices of transports, and consequently general inflation significantly rose. Therefore, both crises had considerable economic consequences. To measure such impacts and seek solutions to the problems they originated might have taken the spotlight in many economical regards, and while they are indeed important, by no means do these new problems invalidate prior issues. The environmental conditions of the planet we currently live in remain a crucial matter that can not be ignored without posing major risks and consequences to humanity, or even to all life on planet Earth.

Many environmental sustainability goals are yet to be reached, and economic growth is still being tuned so that it can be achieved without dire consequences for the world and future generations, if not for current generations as well, which witness increasing natural disasters and other unnatural phenomena. Therefore, this study intends to propose the implementation of circular economy methods, as a means to better coordinate economic growth with sustainable development, rather than having one originated at the cost of the other. Governmental incentive policies and their effects on firm behavior and development shall be taken into account, as practical tools for environmental management in an attempt to make production methods of goods to be circular rather than linear. Thus allows, improving efficiency of used resources, decreasing unnecessary wasters, and reducing the dependency on raw materials that may be running scarce or damaging the environment. In this line of thought, circular economy may also be a way to make firms less dependent on imports of raw materials or other products required in production chains. In order words, it has the potential to promote sustainability, while simultaneously mitigating impacts from shocks such as the freezing of supplier activities caused by the pandemic, and the increased transports cost given the rising prices of oil.

It is important to note however, that in no moment are these arguments promoting or supporting that governments should intervene in the markets. These are measures that, if not properly taken, have a high risk of causing market inefficiencies, and by no means is this study intended to make any kind of political statement, as state intervention is a highly debatable subject. Rather, the goal is to inform of possible solutions, their requirements and even limitations. In other words, if governments choose to promote circular economy as a means of environmental management, or are debating/considering such measures, then they may find relevant information, evidence, and suggestions in this piece of literature, in order to hopefully improve the efficiency of implementing such policies.

The research question can now be pertinently presented as: *"How to enhance government intervention, decreasing wastes and improving firm resource efficiency?"* The goal is rather to provide tools, strategies and methodologies that may assist governments or other entities in their decision-making, in implementing circular economy as an efficient sustainability solution. For this purpose, contributions from three fields of study will be taken into account, namely microeconomics theories and modeling, econometric models and their tests for statistical validity, and the contributions of empirical evidence from behavioral economics.

Microeconomic models should provide insight on quantification and theoretical effects of governmental intervention tools, such as the implementation of higher/lower taxes towards target firms and providing subsidies and other beneficial financial incentives that may motivate firms into shifting to circular economy production systems. These theories should, then, be tested, via construction of related econometric models, which may then verify/reject the statistical significance of how variables such as taxes and incentive can influence sustainable development, using real data to validate/deny the theory. Finally, the statistical and theoretical conclusions shall be complemented by the human behavior properties under the influence of state "paternalism", as much as it may be drawn as an analogy towards firm behavior, as to explain possible discrepancies between the expected theoretical effects, and the effects revealed by the real data.

With the combined contributions of each of these fields of study, it will be sought to arrive at practical answers to "what kind of" policies should be used, by "how much" should firms be taxed and/or granted incentives to promote sustainable change, and "when" are these solutions applicable. With these models, this study grants information and tools that governmental entities may require to make efficient decisions, as well as display findings and methods that contribute to the current knowledge of circular economy and applicability of taxes/incentives to promote it.

2. Literature Review

2.1. Circular Economy

Circular Economy is a concept that proposes alternatives to the traditional linear material usage pattern, in which firms would overall extract materials, make their production, which would then be consumed and thrown away after usage. By overturning this system, it can be transformed into a more resource efficient, sustainable and circular process (Andrews 2015; Lieder and Rashid 2016).

This alternative concept seeks to achieve a more sustainable form of development, reducing environmental shocks, impacts and pressures. To reach such goals, circular economy uses methods to decrease natural resource scarcity, wastes, costs and even the price volatility of raw materials, which would in turn, result in the creation of more sustainable business models (Kalmykova et al., 2018). These ideas are very connected with the well-known concepts of reduction, reuse, (remanufacture) and recycling. (OECD, 2017)

However, some authors would disagree with this form of environmental solutions. For instance, Murray et al. (2017) argues that sustainability considers 3 main aspects: economic, environmental and social. In such regards, circular economy shows no clear signs of integrating social equality. Furthermore, the simplicity and focus of its objectives may prove to have unintentional negative environmental consequences, such as deforestation or increase of toxic gas emissions.

Following in line with such objections, Kirchherr et al. (2017) highlights that correlation between circular economy and sustainable development is rather weak. While other reasonings are not ruled out, this weak correlation could indeed be explained by the diverging objectives/ considered aspects of the two distinguishable concepts (Murray et al., 2017).

Sustainability and circular economy are two concepts which are used both in different contexts and purposes. Nonetheless they share several concerns in terms of industrial production, consumption and level of technology (Geissdoerfer et al., 2016). As such, the focus of circular economy and methods of maximizing material value usage, can still be a sustainable concept or condition which allows society to progress into a better economy that would not aggravate the environment, but rather improve it by solving several current environmental problems (Geissdoerfer et al., 2017; Almeida, 2020).

The results of two Data Envelopment Analysis (DEA) studies regarding the dynamic regional evaluation of circular economy efficiency in China (Wu et al., 2014; Fan and Fang, 2020), reveal that, in response to implemented policies, there are significant differences in the level of development of circular economy between the studied regions. And while those policies have promoted an overall positive effect, the regional differences in efficiency also vary on the type of system that is being studied. The variety of these results could prove to be another possible reason, in terms of stability and consistency, on why different studies present opposing deductions regarding the correlation between promoting circular economy and achieving sustainability goals.

2.2. Regenerative Sustainability

Regenerative sustainability is yet another concept, that also considers aspects such as renewable materials, technology and energy efficiency, in order to develop a self-regeneration ecological society (Cole, 2012; Brown et al., 2018), which increases the scope of analysis, and takes into account the built environment as a whole, as to avoid solving a threat by shifting the problem towards another environmental impact (Reed, 2007). In order words, changing the existing mindset to a more transformative and adaptive process, capable of regenerating/restoring a "green" socio-ecological system and maintaining it in a healthy and sustainable manner (Haselsteiner et al., 2021).

Lyle (1994) created a "collaborative interdisciplinary design process" model for the architecture and construction industry. The theory worked around the idea of managing daily life resources, such as water, food and waste, keeping them in a regenerative cyclical process of energy and materials, building an eco-cycle capable of regenerating and restoring its resources, allowing for a continuous and sustained constructed environment.

This model Lyle (1994) proposed is a "regenerative cycle", aimed at serving as an alternative to the linear and "degenerative" input-output models.

Similarities can be drawn from the ideas/goals behind the "regenerative cycle model" (Lyle, 1994), and how circular economy seeks to change production methods. Therefore, we can argue that regenerative sustainability is a broader development of circular economy, or at least, it has several similarities and shared conceptual pillars.

"Regenerative programs" seem to have broader goals, which consider inclusion or even social fairness, when compared to the "Green" indicators and objectives, these latter indicators/objectives seemingly being more functional, setting for example, clear public health priorities or equality standards (Haselsteiner et al., 2021). Given the similarities with circular economy, then this could serve as a counterargument towards some of the concerns raised by Murray et al. (2017), regarding the exclusion of social equality. While the difference in concepts remain, regenerative programs are an example of how circular economy can still be aligned with and used for sustainability goals.

While the study conducted by Haselsteiner et al. (2021) was focused on the construction and building industry, some of the main barriers found, that proved to be obstacles towards the implementation of regenerative sustainability in this sector, could also be pertinent to considered in most other sectors: increased costs for implementing and maintaining regenerative principles; lack of employees' or companies' knowledge and experience in these methodologies; lack of legally required standards.

2.3. Industrial Symbiosis

After considering a broader scope to which circular economy could be taken towards, now it would also be pertinent to overview industrial symbiosis, which can be considered as one of the key components of circular economy, focusing on production and firm synergies. The circular economy, however, also takes into account the extraction of raw materials, the consumption and post consumption of products/goods, thus making industrial symbiosis one of its subcategories, on the area of production (Ghisellini et al., 2016).

This concept originated as the idea of creating interdependencies between organizations, in order to share common or complementary infrastructures and exchange by-products, as to improve material/resources and energy efficiency of the involved firms. Symbiosis is a term borrowed from biology by Frosch and Gallopoulos (1989), as a metaphor to describe this kind of industrial strategy.

With this kind of synergies, companies are capable of reducing their costs, and even their environmental impacts, as not only do they share facilities, maximizing the usage of energy, water and resources, as well as their wastes can still be used as inputs by their symbiotic partner(s) (Petrikova et al., 2016).

However, there is a difference between industrial symbiosis and ecology. Industrial ecology also accounts for industrial metabolism, eco-systems, as well as environmental regulations, with the objective to achieve sustainable closed-loop systems. Industrial symbiosis can only be considered as a method or tool to achieve these ecological goals, by creating synergies that exchange wastes (Li, 2018). Nevertheless, circular economy engulfs many of these aspects, and can assist these systems in gaining the attention, business and even policies needed to achieve such transitions and synergies through industrial symbiosis and ecology (Ellen MacArthur Foundation, 2013).

One of the most prevalent barriers to the application of industrial symbiosis is the existing knowledge gap of stakeholders, as providing information about methods, technology and opportunities for re-usability seem to generate positive investment and initiative (Lybaek et al., 2020).

This coincides with some of the recommended measures to adjust human behavior biases (including households), to improve their waste management and resource efficiency: simplification of information regarding recycling; feedback mechanisms; and delivery of proper information regarding products lifespan (OECD, 2017).

Furthermore, establishing a platform of communication or other similar methods of approaching firms, in order for them to exchange information, could also serve as a means to promote such synergies. This solution not only fixes issues in asymmetrical information between sellers/suppliers and buyers, but it also seems to foster collaboration between companies, and thus functions as a possible driver to developing industrial symbiosis (Lybaek et al., 2020). The industrial symbiosis case study of Dutch recycled concrete aggregates (Yu et al., 2021) arrived at a similar suggestion, that policymakers could try to establish a regulated platform for information sharing between companies, which would allow to develop their business towards collaboration.

2.4. Supply Chain Management

As previously stated, circular economy considers the whole industrial system from the extraction of raw materials to the production methods, and then consumption (and post consumption) of products (Ghisellini et al., 2016). Many studies have included analysis regarding the supply chains of an organization, or between organizations. However, these have developed in complexity, in such a way that they were divided by criteria, and can be classified according to their level of integration, type of process (Lejeune and Yakova, 2005) and structures involved (de Kok et al., 2018).

The complexity of supply chains can be attributed, not only to how they specifically operate and their environment, but also to chain reactions (any change applied in one area might have side effects in related areas). Agents involved in supply chain roles also tend to adapt, in order to increase gains over time, considering that these gains depend on the decision of other agents (Braz and Mello, 2021).

Following this issue, buyer and supplier relationship dynamics may be lacking in empirical evidence, when considering the implementations of circular economy in products and supply chains, which result in yet another obstacle to the application of these complex circular systems (Braz and Mello, 2021).

To circumvent such issues, firms can opt to gather and manage wastes, treating their customers as suppliers, as well. That is, by making waste treatment offers, firms will collect post consumption products/supplies at no cost, or even be paid a commission for their collection service. This proves to be a more efficient solution, that does not trigger complex chain effects in production systems (a collaboration between customer and sourcing strategies). However, despite the prior referred complexity of supply chains, the application of policies and managers decisions can still promote positive reactions at starting points of chains, such as raw material extraction and their usage. This field still seems to have room for improvements, and such policies appear to be more efficient when each incentive is adapted based on the situation and on the involved agent's roles/positions in the chain (Braz and Mello, 2021).

A study utilizing an evolution game theory made by Cao et al. (2021) seems to arrive at a complementary conclusion. According to them, there is room for remanufacturing and other supply chain management improvements, though, economic growth and potential for development towards circular economy is more prevalent in developing countries such as China and Brazil, both regarding economic and environmental aspects. However, to push their development towards an environmentally sustainable path, policies and state intervention are required. Market maturity, capacity and development level may be factors that affect which kind of policy is pertinent. This complements Braz and Mellos (2021) findings, as their customer and sourcing strategies solution was more successful in Brazil case studies, where there were not many other firms competing with the same strategy, or at least collecting the same reusable materials.

Additionally, Cao et al. (2021) found that other possible barriers to the applications of remanufacturing strategies, and subsequently, circular economy in supply chains, could be the level of complexity of such methods, which agents of certain areas in the supply chain may not have expertise with. Furthermore, another issue could be the lack of customer awareness, leading to lower demand towards remanufactured products. We can see that the former barrier is a similar problem to the lack of experience/knowledge pointed out by Haselsteiner et al. (2021), in regenerative systems; while the latter is an issue also faced by industrial symbiosis goods and services, to which Lybaek et al. (2020) would suggest governments and policy programs to promote and use them, to push the market demand forward.

Complementary to these conclusions, Fan and Fang (2020) perceives cooperation between firms as a significant factor for establishing regional circular economy chains, and that this cooperation between companies can be promoted by sharing information regarding circular economy. Other forms they suggest for reaching this cooperation would involve changes in both regulations and laws of China, as a means to defend environmental standards, proper regional resources usage and patent rights. However, spreading information to the general public, rather than just to firms, can also better inform households, and thus assist in changing the market for the most environmentally friendly and sustainable circular economy methods.

2.5. Determinants For Sustainable Supply Chain Management

Taking a different approach, the theory of planned behavior is one of the most used theoretical frameworks in order to predict the firm's willingness to change towards circular economy. It consisted in taking into account the impact of personal determinants, most noticeably attitude, norms and perceived behavioral control (Ajzen, 2013, 1991). The extensive form of the theory of planned behavior has been applied in multiple studies, analyzing the human behavior in contexts such as waste management and sustainability plans. However, most of the previously referred studies did not account for the possibility of firms/organizations having their very own pro-environmental values (Khan et al., 2020, 2019).

Several studies indicate that the adaptations of firms and organizations, regarding circular economy, green supply chains and general sustained development seem to be affected by: social and institutional pressures (Jain et al., 2020; Zhu and Sarkis, 2007); environmental commitment and other inner organizational capabilities (Montalvo, 2003); and governmental regulations and incentives (Sangle, 2010).

Centobelli et al. (2021), applying an extended theory of planned behavior, conducted a study using small and medium enterprises data, considering both the effects from personal determinants and organizational determinants to predict firm's willingness to advance into circular economy.

The organizational determinants considered by the Centobelli et al. (2021) study were:

1) Social pressure - how the organization perceives what other actors, such as government, customers and partners think or believe should be the correct actions for the firm in question. It can be caused by community demand, market demands, financial and/or regulatory institutions;

2) Environmental commitment - company's inner and intrinsic values regarding the protection of the environment, and their awareness in terms of sustainable development. The consciousness present during production, as well as executing it in an environmentally responsible process. Recycling resources;

3) Green economy incentives - state intervention that allow firms to achieve positive results, which otherwise could not be present, given the existing alternative costs. They consider benefits such as direct subsidies, tax benefits, or even allowing cheaper prices/lower costs for recycled raw materials.

Once more, we find a similarity to yet another measure promoted by the OECD (2017), which imply that paternalism or behavioral intervention on social conduct should consider "Social Norms". This is related with how individuals perceive what they should or not do, which is influenced by what they believe other citizens do, and what kind of conduct rules everyone expects the other person to follow, if they wish to be respected in the society. This can also be interpreted as social pressure.

Returning to Centobelli et al. (2021), rather than analyzing the direct impact of these 3 variables in the circular economy capability or willingness of firms, the "supply chain relationship management" together with the "sustainable supply chain design" were created as interconnecting variables. The study itself proves that positive changes in either supply chain relationship management and/or the sustainable supply chain design, result in an increase of the circular economy capability. In other words, confirming that improvements in management or designing changes towards sustainability both promote the application of circular economy.

In turn, all 3 of the organizational determinants are also proven to have positive results in either supply chain relationship management or the sustainable supply chain design changes. This reasoning implies that their ability to positively influence the circular economy capability holds true (Centobelli et al., 2021).

Furthermore, not only does social pressure positively influence both utilized supply chain variables, but it is also demonstrated that it increases the application of green economic incentives, and directly promotes the environmental commitment and consciousness of organizations. Although, social pressure seems to have a stronger effect on green economic incentives (Centobelli et al., 2021).

The proposition that social pressure would positively influence firms' environmental consciousness are corroborated by Braz and Mello (2021) findings, which indicate that agents, and their adaptive behavior, seem to be the key pieces to influencing internal mechanisms, inner and outer environments of supply chains. Given that these agents are human beings, their behavior may be subjected to the social norms/pressure. Hence, we can logically conclude that these social pressures, along the supply chains, are the ones that impact firms' intrinsic values.

Finally, the existence or increase of green economic incentives also appear to create a better degree of environmental commitment (Centobelli et al., 2021).

Braz and Mello (2021) would agree that taxes and regulations affect the firm's environment. However, their studies also pointed out that such incentives and norms would also affect stakeholders' decisions. If stakeholders are considered to be part of those responsible for applying social pressure on organizations, then, while not objecting to Centobelli et al. (2021) conclusions, it would imply that green economic incentives also affect social pressure, meaning that both of these variables would be correlated.

Nonetheless, one question could be raised on these findings - are firms really behaving with higher morality/commitment because such incentives increased their awareness?

2.6. Incentives, Policies, Regulations and Effects

Behavioral economics would demonstrate that paternalism and incentives can actually have controversial results, by triggering behavioral reactions in economic agents, that were different from that is rationally expected. Gneezy and Rustichini (2000) conducted an empirical study on children's daycares. In an attempt to decrease parents delays at picking up their children after the daycares' closing hours, a fine was issued to those who arrived late, increasing it the longer the delay was. As this incurred an additional cost, it would be expected that parents would show up in time more often, as to avoid that extra cost. Results proved otherwise, the frequency of delays in the tested daycares remained almost the same as that of the control daycares that were not subject to this fine. When the fine was removed however, the tested and control groups diverged. The groups who had been exposed to a fine, now presented worse behavior/more frequent delays after the measure was removed. This demonstrated how individuals had intrinsic values, and were influenced by a social norm of respect for the rules/pick up time, before the incentive was applied. Regardless, given the way the fine was inserted, it took away such social norms and turned it into a more cost-benefit analysis. While the cost would in fact incentivize parents to arrive on time, they no longer felt morally obliged to do so, which is why the overall effects were controversial.

Given that companies are considered to have their own moral values, that result in their environmental commitments intrinsically, then an analogy from Gneezy and Rustichini (2000) behavioral findings can be drawn. If the incentive, tax or policy is implemented in an incorrect manner, it may make firms lose their moral consciousness, rather than further developing it, as they could end up shifting to a more traditional cost-benefit maximization. In other words, despite Centobelli et al. (2021) results, state intervention could risk having controversial results as well, in case it substitutes companies' intrinsic environmental concerns, by turning them into just another one of their costs. Green economy incentives could have a positive influence towards circular economy. Nonetheless, if the social pressure/ firms' commitment decrease as a consequence of the previous incentive, then the overall effect can be negative instead.

An example of another undesirable type of trade-off is given by Simon (2019). According to this author, policies for promoting circular economy in Germany ended up reducing the number of produced refillable and reusable plastic bottles, which were already products that allowed a circular environment.

Considering other contributions from more mathematically economic studies. Firms will react preemptively to an expected application of subsidies or their retraction, or to a legally limiting measure, if the cost of changing production before that measure is lower than the profit they may get from the policy had they invested beforehand. Or, alternatively, if the former cost is lower than the expected cost of adapting to the retraction/restriction measure afterwards (Weerdt et al., 2021).

Lack of financial incentives were viewed by construction firms as being barriers, rather than seeing incentives as drivers for regenerative sustainability. This would imply that, in this specific sector, the implementation of regenerative principles is sooner a needed requirement, instead of an incentive towards change (Haselsteiner et al., 2021).

In terms of plastics, despite the most recent evolution of prices, like the increase in raw material transport costs due to the pandemic, and the fluctuations of oil prices, the cost gap between raw and recycled plastic fibers seems to have shortened. However, this cost gap is still too significant. As such, large scale organization changes can only occur with support from government incentives or triggered by regulation policies. Further supporting this deduction, is the fact that some types of recycled plastic do not have the same level of quality stability as their counter parts made of raw resources, which is another spectrum of uncertainty that producers may prefer to avoid (Weerdt et al., 2021). Certain plastic polymers may get contaminated by other impure plastic wastes, making them unsuitable to be used as they may contaminated the remaining plastics, and the final product does not reach required minimum quality standards, which explains why many firms / industries may heavily prefer to use quality raw materials, instead of the circular options of recycled plastics. This unstable quality of plastics can be viewed as an operational risk for firms (Simon, 2019).

The Yu et al. (2021) agent and cost base model, also proved that, in order to promote industrial symbiosis in the concrete industry, it is necessary to have strict classifications of wastes and defined regulations regarding their purity. Subsidies should also be provided in order to innovate technology and make the circular business model more viable, when compared to its alternative.

Lybaek et al. (2020) on the other hand, found that industrial symbiosis is indirectly affected by other policies, sometimes not even intended to it. Indirect policies, such as applying considerable taxes on waste incineration, providing benefits to good waste management, as well as penalizing bad waste management practices done by organizations, were the most influential policies. While indirect incentives seemed to be more effective, it is highlighted the potential of direct incentives, benefits and support, however, rather than applying such measures exclusively to top-down management, the authors recommend incentivizing adapted bottom-up strategies. These positive policies should be adapted and support companies at a local level, in order to reach their potential and best results.

In terms of discussing fiscal policies, then tax benefits should be granted to firms recycling and conserving resources, while subsidies should be given for research and development of circular methods. Even financial policy can be applied to assist in granting loans to build required infrastructures for circular economy purposes (Fan and Fang, 2020).

On the one hand, Wu et al. (2014) attempted to take deductions that could be applicable to other countries as well, although, it is acknowledged that their conclusions are more so directly applicable to developing countries. Regardless, they highlight that economic growth in China came at the cost of using excessive energy and emitting an increased amount of pollutants, thus allocating the waste management responsibilities/role to the governmentally supported institutions. On the other hand, Robaina et al. (2020) conducted a Multidirectional Efficiency Analysis to waste and reusage of plastics in European countries, which arrived at the exact opposite conclusions. The differences in terms of progress towards efficiency, between countries, were not mainly due to their reduction of wastes or emissions, instead, said differences were explained by the improvements in their respective economic growth, in a circular manner (increasing their GDP, along with improvements recycling methods), in terms of the outputs. Robaina et al. (2020) also found that, in terms of inputs, the main driver to developing plastic management efficiency was to increase firms' capital.

However, Robaina et al. (2020) did not imply that companies should ignore waste management, on the contrary, in order to achieve a sustainable development, incorporating plastic waste back into manufacturing chain value is still relevant, and recommended by improving technology that collects, sorts and cleans plastics wastes. But, simply put, investments and capital are crucial for overcoming technological barriers and progressing towards circular economic growth.

An example of a non-financial legal restriction, also applied to plastic-based productions, could be the Single Use Plastics Directive, which was accepted by the European Union at around the end of 2018. This legal restriction prohibits specific plastic products to be used only once. Having been a directive, EU members had the freedom to transpose this regulation as they deemed fit, as long as the target results were reached (EP 2019). In Portugal, this measure began on the 1st of November of 2021, directly prohibiting markets to sell plastic products that could only be used once, such as dispensable cups or plates.

When government regulations or restrictions are applied, especially those that restrict certain use of materials or production methods, they force production to halt and adapt towards alternatives. Given that policymaking may be affected by social pressures (Centobelli et al., 2021) and public opinion (Wlezien and Soroka, 2012), then such policies will often create an uncertainty to when they shall be applied. This can create some market distortions or “policy uncertainty”, as firms would seek to adapt at least in two phases of investment, one being preemptive to the regulations application (Weerdt et al., 2021).

Despite this discussion not taking place in the financial market, Keynes’s well-known theories on the importance of expectations (1936) seem to also manifest in this firm adaptation and investments towards circular economy measures, regarding policy uncertainty. This may highlight the importance of considering the effect of expectations in both human and firm behavior.

Not only do the results of the stepwise investment in circular models (Weerdt et al., 2021), considering policy uncertainty, solidify the previously mentioned theory of firm’s temporal behavior to invest in at least two moments (as the first preemptive investment will tend to be lower than the following one), in order to maximize profit. But it also confirms on the one hand, that if the applied legal policies are too strict, this could in turn damage the market by turning it non profitable, thus pushing away companies from these markets. On the other hand, if the incentive policies are not strong enough, then they will not significantly affect this timing based firm investments/decisions. In this regard, clear, well defined and announced legal policies/regulations seem to have faster effects on company decisions towards investing into circular economy, given that incentives which can be predicted and accounted for, result in time optimized actions towards maximizing possible profit.

While the results of Weerdt et al. (2021) demonstrate the importance of the value of the incentive in question, they also show that results may differ depending on the kind of policy approach is taken. Lybaek et al. (2020) also implied that the way/method how the incentive is applied can alter its impacts. Or we could even say, how organizations and agents perceive these incentives and their social message, thus possibly altering their reactions. Finally, the findings of Wu et al. (2014) which are later tested and further supported by Fan and Fang (2020), acknowledged the heterogeneous nature of circular economy policy effectiveness in different regions (of China), which demonstrates the importance of coordinating general policies with locally adapted regional policies.

3. **Methodology**

3.1. Overview

In order to create a formal study regarding the usage of incentives to promote circular economy, as a means of environmental management, then, the first essential step was to verify the point of situation in current studies. As such, the prior literature review was conducted by first, checking the most recent papers/research projects made in the areas of environmental management, circular economy, incentives/policies, and even human/firm behavior. Secondly, and after identifying which studies were more intrinsically connected to this field, then performing a background check to the older studies that these papers reference was also in order. This second step was crucial to both verify methods and/or claims, as well as gain further insight on what has already been investigated, and their respective conclusions. Finally, further literature from slightly older periods, and that were heavily connected to circular economy, were also added to complement any possible missing information during the investigation of this dissertation.

Trusted sources of information such as Scopus (Elsevier) and Web of Science (Clarivate Analytics) were used in order to perform the above-mentioned methods of gathering present information.

During this process however, logical connections were also established with other notorious past theories, such as the ones written by Keynes (1936), Gneezy and Rustichini (2000), which at a first glance do not seem to be related to the topic of promoting circular economy, however, both of the importance of Expectations, as well as controversial reactions towards fines, seemed to prove significant in complementing or arguing with the findings in literature directly connected with using incentives and policies for managing the environment.

Now, taking a step back and recalling the research question of this specific study:

"How to enhance government intervention in circular economy, decreasing wastes and improving firm resource efficiency?"

Current literature already displays multiple insights on what could be done or what it may be required to do, from a spectrum of simple firm/industrial strategies to the implementations of new laws to enforce the desired change in the market, from non-financial methods such as the better spread of information and promoting collaborations between firms, or removing/containing certain type of goods with legal restrictions, to fiscal like policies, using direct and indirect taxes, and even giving positive incentives to firms directly such as subsidies or funds for research and development.

The gathered literature is very well structured in the behavioral fields. However, when it comes to the microeconomics segments (and in some cases macroeconomics as well), the studies either give their policy suggestions, demonstrate their case studies, or display advanced theory to attempt and accurately determine optimal values/equilibriums.

Focusing our study in the two of the most suggested methods, to which this study shall now designate them as the two main tools of government intervention, as a means to achieve an environmental circular economy market solution, regarding both reducing/reusing wastes, and achieving the best efficiency out of the used resources. These two tools are: Taxes (directly) applied to the firms in question, lest it be the ones already attempting to perform circular economy, or firms adapting other similar methods. Taxes are also defined as the obligations the governments impose on firms, and to which said firms must pay the government under their assigned circumstances; Incentives, (positive) monetary measures, such as subsidies, or any kinds of funds that the government may grant to firms, in order for them to successfully apply circular economy methods, without drastically changing the market prices, and thus making them competitive with their linear counterparts.

Given these two tools, a person that may attempt to present a proposal to the government, parliament, other representative entities, or even directly to a specific firm, may struggle to find a middle point between the recommended measures of current literature, and the more advanced measurements of "how much" either a Tax or Incentive should be applied in said proposal.

As such, this study will firstly present a purely theoretical model, using the plastics sector as an example to demonstrate how to practically apply microeconomics to determine a provisional value, or at least, a general preemptive measurement of "how much" should a Tax and/or Incentive be in order to promote change in the target market, towards circular economy.

On the one hand, this theoretical chapter will not be presenting an optimized or accurate answer, as it is not intended to replace or correct other studies of this field, but rather complement them, by presenting a basic working ground. On the other hand, the level of simplicity can also make it comprehensible to a wider general audience, including entities and institutions with different formal knowledge backgrounds outside of economics, which could be the case of many individuals who would still seek to present circular economy proposals, in order to achieve a more sustainable society.

However, as this study presents a possible measurement of such tools, it is also pertinent to verify if Taxes and Incentives towards (the overall) implementation of circular economy in firms, can indeed bring about a more efficient and sustainable economy. This is a point where statistical studies and findings had some disagreement on.

Therefore, the following subchapters will seek to use econometric methods, to test the statistical significance of using direct taxes and positive incentives as policies to promote circular economy, and determine if they indeed explain a positive movement of countries towards target sustainability goals.

To the best of our knowledge, no prior literature has used such basic econometric methods to analyze the correlation between a sustainability goal, and the suggested tools of government intervention along with other circular economy drivers. Therefore, this segment will attempt to fill this gap in literature, as to give a small contribution to the current knowledge, on these topics.

For this purpose, quantitative data is required. However, current indicators and data are often incomplete or contain other pieces of information not suitable for evaluating the efficient progress of circular economy towards sustainability in countries. As such, more general and trusted (publicly available) databases shall be used, to draw logical conclusions on whether the two recommended tools, that the theoretical model attempts to calculate, incentives and taxes can statistically explain progress towards resource/waste efficiency goals, or if they are not significant at all.

Panel Data methods shall be applied, as the utilized variables/data are representative of 19 different countries, and observed once per year, over 10 years (a total of 190 observations). The panel is fully balanced and without missing values. All tools and methods used shall be fully explained, as to allow any other investigator to replicate them.

3.2. Theoretically Applied Microeconomics Models

In order to demonstrate how basic economic modeling might be applied in determining "how much" should either a positive government incentive be, or a governmental tax, to promote a shift of the market towards more circular economy firm practices, then a more specific scope of study will be taken into account.

Plastics and their fibers are very often used in the industrial manufacture. Therefore, building a model considering them can be quite pertinent for influencing the supply chain management. Furthermore, they are some of the few products from which there is a broader access to publicly available data, which justifies why several other literature studies have focused on plastic producing or similarly related firms. As such, the sector of plastics makes for a great specific case to be used in models, as an example on how simple Cost and Profits functions can be applied, to quantify the values of incentives and/or taxes that are necessary to shift the target market.

Despite the amount of data publicly available, it is still insufficient to perform a specific case study, like the Yu et al. (2021) approach regarding recycled concrete aggregates. This is mainly due to the lack of reliable and complete information concerning general or targeted plastic costs, prices, sales and the overall profits. However, in a purely theoretical spectrum, it is still pertinent to consider that in order for the firms to shift their production (or other phases of their chain), towards circular economy solutions, then the Costs of producing recycled/circular-project plastics has to be at least equal to, or lower than the Costs of producing plastics in their "original"/linear/conventional/traditional methods.

On a similar line of though, another condition that would make sense to analyze would be that: firms could change their behavior or structured productions if the overall Profit of ongoing circular economy methods was at least equal to, or higher than the Profit obtained by current linearized production chains that do not consider reutilization of plastics. An example to consolidate this reasoning, is an analogy with general market theory, in which it is expected that new firms will try to join/enter a market and/or sector that is demonstrating higher Profits (as long as there are not any barriers to entry of new businesses that may make such Profits inaccessible), likewise a surplus or at least an equal level of financial results could incentivize firms to take environmentally friendly circular methods. Weerdt et al. (2021) also considered that, if governmental policy is expected to occur, companies would take a preemptive investment if the Costs of preparing for such an adaptation were lower than the Costs to adapt after the policy is applied; or if the Costs of preemptively investing were lower than the expected Profits attainable from that governmental policy.

The following models contain general microeconomics theories than can be found in a wide variety of books, such as Carlton and Perloff (2015). To assess a comparable working ground regarding Costs, then we shall begin by representing a general (average) Total Costs function for firms.

$$ATC = \frac{TC}{U} = \frac{FC + VC}{U} \tag{1}$$

ATC - stands for Average Total Costs and, as such, represents what is the total cost of production for each unit of plastic produced.

U - stands for Unit, and it represents the quantity or number of units of plastic produced.

TC - stands for Total Costs, this is the sum of all costs related with the production of the plastics.

FC - stands for Fixed Costs, these represent all costs that do not depend on the level of production, such as machines, technical gear, buildings (acquiring new ones, or maintaining current ones), Research and Development, marketing, and wages for the work force required for the firm to operate but that are not connected to the production of plastics itself.

VC - stands for Variable Costs, these represent the sum of the remaining costs not included in FC, which do depend on the amount of produced plastics (Units). This implies that variable costs will also increase if the number of produced units increase. We may consider: wages of workers who produce plastics; costs with acquiring and transporting raw materials/input; and energy or any other expendable needs required for each production process.

In most cases, it is more intuitive to sum the Fixed Costs and then dividing them for each Unit produced. However, if the Variable Costs are preferable to be accounted for as the direct/added Average cost of each produced Unit, then we can represent it as "AVC". Nonetheless, "AFC" can also be used to represent the Average Fixed Costs:

$$AVC = \frac{VC}{U} \ (=) \ VC = AVC * U \tag{2}$$

Then:

$$ATC = AFC + AVC \tag{3}$$

If Total Cost is preferable to take into consideration, then we can rewrite these formulas as:

$$TC = FC + VC = FC + AVC * U \tag{4}$$

Any of the formulas 1,3 and 4 can be used for comparing production costs. This demonstration shall focus on using formula 4, which displays the Total costs as a function depending on U.

Now, this study shall use the terminology of lower-case "l" (stands for Linear), and "c" (stands for Circular), to distinguish the functions that represent the linear processes of plastic creation (which may also be addressed as conventional/traditional methods, or addressing the plastics as raw/"original"/"virgin"), from those that represent production methods following circular economy strategies, respectively. As a reminder, these models focus on the production segments, though supply chains also take into account other phases such as raw material extraction, consumption and post consumption, to which these models could also be tailored towards.

Linear production/supply chain firms:

$$TCl = FCl + AVCl * Ul \tag{5}$$

Circular economy production firms:

$$TCc = FCc + AVCc * Uc \tag{6}$$

Assumption 1: The Total Costs of producing plastics in a Circular method are higher than the costs on linear productions (TCc > TCl).

Many studies (Fan and Fang, 2020; Lybaek et al., 2020; Haselsteiner et al., 2021; Yu et al., 2021) agree with this assumption, as otherwise they would not state that governmental intervention and/or incentives are required to shift the market and to support circular economy in the plastic sector.

Some components of both FC and AVC may be separated, in order to allow a comparison with their counterparts. The lower-case letter "o" ("Other") will be added before FC and AVC, as to represent the remaining costs without the separated variables (oFCl; oAVl; oFCc; oAVc).

Within Fixed Costs:

RD - shall represent Research and Development, as currently linearly functioning firms may always be investing in scientific research to produce their plastics in a cheaper way. Likewise in order to produce plastic in a circular and competitive way, without causing any trade-offs/other environmental problems, then there must be a significant cost in investing in research.

Within Variable Costs:

RmT - shall represent costs related to Raw material and their Transport costs. This is one of the key points that circular economy may help minimizing costs. It is worth noting that, recently, the Transport of such materials became even more relevant given the pandemic (which for health reasons, lead to lock downs, thus making other firms inactive, or making transports, especially among countries/long distances unavailable), as well as the embargo and other measures taken towards Russia in 2022, who was an oil/gas provider. These events resulted in an increase on the oil/gas prices, consequently increasing the cost of transports, and the general prices. Unlike general goods, which were indirectly affected by the chain reaction of transport costs, the production of certain plastics that use oil itself as a raw material, has also led to a direct cost increase.

Consequently, the cost of energy also increased. However, unlike Raw materials, we have no evidence to assume that this increase affected Linear and Circular methods of production differently.

Ta - shall represent governmental Taxes. This is one of our two main government intervention tools, and it serves to control firms and their optimized behavior. Taxes could also be applied as a percentage of the firms' overall profits. However, we shall choose only to assign direct taxes towards the produced quantity of Units (akin to variable costs). This way we can have one equation to determine Taxes, while Profit equations will also include the other undetermined variable of governmental intervention, like subsidies/incentives. Note that these are only for the directly applied taxes. The indirect taxes (for example, towards wastes of plastic) should still be included in Other Average Variable Costs (oAVl and oAVc).

Making these alterations to our equations, we get:

$$TCl = oFCl + RDl + (oAVl + RmTl + Tal) * Ul \tag{7}$$

$$TCc = oFCc + RDc + (oAVc + RmTc + Tac) * Uc \tag{8}$$

Assumption 2: Research and Development costs, in the current market situation are lower for Linear processes, given that circular economy methods are more complex, require more investigation, optimization and more scientific effort in order to not controversially cause other negative environmental impacts, and thus promote a more environmentally friendly economy, rather than a trade-off (RDl < RDc).

Assumption 3: Circular economy can reutilize plastics. As such they require to use less raw materials and are less affected by increases in their transport cost. In other words, Linear productions face a greater cost with obtaining Raw materials (RmTl > RmTc).

We do not have enough evidence to assume that the difference in costs on assumption 3 is strong enough to conclude that the variable costs of linear production are higher than those of circular plastics. So, we can not claim that Tax benefits towards circular plastics would only be required in the first development phases, until eventually they reach a production level high enough to out scale their higher fixed costs of Research and Development. In contrast, Weerdt et al. (2021) found that after the pandemic, the gap between linear and circular plastics decreased, given the increase of raw material costs when compared to recycled plastics. However, this was not enough to close the gap and shift the market. No complementary study was yet found that managed to account for the recent increase of oil prices and transport costs of 2022.

Taking a direct look to the plastic market itself, one more property may be highlighted. For the households, plastic bags, cups, or other products tend to in fact be sold in Unit(s). However, an official website such as Vraag & Aanbod (a Dutch company) presents updated market values of plastic values not by units and type, but rather by Volume/Weight of each type of plastic and fiber (per ton, per 5 tons). Likewise, Novo Verde (Portuguese company) gathers, estimates values and/or recycles various types of residual bags, such as plastics, and all of these materials are valued as euros per ton, in other words, priced according to their weight. Finally, Sociedade Ponto Verde (Portuguese private entity) is a legally authorized entity that collaborates with many firms to gather wasted bag/packages and recycles them back into usable materials. The value in which these circular/reusable materials are sold back to firms is a multiplication of 3 components: The value/price of each material, the weight of each bag/package and the number of bags/packages.

Considering that plastics (and some other materials as well), are sold in either units of the product, weight of the plastic type, or both, rather than expressing Units of X, it can be pertinent to multiply Weight (W) and Quantities (Q) as a function of X products/materials. If the price/costs is measured in Weight only, then Q can be set to 1 (W * 1 = W). In cases where only the Quantity matters, as the Weight of each unit is the same or is not accounted for, then W can be set to 1 (1 * Q = Q).

Substituting in our equations:

$$U(x) = W(x) * Q(x) \tag{9}$$

$$TCl = oFCl + RDl + (oAVl + RmTl + Tal) * Wl * Ql \tag{10}$$

$$TCc = oFCc + RDc + (oAVc + RmTc + Tac) * Wc * Qc \tag{11}$$

Assumption 4: Each type of X material/product will have the same function of W * Q along the model.

The above assumption is taken to simplify the demonstrated theoretical equations. Using RmT as an example, if one of the required raw materials (y) is purchased from different providers, and each provider sells them at different combinations of per Weight and Quantity prices. Then, to represent this mathematically, a discrete integral could be used, such as the example below:

$$\sum_{i=a;j=b}^{A;B} W_i(y) * Q_j(y) \tag{12}$$

This means that, if a raw material/cost or product is measured in different ways regarding their Weight and Quantities, then, instead of simply multiplying a component like RmT by W * Q, it is required to multiply each raw material by the corresponding combinations of Weight and Quantities in which they were purchased. Therefore, rather than just one multiplication, it must be calculated as a sum of each different multiplications that were required.

However, regarding the analysis and deduction of the model itself, to equalize the Total Costs (or Average Total Costs) of Circular plastic, or to make them inferior to, the respective Costs in Linear production may still be an insufficient condition to change the market of plastics. Weerdt et al. (2021) points out that some kinds of recycled plastic polymers do not have enough reliable quality for production processes. Several plastics made from new raw materials are more stable, thus making their circular/recycled counter parts riskier, whereby firms will prefer to avoid these risks in their productions. In line with this issue, Simon (2019) states that certain recycled polymers of plastic have drastic difference in quality which can contaminate the remaining materials during production, and that this is an operational risk that leads firms to not accept many of these circular plastics.

Assumption 5: If a firm chose to (re)use circular plastics in their production, then, even if proven to be unusable, they will still pay the full price of these materials (as part of RmTc). Or, the fiber of plastic will be used in their general production, thus being part of the Total Variable Costs (VCc), even if the generated product can not be sold.

With this assumption, we can claim that the risk of such plastic polymers being unusable (Ω) does not alter the Total Costs of circular methods (TCc), but rather it will make part of their stock unable to be sold, and thus cause a loss in their sales/revenue. As such, this risk can be considered as part of the Profit functions, and it is accounted for as an expected percentual risk, as such $0 \leq \Omega < 1$. In case the total stock of the circular economy firm is considered as 1, then the expected level of stock that can be sold will be represented by (1 - Ω).

Profit functions will be of the type:

$$\pi = P * U - TC(U) \tag{13}$$

Equivalent to:

$$\pi = P * U - ATC * U \tag{14}$$

π - shall represent the total profit of the firm.

P - shall represent the price at which the firm sells each Unit of their plastic-based product.

Then, following our model, the linear firm profit function is given by:

$$\pi l = Pl * Wl * Ql - TCl(Wl * Ql) \tag{15}$$

While Circular plastic firms would have the following profit function:

$$\pi c = (1 - \Omega) * Pc * Wc * Qc - TCc(Wc * Qc) \tag{16}$$

Subject to:

$$0 \leq \Omega < 1 \tag{17}$$

Now we can add our second main tool of governmental intervention - "In", which represents the positive incentives and/or subsidies attributed to the firm performing circular methods of plastic production. While these incentives could also be applied as a variable depending on the produced quantity of the plastic product in question, or as a percentage of the firms Profit/Costs, this model merely chooses to incorporate them as a beneficial fixed number (akin to that of Fixed Costs).

Including *In* as the positive governmental intervention tool, we get:

$$\pi c = In + (1 - \Omega) * Pc * Wc * Qc - TCc(Wc * Qc) \tag{18}$$

Assumption 6: To avoid causing any undesired and complex supply chain production reactions or general market instability, the Prices of the circularly produced plastics must be competitively close to that of the current linear productions available in the market. As such our equations must respect the following condition:

$$Pl * Wl * Ql \ \cong Pc * Wc * Qc \tag{19}$$

Thereore, the difference in Revenue can be written as:

$$In + (1 - \Omega) * Pc * Wc * Qc - \ Pl * Wl * Ql \cong In + (1 - \Omega - 1) * Pc * Wc * Qc \tag{20}$$

So, if we were to determine *In* by using the difference between profit functions (πc – πl):

$$\pi c - \ \pi l = In + (-\Omega) * Pc * Wc * Qc - TCc - (-TCl) \, (=) \tag{21}$$

$$(=) \, In = \pi c - \ \pi l + \Omega * Pc * Wc * Qc + TCc - TCl \tag{22}$$

Do note that both TCc and TCl include our prior instruments of governmental intervention, which are the taxes Tac and Tal, respectively. So, the equations number 21 and 22 have both variables we want to measure. However, it may be more challenging to determine them simultaneously. For that we should opt for a different method which, although only being just one possible answer and not necessarily the best maximized outcome, should be more feasible and easier to obtain a general quantification of both desired instruments (Taxes and Incentives).

Considering the difference between Taxes and Incentives from the perspective of the governmental entity, Taxes will grant more money for the government, which could later be invested in other plans, while Incentives or subsidies are a cost that will either take away funds from other possible investments or increase public debt. From this point of view, Taxes would seem to be a preferable measure, so we shall attempt to calculate them first. However, there is a rational limit to how much of a Tax benefit/reduction a government may give to firms opting for circular plastic production methods, since a Tax can not go below 0, otherwise it would become a positive incentive like subsidies. In turn, Taxes towards linear firms can not be too high either, there is a (non-clearly defined) limit to how much a Tax can be applied in which the current plastic market can tolerate. If it is surpassed it may end up destroying the market of plastics. So, Tal has an upper limit, while Tac has a lower limit. Therefore, the value of Tax benefit that a government can give to circular firms over their linear counterparts is also limited (Tal – Tac). In opposition, governments can not limitlessly provide subsidies to firms either, but incentives should prove to be a more flexible instrument.

If all our assumptions hold true, then this model can possibly be solved by using the Taxes to make the (average) Variable Costs of either method as close as possible, as in adjusting the difference between Tax benefits (Tal – Tac), complemented by higher prices of raw materials for linear methods

(RmTl > RmTc) to close the gap between Other (average) Variable Costs in favor of circular economy for plastics. By achieving this, then both the direct added costs of producing each Unit and/or Weight times Quantity of the plastic good, as well as the market price at which they are sold, should now both be equivalent between Linear and Circular methods. As such, two types of distinguished costs remain as disadvantages of shifting the market from Linear to Circular Economy: the difference between Fixed Costs (especially the higher Research and Development of Circular methods RDc), which could serve as a barrier to this market shift; as well as the loss in revenue due to the Risk of using recycled plastics that may not have the desired standard quality. Incentives and/or subsidies shall be the ones applied to allow circular plastic methods to surpass such fixed cost barriers (RDc and oFCc), allowing them to invest in whatever costlier equipment and additional investigation that is required over their linear alternatives, as well as to compensate them for the Risk that will cause an expected percentual level of Ω revenue loss. If both governmental instruments are sufficient to perform these roles, then we are able to reach the goal condition that may change the plastic market: the total Profit of Circular methods being at least equal to, or greater than the Profit of current Linear productions.

If:

$$AVCl \cong AVCc\ (=) \tag{23}$$

$$(=) Tal - Tac = oAVc - oAVl + RmTc - RmTl \tag{24}$$

And:

$$In = \Omega * Pc * Wc * Qc + oFCc - oFCl + RDc - RDl \tag{25}$$

Then it becomes possible to have:

$$\pi c \geq \pi l \tag{26}$$

In this suggested solution, Taxes are first applied (which expresses what would be the preferred instrument by government), but Incentives may play a bigger role. This complements the conclusions of Lybaek et al. (2020), which stated that indirect taxes (such as those towards wastes) proved to be more effective. However, direct taxes could still prove useful, and positive incentives had the most potential, though both of these latter instruments had to be applied in a different way than their predecessors, in order to reach the desired results.

This was a demonstration on how to apply basic economics, and achieve a theoretical model to determine a provisional value for “how much” Taxes or Positive incentives should be applied, if the user has access to data on all required values. The simplicity of the demonstrated theory holds the benefit of making it accessible to (and usable by) any firm, institution, government, or other similar entities and policymakers that seek to implement Circular Economy. So, these models may prove to be an assistance in assessing a general overview value of how much investment, incentives or tax benefits that such a proposal and/or measure can require.

Taxes do not specifically need to be placed in the cost function, nor do incentives have to be placed only in the profit function, they are both tools of government intervention, and their position in such equations may be inverted. Or taxes can be included in both equations and incentives only in one of them, or again the inverse reasoning, or applying both tools to both equations. This example used Plastics as their target of investigation, however, similar logics may be applied to products based on wood, paper, glass, metals and possibly even adjusted for construction materials, mechanical gadgets/accessories/pieces and gas sprays.

On a slightly more complex perspective, the theoretical model may be extended to allow for a more general representation of economic theory results, including marginal analysis, market structure or behavioral aspects.

As a final note, the following chapters seek to statistically study if our proposed main governmental tools (Incentives and Taxes) have a significant impact in explaining improvement towards environmental goals of sustainability and optimization of resources. This is pertinent given the debate whether Circular Economy truly has the capability of promoting a green Economy, which certain authors such as Murray et al. (2017) question. While relatively simple econometric models will be used, this study will take a more expert approach, which is more rigorous in both economic and statistical terms. Nonetheless, the final Conclusions of this dissertation should be generally accessible, and both the gathered literature and our theoretical reasoning shall be complemented with the main implications of statistical findings.

3.3. Application of Econometric Models

As history came to demonstrate, economic theories that were theoretically constructed could indeed be built upon logical sense and mathematical corroboration. However, many of them eventually proved to not correspond to the human/firm/country reality, once empirical results that contradicted them came to light.

In the literature, there are some authors (such as: Murray et al., 2017; Kirchherr et al., 2017) who argue that there is no significant correlation between investing/progressing in circular economy and the environmental efficiency goals. After having presented the previous theoretical models, which are intended to assist in offering possible solutions for measurements of state interventions/policies, it now becomes crucial to verify if empirical data contradicts the former arguments and supports our models. Namely if shifting the market towards circular economy firms, in sectors such as plastics (or other applicable sectors), has statistical significance in explaining sustainable development.

Econometric models and tests are used for such purposes, and while suitable values were not found, in publicly available data, to calculate the real numbers of the prior theoretical models, a step back shall be taken, broadening the studied types of sectors/firms, in order to perform tests that will give us further insight on the correlation between both our presented government tools (direct taxes and positive incentives) and an indicator of sustainability.

To establish this type of regression models, then the dependent variable Y shall be represented by an official sustainable development indicator(s), and the main studied tools of government intervention- Taxes and Incentives, shall each represent an explanatory variable.

However, the estimations of these models will always have an error "u". This error term includes all information not explained by the defined explanatory variables, and it is important that such variables are not correlated with the error term. So, other suitable explanatory variables that may drive firm adherence towards circular economy must be included as well, to ensure the model is consistent.

For this affair, considering the findings of Centobelli et al. (2021), the determinants of (small and medium) firm willingness to change towards circular economy methods were: social pressure; (intrinsic) environmental commitment; green economy incentives. According to the authors, all of them presented a positive correlation towards improving circular economy applications.

In terms of social pressure, the authors included the direct taxes in this variable. However, as the direct taxes are one of the main tools studied in this dissertation, then they shall be split into a separate variable, as mentioned above. Also, to note, the higher a tax is, then it is expected to have the opposite effect of positive incentives, in other words, it would be expected that higher taxes applied to circular method firms would decrease their environmental efficiency, while as social pressure proved to have a positive effect in the Centobelli et al. (2021) study. The environmental commitment of a firm will be considered an explanatory variable in itself, while the green economy incentives were already being included in our other main explanatory variable of government intervention.

The following table 3.1 summarizes the correlations between these explanatory variables that were either verified in literature, theoretically supported, or logically deduced. These findings justify the previous arguments regarding the selection of the explanatory variables.

Table 3.1: Effects between explanatory variables

"\" - is excluded from this table.

“+” - represents positive effects.

“?” - deduced positive effect, but not statistically confirmed.

Blank spaces imply that there were no theoretical nor empirical evidence of correlation.

	B				
	A has effects on B	Social Pressure	Environmental Commitment	Green Economy Incentives	Direct Taxes
A	Social Pressure	\	+	+	
	Environmental Commitment		\		
	Green Economy Incentives	?	+	\	
	Direct Taxes	+			\

Source: Own elaboration, based on Centobelli et al. (2021).

The excluded entries are merely due to the possibility that the past value(s) of the variable may affect their next/current value, however these are the independent/explanatory variables of our model, so the objective of this table is to present their effects on other variables instead.

These positive effects were the results shown by Centobelli et al. (2021). They had considered Direct Taxes as a part of Social Pressure, the higher general taxes are, then the higher the Social Pressure should be. By definition, the standalone variable of Direct Taxes also positively affects Social Pressure.

As such, the standard regressions models should follow (excluding cases which computed omissions, or variable instrumentalization) the general format:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + u_i \quad (27)$$

$$i = 1, (\dots), N \quad (28)$$

N - Represents the number of the final observation, which should match the total number of observations.

X - Represents one of the four explanatory variables considered in the model (social pressure, direct taxes, environmental commitment, and positive incentives).

β - Represents the coefficients assigned to each explanatory variable, that is, the betas represent the increase/decrease of Y when the matching number of X explanatory variable increases by 1 unit. Except for the beta assigned with the number 0, this component is instead a constant that represents the increase/decrease of *Y* when all explanatory variables remain constant. Note that in Panel Data, this component is often designated as "α" to further distinguish it, given that some models require α to not be correlated with any β.

This chapter features basic applications of econometric methods which can be consulted in Verbeek (2017), and other similar econometrics books.

The chosen level of significance will be 0.05, in other words, the null hypothesis H0 will be rejected if the probability of H0 being a correct/true hypothesis is lesser than 5% (or 0.05). Results and interpretations may discuss the conclusions if other commonly chosen levels of significance (0.1 and 0.01) were taken, however all tests and core results shall be taken at 0.05 specifically.

The software tools required to perform this statistical study are Microsoft Excel and Stata.

3.4. Collected Data

Previous studies demonstrate that different regions may show different results in terms of how efficiently they respond to policies that promote circular economy. Also noting that past studies had difficulty in finding or building indicators, to evaluate the performance of firms in circular economy terms. Then searching for already existing data, from trusted sources, and with country level of representativity, may be a suitable means to gather a set of data capable of representing the overall correlation between sustainability and the possible main drivers of circular economy.

Firstly, it was required to extensively search all databases on trusted/official websites such as: PORDATA; FRED; Eurostat; OECD.

In these websites, all relevant databases (and their connected investigations/publications) that were related to the environment were checked, in order to find the most suitable indicator for a sustainability goal, the representation of social pressure levels, and the representation of firm intrinsic environmental concerns. General economic databases with specification on environment were also checked, as to attain possible information that could present the taxes and incentives, which are the designated government intervention tools, which they can directly use to influence circular economy.

Using any preview/table customization functions of their respective website, each tab/section that allows customization should be adapted to show all available countries, years, frequencies of registered data, categories, and sub-categories.

After assessing all available information, it was then chosen one indicator to represent each of the variables. The selection criteria followed the reasonings of: how closely the indicator description fit that of the theoretical variable desired to be measure; how many observations were available (the more observations, then the more solid may the statistical study be, however nearly 200 observations is already considered to be a proper number to avoid small sample statistical inconsistencies); if the gathered data matched the countries, years and frequencies of other available variable indicators; how complete were the databases and/or the less missing values they had.

The matching time frame that was found consisted of 10 years, namely between 2003 and 2012 (inclusively). Over 20 countries matched, however, the final list of countries present in the data shall be included in the data analysis subchapter, which explains how data was treated, filtered and sorted.

Regarding the information and choices of indicators/data assigned to the dependent variable and explanatory variables:

Resource productivity and domestic material consumption (DMC)- this indicator shall represent the sustainability factor identified as the dependent variable. It belongs to the "Sustainable development indicators Goal 12 - Responsible consumption and production".

The development goal of responsible consumption and production seems to be one of the goals most in line with the circular economy objective of decreasing wastes and optimizing resource utilizations. By choosing this indicator, controversial trade-offs with other goals are not being considered, as such this should allow to directly verify that circular economy can indeed be a means to achieve such a sustainability goal. However, it is important that it does not come at a cost of other objectives. This analysis is merely an inference to verify direct statistical relevance, since it is still important that circular economy can increase this type of efficiency, while developing methods that do not come at the cost of further pollution or overuse of resources.

The description informs that this indicator is calculated by using the gross domestic product (GDP) and then dividing it by the domestic material consumption (DMC).

Environmental Policy Stringency Index- this indicator shall represent one of the explanatory variables which governmental entities do not have direct control over, which is social pressure. It measures the intensity in application of a set of environmental policy instruments, within each country.

This present study was conducted using data that only had fully registered values until 2012. The Index had seemingly been discontinued for possibly leading to incorrect conclusions, as the considered indicators were rather simple and did not fully portray the full reality of applied policies. Nevertheless, they were still consistent throughout the comparison between countries.

As of the 29th of August 2022, this database was updated, being added all values up until 2020. Some prior registered values were also corrected, as such, any attempts of replicating this study, should prove to have slightly different final results (mostly in the coefficients), even if the same indicators and time periods are used. Unfortunately, this update had been published only after this econometric study had been finalized, and without due time to repeat it with the most updated data. However, given that social pressures also account for variables that the government can not control, but rather only influence, such as the expectations of stakeholders and general population, then this change in the indicator does not bring us that much closer to our study target, as stringency is mostly controlled by governmental decision. Nonetheless, the fact that the indicator had not been discontinued is a sign that, even with a different criteria, the prior data was still a fair comparison between countries, and as such still gives us reliable statistical insight on the movement of the social pressure variable, even if it is now just a second best option.

Trade in Environmentally Related Goods - an indicator under the Policy Indicators on Trade and Environment segment, shall represent the (intrinsic) environmental commitment of firms.

No indicators can be fully associated to showcasing how much the firms of a country may be concerned and taking measures towards environmental sustainability, however, even if it is not possible to represent their full effect, it may still be possible to capture a fragment of their intrinsic values, thus analyzing the possible flow if said concerns increased from a year to another. Therefore, the trade in environmentally related goods were chosen, as it underlines the following assumption: If the concerns related to the environmental commitment of firms increased/decreased, then their country will have imported more/less of these environmentally related goods. While being distinct variables, they should offer a movement coordinated enough to represent statistical significance.

The medium of Environment Monitoring, Analysis and Assessment Equipment was selected as it was the one most arguably reasonable to represent firms, as in, a percentage of which were purchased by regulation entities, representative of affiliated with government and laws, households should have close to no interest in purchasing these goods, and the higher percentage of purchases could be assumed to belong to the firms themselves, in attempts to measure their own environmental efficiency, let it be for intrinsic reasons or for trying to respect legally announced limits. This composition also allows to explain that, if governments were to purchase most of the monitoring and assessment equipment, to take that role onto themselves, rather than allowing the moral values of firms/markets, then this could be an analogy to a policy restriction that takes away responsibility from firms, thus increasing government intervention, but also possibly decreasing firm intrinsic concerns, and having an overall lower or even negative impact on efficiency.

Other pertinent types of goods that could be considered were: Cleaner or more resource efficient technologies and products; Environmentally preferred products based on end use or disposable characteristics.

Environmentally Related Tax Revenue (all countries) - this indicator shall represent the (direct) taxes explanatory variable, which is one of the two recommended tools for government intervention.

This indicator uses the revenue of policy instruments used for environmental management. While it accounts for the revenue of the entities gathering these taxes, it is still a direct logic towards said taxes, that is, the higher the revenue of these entities, then the higher of a value is being taxed as a cost to firms. Note that higher revenue could also be a sign of economic growth and/or inflation, while the ratio of the tax remained the same, but since the measurement is that of percentage of the GDP, then it mostly represents the movement of tax policies themselves (as otherwise it would require an implication such as economic growth/inflation having only occurred to the environmentally related firms and measures, during said year).

Government expenditure by function (COFOG), 2019 archive; Function: 050 Environment protection; -This indicator contains the information relative to the remaining tool of recommended government intervention, which are positive incentives.

Not all of the government expenditures are intended to be used in this model, but only those that were designated to the function of environmental protection. Other data sources had closer descriptions to the green incentives our variables would seek to represent, however, given how incomplete and incompatible most data were, the most compatible and usable indicator was that of general government expenditure. The sub-option of "Subsidies" is available, under environmental protection. This study used the total government expenditure in environmental affairs, as it should contain all desired information of the designated incentives, but it might also contain other expenses that did not serve the purpose of incentives. Meanwhile subsidies would most likely not include too many entries not related to incentives (promoting a more efficient economy via state intervention), however it would probably leave out other relevant information such as certain benefits or capital transfers. Either could prove to be indicators that represent the general statistical movement of incentives, but not capturing their exact behavior. Facing this choice, the decision was merely a preference towards including extra information rather than excluding possible significant information, given that in econometrics, the noise of not required information might make a model not be the most efficient, however discarding important information and placing it in the error can make said models inconsistent instead, which is a worse outcome.

During the elaboration of this study, two more variables were required to be used, represented as complementary data and retrieved from the Economic Outlook:

Customize the Economic Outlook table to show yearly data between 2003 and 2012, inclusively; Unselect all countries; select only the chosen countries of interest; Unselect all variables; Select under the Expenditure and GDP option:

Gross domestic product, nominal value, market prices;

Gross domestic product, nominal value in USD, constant exchange rate (2015).

Each GDP should be extracted separately, to facilitate the usage as two different indicators.

Table 3.2: Additional information on gathered indicators

Indicator	Source	Unit of measure	Data of final extraction
Resource Productivity and DMC	Eurostat	Index, 2000 = 100	2nd of June 2022
Environmental Policy Stringency Index	OECD.Stat	Index, 0 to 6, increases with higher stringency	2nd of June 2022
Trade Environmental Goods: Monitoring	OECD.Stat	Value of imports in current USD	4th of June 2022
Environmentally Related Tax Revenue	OECD.Stat	Percentage of GDP	3rd of June 2022
Government Expendi. Environment Protect.	OECD.Stat	Millions of local country currency	7th of June 2022
Complementary data: Nominal GDP, Market	OECD.Stat	Units in local country currency	17th of June 2022
Complementary data: Nominal GDP, USD	OECD.Stat	Unit in USD (2015 Const. Exchan. Rate)	17th of June 2022

Source: Own elaboration.

All of the above-mentioned indicators were limited/selected the target information as much as possible using the table customization options in Eurostat and OECD. Once only the target information was selected in the database, then the files were imported as CSV format.

Microsoft Excel is the software used to open these CSV files, except the Trade in Environmentally Related Goods (environment monitoring, analysis and assessment equipment) variable, which also required being saved directly as an Excel file.

3.5. Data Analysis

Before analyzing the data, it is required to first prepare it.

For big data sets, coding software may be recommended. However, the data obtained for this study consisted only in about 190 (final) observations. Therefore, limiting data in their source sites, and manually treating them in Microsoft Excel, was sufficient to create a pertinent data file compatible with Stata (which will be used for the statistical study/tests). Nevertheless, if needed or preferred, then similar results could be obtained by using software such as Jupyter (Python) or Pluto (Julia).

Regarding the procedures taken, firstly, verify if opening the CSV in Excel displays the data as a column with the Countries or their tags, and that each country is repeated (in this case) 10 times, as another column will register the available years, following the same order downwards in the column of years should have a logical/chronological sequence repeated times equal to the number of registered countries. Remaining information columns may be displayed, repeating either 10 times in a row, or repeating the same sequence, with the exclusions of the observation/values on each indicator which should be only one single unrepeated value. Reading the same row should give information such as - the country in question, the year in question, additional information like units, and the matching single value/observation. This is the most fitting format to import Panel Data.

For consistency, it was required to manually rename all countries that had different designations. This occurs given that data from both Eurostat and OECD was used. As only one variable was taken from Eurostat, then it was more convenient to use the naming system created by OECD. The Search and Replace function in Excel is not recommended to be used for homogenizing the names and/or tags designated to each registered country, as it may alter unintended cells which may accidentally coincided with the input option. It is recommended to manually change the name and tag in the first entry of a country, then copying this change to the 9 cells directly below.

Following this reasoning, then the Sort function was used, not from Excel, but from the panels/data files themselves, to sort the country name column by alphabetic order. Namely the Resource Sustainability indicator that had to be renamed, and also any other file, that for some reason might have been transferred in a different order.

Some variables had missing value in the first few years, namely 2000, 2001 and 2002. Given the substantial number of observations, then, these missing values were removed by pushing the starting year of the analysis to 2003 instead. Likewise, countries which had missing values in any of the indicators were simply removed from the observations (except for Trade in Environmentally Related Goods, environment monitoring, analysis and assessment equipment). Note, the cells with missing values were not deleted, but rather all cells from a specific country that had any missing values were removed. In case the prior removed data may be desired to be retrieved, then it is only required to reopen the CSV in a new Excel sheet. In this study, countries such as Norway, Slovenia and Turkey are examples of data that had been collected at first, but then removed for having some missing values. The final list of observations contemplated 19 countries over the 10-year period of study, which amounted to a total of 190 observations. The final list of studied countries, by alphabetic order of the chosen naming system were (Name; tag):

Austria; (AT) // Belgium; (BE) // Czech Republic; (CZ) // Denmark; (DK) // Finland; (FI) // France; (FR) // Germany; (DE) // Greece; (EL) // Hungary; (HU) // Ireland; (IE) // Italy; (IT) // Netherlands; (NL) // Poland; (PL) // Portugal; (PT) // Slovak Republic; (SK) // Spain; (ES) // Sweden; (SE) // Switzerland; (CH) // United Kingdom; (UK).

Regarding the variable of Trade in Environmentally Related Goods, which was pointed out as an exception to some of the above-mentioned rules, its problem consisted in listing the values of several different types of environmentally related goods (monitoring, analysis and assessment equipment). Without a “total value” option, this variable had a significantly different format in the Panel Data, presenting more than one value for each combination of Country-Year.

To solve this, rather than directly using/opening the CSV on Excel, the data was transferred as an Excel (which had a format that would damage the data options of the tables), that instead allowed to have years as the variable changing along one row, and each type of good (inside of each country they were imported to) changing along the same column. This allowed to create a new row of 10 entries (starting off with one cell and then copying the pattern along the remaining 9 entries), which was the sum function of all different types of environmentally related imported goods of 1 country along each of the 10 registered years (one year per column).

Some of the goods had no value, which seemed to not be coincidental, pointing out they were either goods that were removed/replaced from the market or the data track list. One random missing value in one cell or another was also possible, but since there was a significant amount of goods, none of them should be big enough to cause “outliers”, as such simply summing all of them, would solve the missing values issue, as all Years and all Countries would have a solid value out of all remaining goods.

After manually repeating the processes for all countries, the data still remained as each column representing a Year (changing through the same row), and each row represented a Country (changing through the same column). So, to fit the desired format for the Panel Data, each row was copied to a new Excel file, in which only the Values were copied, and not the formula of the previous cells, ensuring that this was done following the alphabetic order of countries. Then from the rows in the new Excel file, the entries were copied, and selected the option to converted them into a column. All entries were copied onto one single column, by order: from the alphabetic sequence of the countries, and from 2003 to 2012 in each countries sequence.

The final matrix (for this specific variable) was verified to be 191x1 format, as to guarantee no entries were missed (the first row being the title and the remaining being 19 countries times 10 years which equals 190 values).

With all variables sorted and prepared for the same size and format, then a new Excel file was created, in which the first row was used to name each variable, and each matching column would hold the information of said variable.

3.3 Identification of the variables

Variable Name	Assigned Indicator/Information
Country	Column with all the country names.
Years	Sequence of the 10 registered years for each of the 19 countries.
RPI	Resource Productivity and DMC Index (sustainability goal).
EPSI	Environmental Policy Stringency Index (social pressure).
TGMA	Environmentally related Goods, Monitoring, Analysis and Assessment equipment (environmental commitment).
ERTR	Environmentally Related Tax Revenue (direct taxes)
GEEG	Government Expenditure in General Environment protection (green economy incentives).
GDPALL	Nominal Gross Domestic Product in market prices.
GDPUSD	Nominal Gross Domestic Product in US Dollars.

Source: Own elaboration.

To conclude, the Excel function of Search and Replace was used to convert all dots "." into commas "," and as such, this final Excel file can now be properly imported into Stata.

In order to place the data in Stata, a possible method is to simply choose the "File" and "Import" option, selecting "Excel spreadsheet", opening the final Excel that was created, and activate "import first row as variable names".

Since Panel Data is being used, the graphs and similar diagrams are not very suitable methods of looking at the variables, as such only simple Summarize commands were applied to them.

It was also noticed that TGMA and GEEG are variables that carry two undesirable effects, more specifically, both the Trades/imports of environmental goods and Government Expenditure are affected by Inflation, as well as the existence of significant differences in values among countries given the discrepancy in size of each country/scale of each economy. Government Expenditure also has a third added problem of featuring more than one currency, making it even less feasible to compare values between countries.

The most efficient solution for these problems is to convert both variables into percentages of GDP. Therefore, matching GDP variables were gathered, in nominal value since inflations effects had not been isolated (GDPALL and GDPUSD). It is also, pertinent to consider the units in which each variable was registered, in which GEEG was the only one in millions of unit, while as the remaining 3 variables were all in per unit values.

In Stata, a new variable “gdpall” was generated, as a result of dividing GDPALL by one million. Now that each explanatory variable matches the units of the respective added variable, then two more variables shall now be generated to replace them.

“tgma” is generated by dividing the values of TGMA by the values of GDPUSD, and afterwards multiplying by 100 (which brings it closer to the values of other used percentage of GDP variables). tgma now represents values of imports in monitoring and assessment goods as percentages of their country GDP, in one year.

Similarly, “geeg” is generated by dividing the values of GEEG by the values of gdpall, and afterwards multiplying by 100. geeg now represents the percentage of GDP that each government spent on environmental protection, in one year.

Before creating any models of performing tests however, it is required to properly inform Stata of the type of Panel Data being used. To do this, both a temporal and identity variable are required. Year is already a time variable in suitable format, though a number is now required to identify each country. As such, a new variable N was generated, as equal to 1. N was then replaced by another number for each different country registered.

In terms of suitable statistical test for Panel Data, this study shall apply a Hausman test, as well as first-order autocorrelation and the Hansen’s J tests to some of the dynamic models.

The Hausman test allows to determine if either Random Effects or Fixed Effects are the most suitable models to be applied.

This test is related with the condition of the constant α not being correlated with the explanatory variables, if they are not correlated (which implies explanatory variables are exogenous), then Random Effects are consistent and efficient, but inconsistent otherwise. While as Fixed Effects are consistent in both situations, but they are only the most efficient if there is a fixed correlation between the α constant and the variables (in other words, if the explanatory variables are endogenous).

By computing estimates of Fixed Effects firstly, and then the estimates of Random Effects, then the null hypothesis of this test will be that the differences in coefficients are not systematic. In other words:

H0: correlation is 0, as such both models are consistent, but Random Effects are the most efficient.

H1: correlation is different than 0, thus only Fixed Effects are consistent.

Regarding the dynamic models that shall be performed, which require increasing restriction, then two tests can be performed to these models as well:

Test for autocorrelation (first-order autocorrelation of the variance in the error).

H0: There is no autocorrelation.

H1: First-differenced errors are autocorrelated.

Hansen's J test of overidentifying restriction for instrument validity.

H0: Overidentifying restrictions are valid.

H1: Overidentifying restrictions are not valid.

3.6. Econometric Models and Specifications

Depending on the results of the Hausman test, then the Panel Data that was gathered shall be applied in a set of either Random Effects models or Fixed Effects models.

Without clear statistical properties indications in the already existing literature regarding the circular economy drivers that may explain sustainable development, then all basic/standard models (for Panel Data) of each type of effects shall be applied. The only taken assumption, is that we are not dealing with a long panel of data, as they consist in only 10 years.

In terms of considered Random Effects models:

- Pooled Ordinary Least Squares (OLS) Estimator, usually suitable for nonlinear models, requires contemporaneous exogeneity between the error term and the explanatory variables.

- Between Effects Estimator, not so commonly used lately, since it is now a second-best option, as it loses information for using averages instead of the real values, requires strict exogeneity.

- Random Effects Estimator, the most efficient model (when consistent) of the displayed options, also requires strict exogeneity between the error term and the explanatory variables.

In terms of considered Fixed Effects models:

- Fixed Effects (Within) Estimator, also requires strict exogeneity between error and explanatory variables, however it is still consistent even if differences in coefficients is systematic.

- First-differences Estimator, the autocorrelation condition of this model does not require strict exogeneity, and is still consistent even if differences in coefficients is systematic.

Recalling that Centobelli et al. (2021) had considered the explanatory variable of direct taxes, as part of the social pressure indicator, then two Instrumental Variables Estimators, using ERTR as an external instrument associated with EPSI. The two applied types of these External Instruments models will consist of either Between Effects and Random Effects estimation, or of Fixed Effects and First-differences estimations. These models will still be applied even if ERTR proved to have significant in explaining movements of resource productivity (on prior models), as a means of verification that direct taxes, being one of the government interventions suggested tools, does indeed have direct effects on the chosen sustainability goal/indicator.

Regarding Internal Instruments however, we have no theoretical background that proves that any of the values of our explanatory variables, in a prior time period, has any effect whatsoever on the current value of the dependent variable of sustainability. As such, none of these models will be applied.

In opposition, Weerdt et al. (2021) argued how firms will take decisions in two moments in time, as a response to strong enough governmental policies, as a means of optimizations, being the first moment a lesser investment, but, preemptive. Complementing this assertion with the statements of Braz and Mello (2021), which find agents to be key pieces of internal functioning of firms, and while these agents are human beings with adaptive behavior, we may consider that firms are less often to completely change their work force/agents from one year to another. Then both arguments can lead us to believe that the level of sustainability/ resource productive, that is originated by firms, is more so influenced by their previous year value, rather than being an isolated value, measured through each particular year.

Given this deduction then it is pertinent to consider the possible dynamic behavior of our model, as such the most usual dynamic Panel Data models will be applied as well.

The following listed dynamic Panel Data models are in order of increasing model efficiency, which also represents the order of increasing/heavier required assumptions, or in other words, by decreasing number of suitable cases: Anderson-Hsiao (1981); Arellano-Bond (1991); Blundell-Bond (1998).

By computing these models in Stata, then relevant information shall be returned regarding the statistical relevance of the explanatory variables in affecting the dependent variable. In other words, these estimations provide evidence if the two variables representing the tools of government intervention (taxes and incentives) indeed have proved effects as our theoretical model suggested, or if these instruments prove to have too many issues to have any real significant effect, and also make inferences on the remaining two theoretical values (social pressure/policy stringency and environmental commitment). In order to verify this, the statistics accounted for are that of the t (or z) tests of individual significance of one parameter, as well as the statistics of F (or Chi2) tests of joint significance of the full set of all four chosen parameters.

The t (or z) tests have an H0 that the β coefficient of the variable in question is equal to 0, rejecting H0 proves individual significance. As for the F (or Chi2) tests have an H0 that the sum of all tested coefficients is equal to 0, rejecting H0 proves joint significance of the chosen set of parameters.

The t/z tests are the ones that will gives us the most crucial information, to conclude if the drivers of circular economy, and especially taxes and/or incentives can truly promote a more sustainable and greener economy. The joint significance tests are still relevant as a deduction of the full system and even as a measure in itself for interpretation of all the applied econometric models.

However, there are other types of models/methods that did not have suitable data to bringing out appropriate results, such as the VAR type models, the Stochastic Frontiers models and the Program Evaluations models.

VAR type models could have been interesting to study, as they could even display information such as impulse response function, and consider correlations between all variables, rather than just between the one dependent variable and the explanatory variables. However, to perform these types of models, it would be required to have variation of the variables on the time horizon, that is, it would be required to have several more years of data, or at the very least, that the attained data could have been set at a quarterly frequency, rather than annually. Meanwhile only one representation of each variable would be studied over time, that is, only one country would have been the target of such a study, or even an EU average. Such level of frequency and/or number of registered years were not found, making the study of perfectly balanced Panel Data to be more solid.

Stochastic Frontiers models try to maximize possible outputs with the available combinations of inputs, this could have been pertinent as the theoretical model is a costs and profit based function. However, general public and even researchers can not easily access enough real cost, profit and/or revenue data from firms, making these models not applicable, with the available information. This is the same restriction that forced this study to engage in a fully theoretical model as a demonstration without exact/example values, and thus required other models to statistical verify the theory.

Lastly, and possibly the hardest to implement in this study case, were Program Evaluation type of models, which study the effects of policies and similar instruments of state intervention. While very pertinent for the subject of this dissertation, this type of models requires to have data from two split groups of observations, one of them being the control group that is unaffected by the policy, while as the other group is under the influenced of the studied state intervention. This kind of data would require either experimentally crafting a small-scale experiment, or it would require the support of governmental (and other related) entities in order to perform such an analysis to a wider scale.

Regardless of being unable to perform these models, the Panel Data models that were mentioned, may be rather simple in terms of application, however they bring forth statistically verified data, relating circular economy drivers directly to sustainability results. Current studies attempt to either measure drivers that may improve circular economy, while other studies focus on the correlation between level of implemented circular economy and sustainability goals. This implies that the models in this dissertation bring forth information relevant to this discussion (on the current time), as well as create a bridge within these other methodologies, applying econometric models in a way that, relative to the current gathered knowledge, had not been done previously.

However, this study is not without flaws. Many assumptions were made when gathering data that could represent the desired variables, and while these assumptions were logically justified and expected to follow a similar/connected path of fluctuations to their respectively associated indicators, there is a limit to how much they can represent them. In other words, while t and F tests may hold similar/equal results, the obtained coefficients are specific to the four used indicators, and not the 4 desired theoretical variables. This implies that the exact values of these coefficients are not of use. The only piece of information that may be safely extracted from them is rather if said coefficient is above or below 0, as in, if they have a Positive or Negative effect in explaining the dependent variable.

Nonetheless, if statistical significance is found, then this would be solid evidence of the correlation between the theoretical variables as well. As in, theories and their assumptions most likely hold true, and rationally explain the correlation between the indicators used on the methodology. Otherwise, it would be required to find another plausible justification on how those variables coincide with the movements/changes of sustainable development, which are statistically unlikely to be a simple coincidence or trend.

The coding of the Stata DO file used can be found in the Appendix A.

4. Results and Final Arguments

4.1. Results

The Hausman test had probability of Chi2 approximately equal to 0.522, which is greater than 0.05, as such H0 is not rejected. Therefore, Random Effects estimators shall be the ones used for modelling.

As for the autocorrelation tests of the Arellano-Bond and Blundell-Bond dynamic models, all values of the three orders do not reject H0, however, when using the maxldep(1) statistical command on either model, then the first order probability is rejected at the assigned 0.05 significance level. As such, neither models shall use any maxldep command, as the original versions had no autocorrelation.

In regards to the Hansen's J test, both of the Arellano-Bond and Blundell-Bond present really high probabilities of not rejecting H0 (0.9979 and 0.9999 respectively), as such overidentifying restrictions for instruments are valid for both models.

Eight of the computed models, according to which proved to be more suitable, have their pertinent results summarized in table 4.1.

Table 4.1: Results of the 8 pertinent computed models

" * " - reject H0, explanatory variable significance holds at a stricter 0.01 significance level; " ** " - reject H0, explanatory variable holds significance at chosen 0.05, but not at 0.01; " *** " - do not reject H0, explanatory variable does not hold significance at chosen 0.05, but would hold at 0.1 in which case H0 could be rejected.

Model Type	Coefficient β				Prob > |t| or Prob > |z|				P > F or P >Chi2
	EPSI	tgma	ERTR	geeg	EPSI	tgma	ERTR	geeg	
Pooled OLS	+ 8.73	+ 26.16	- 6.04	+ 12.41	0.001 *	0.029 **	0.002 *	0.011 **	0.000 *
Between Effects	+ 4.80	+ 22.48	- 4.57	+ 13.81	0.438	0.129	0.246	0.076 ***	0.165
Random Effects	+ 9.69	+ 28.83	- 6.36	+ 9.39	0.000 *	0.017 **	0.002 *	0.019 **	0.000 *
External Inst. B.E.	- 10.12	+ 17.23	Inst. To EPSI	+ 10.88	0.417	0.281	Inst. To EPSI	0.211	0.157
External Inst. R.E.	- 170.7	+ 177.6	Inst. To EPSI	- 7.62	0.747	0.654	Inst. To EPSI	0.916	0.882
Ander. - -Hsiao	+ 0.54	0	+ 10.51	- 22.39	0.848	Omit-ted	0.172	0.058 ***	0.359
Arella. - -Bond	+ 7.44	- 14.82	- 7.73	- 1.51	0.515	0.942	0.932	0.987	0.000 *
Blund. - -Bond	+ 4.57	- 11.13	- 8.09	+ 10.14	0.400	0.930	0.848	0.914	0.000 *

Source: Own elaboration.

4.2. Interpretations

Starting off with the external instruments models, both end up with a similar conclusion: none of the explanatory variables are relevant in explaining the movements of resource productivity, and even the joint test of all the explanatory variables does not prove any statistical significance. It did not make much sense to apply ERTR (taxes) as an instrument for EPSI (social pressure/policy stringency), when ERTR showed to have individual significance in other models.

However, both results of the external instruments models serve to further prove that direct Taxes should be accounted for as a tool that directly affects sustainability (via circular economy, in this case).

In regards of the random effects models, then, only the Between Effects estimator showed neither individual nor joint significance of any/all explanatory variables. This would imply that none of the variables statistically explain sustainable resource productivity. However, in terms of individual significance, geeg could have been considered to have an impact different than 0 at a significance level of 0.1, and in such case, it would display a positive effect in increasing sustainability. This would make theoretical sense, since the more the government spends on/ gives incentives to firms then the more their environmental effectiveness (to which such green incentives were designed for) increases as well. However, the sum effect of all explanatory variables is still statistically zero, in explaining said efficient progress, and as such this model does not rend the best results.

Recalling however, the Between Effects computes averages instead of the exact/specific values, which takes away information from the variables. And this is noticeable, as both of the other two models, including the most efficient Random Effects estimator show completely opposite results.

Both the Pooled OLS and the efficient Random Effects estimators display the same statistical conclusions: all explanatory variables prove to have significance in explaining resource productivity, as well as the joint significance of the whole model holding true (different from zero). This serves as solid proof that indeed, the drivers of circular economy- social pressure (policy stringency), intrinsic environmental commitment (purchases of environmental monitoring equipment), green economy incentives (government expense in environmental protection) and direct taxes (revenue), all of them can also prove to have statistical effects on sustainable development (productivity of resources).

However, these tests regard the data of the used indicators, rather than data entirely representative of the theoretical variables themselves. Despite this, as previously argued, if we take tgma as an example, then, a country buying more monitoring/assessment equipment for environmental management, proves to have a positive effect in resource productivity/efficiency, this seems logical. Although, if this was only an effect of policies/stringency, then the significance of tgma could conflict with that of EPSI or ERTR with already account for policies/stringency, this implies that tgma has value in itself as well, and if policies were not the (only) reason why firms purchased more of such equipment, then what was the cause of change in tgma? Here is where this study argues it was indeed the intrinsic environmental concerns of firms that firstly drove them to purchase and use such equipment, and thus resulted in a more sustainable development. While no other theoretically supported reasonings are verified, then these results serve to support environmental commitment as well, as a driver than achieves better circular economy, and can make the economy more efficient.

Following this train of thought, then these results show us that, tgma has a positive and significant effect on the dependent variable RPI. The incentives (geeg) also prove to have a positive effect, which means that, when there is a green economy incentive given to a form, to promote circular economy, this can indeed promote sustainability. Regarding direct taxes (ERTR), these have a negative effect, which is logical if we consider that the regular activity of circular economy firms has less available capital, as it is paid to the government/entity, then it has a reverse effect of incentives, and instead, the higher the tax, then the less efficient is the progress towards sustainability. While as social pressure (EPSI) has a positive effect instead, in other words, the higher the intensity of social pressure and/or policy stringency in environmental affairs, then the better firms perform in general in approaching sustainability goals- this is another proof that direct taxes should be considered as a stand-alone instrument of state intervention that directly affects circular market development. It is to note however, that both tgma and geeg would not reject H0 of zero effects, if the level of significance was 0.01, which does not take away from our above state proof, but it does display that ERTR and EPSI had a more statistically significant role.

On the other hand, the dynamic models return to less statistically relevant results. Anderson-Hsiao model shows no individual nor joint variable significance, possibly with the exception of geeg yet again (if 10% was considered instead of 5%). However even at a 0.1 significance level, it would suggest that incentives have a negative effect on sustainability, which is contradictory to both theory and the already attained results. Additionally, Stata omitted tgma in this model, as such it does not seem to be the most suitable model. In regards to the remaining dynamic models of Arellano-Bond and Blundell-Bond estimators, then both display the same key results, that none of the four explanatory variables has individual significance, yet joint together they do have a valid level of influence on the dependent variable of resource productivity. Therefore, while they can indeed influence the development of a country, none of the tools is sufficient by themselves. This does not necessarily contradict Weerdt et al. (2021), as the frequency of this studied data was yearly. What this implies is that, if firms do take a preemptive investment to prepare themselves for governmental policies, then such is made in less than a year, before said policy takes places, in other words, their first reaction occurs in the short term.

4.3. Closing arguments

The theoretical model for shifting the market in favor of circular economy is supported by the econometrical model findings. Statistical relevance of representative variables provide evidence that, the more the government/state financially supports or incentivizes circular and green economies, then the more sustainable becomes the resources efficiency and waste management. Likewise, if the government decreases the taxes directly applied to circular economy or other environmentally related firms, then sustainable development increases as well. Furthermore, the stronger the social pressure and/or policy stringency, the more the economy tends towards sustainability. As well as, in terms of firms, the higher their intrinsic concerns in monitoring their environmental impact, then the more environmentally sustainable their development shall be.

Although in this study it was not possible to use real values to obtain a final result, the state, government and other related institutions may be the entities with the best means of attaining the required information to use such theoretical models. The Banco de Portugal Microdata Research Laboratory – BPLIM (or other similar country specific entities) can be used as an example, their database might contain firm-level data which may prove useful for future research. Alternatively, state representative entities can issue firms to reply to surveys, in order to attain pertinent data of more behavioral/opinion-based/agent perspective aspects, which may not be included in current databases.

On another note, policies seem to cause results in the same year they are applied and/or in the short term, rather than having lasting effects on sustainability. However, positive incentives and environmental concerns were the two variables with higher probabilities of their individual significance being rejected. These were the two variables that were divided into percentages of GDP, and while they display a smaller percentage than that of tax (revenue), this should not affect the statistical results. A possible explanation of this, is that some incentives may not cause progress towards environmental efficiency, as noticed from the literature review, it could be for either causing an undesirable trade-off and promoting circular economy but also causing deforestation or increasing toxic gas emissions, for instances. As for trades in monitoring equipment, this may indeed be given by the fact that intrinsic values of a firm will most likely be expressed in other management choices, or even by the heterogeneous levels of intrinsic values caused by regional differences.

There is, however, another explanation that involves both variables, similar to the findings of Gneezy and Rustichini (2000), but regarding positive incentives rather than fines. That is, when a government provides subsidies to support, for instance, research and development, it may be possible that firms will start to depend on such subsidies, and begin to compute and rationally account for them, taking away from their own intrinsic values. In other words, there may be a trade-off between both variables, to a point which, if the governments would take away such subsidies, firms might interpret it as the market no longer needs them to invest in sustainable research and development, which they would previously commit to since they felt that protecting the environment was also their own responsibility. Thus, explaining why their statistical significance might not be as consistent.

While this study focused on a basic theoretical model to assist in the quantification of policies, as well as to try and econometrically test/verify the significance of said policy instruments, these were the areas where literature had room to be complemented. However, in behavior terms, the real response of firms, their interpretations and unique values are also accounted for, and are still of critical importance. As argued, most noticeably in terms of providing information, some of the suggestions to assist firms still had similarities to those of the OECD (2017) report, regarding households. Given that a firm behavior can be closer to that of the human agent, then when creating policies, it may be pertinent to consider questions such as: Does this create the idea that almost no one is caring for the environment? Or that the state is only doing their part, because their assistance was needed? Will firms believe that the government is taking control of the markets, because most of their competitors do not respect current measures? Do they express the idea that individual efforts are too insignificant? Or is it seen as an encouragement to do what is right? Is it just a question of profit, or also respecting the environment for the future generations? Do firms trust the government and other similar institutions? What about the households, how much do they trust institutions? Can these funds be exploited for other purposes? Are measures so strict that they give an idea of the government totally distrusting firms?

These were just some logical examples of qualitative/behavioral/non-monetary questions that are pertinent to be considered as well. However, these are not the only sources of possible controversial responses to taxes or incentives, as mentioned by Simon (2019), it is undesirable to increase the number of plastic bottles that can be recycled, by reducing the number of reusable plastic bottles. It is also to note that we used only one development goal in the econometric study, when it is still essential that promoting circular economy may increase efficiency in waste management, but without increasing the pollution of oceans, for example. To avoid such undesirable trade-offs, then investment in research and development is required in order to discover new production methods that avoid such controversial costs.

On the topic of plastic bottles, a very recent study conducted by Leslie et al. (2022), revealed that that 77% of their blood donors had microplastic fibers present in their very own blood. This study was not included in the literature review as it is from a field of study very distinct from economics, and also because these results are still very recent and experimental. However, the results of this study point out to the fact that, fibers of plastic, which are very commonly used in bottles and plastic bags, are contaminating the human blood. These results are quite concerning regarding public health, and while many things are not yet certain, one could ask – were plastics already contaminating our blood, and we simply did not have the technology to detect them? Or is this a result of recent events and production methods? These are questions for further research. Even on an economic perspective, this highlights the possibility of a production "cost" in human/population health and life, that must be accounted for as soon as possible.

5. Conclusions

Circular economy has the potential to be a solution for reusing materials and recycling products in order to develop a green and sustainable economy. It can be implemented in several ways, such as creating regenerative systems, industrial symbiosis, or even changes in supply chains of productions. And while reaching sustainability goals regarding resource productivity and waste management, it can also offer an answer to the scarcity of raw materials, or to minimize external shocks such as the Covid19 pandemic which resulted in the limitation of imports and general production, or even the increase of transports costs given the embargo to Russia, who was one of the biggest oil providers. Despite the consequences of such external shocks, the current markets still require government intervention to change from linear systems to circular methods.

In terms of non-financial means of intervention, governments and states could implement laws or regulations to control/stop the production of non-sustainable goods. However, such an extreme measure could result in destroying markets, rather than helping them developing sustainably. Other safer recommendations would be to provide information to firms about circular economy, allow them to communicate with each other, provide a regulated environment to which they can collaborate with each other, promote the usage of circular goods to the population and household, declare legal standards regarding quality and sustainability, and approve of post consumption collection and reutilization strategies.

In terms of monetary intervention tools, governments can implement policies via indirect taxes to wastes and resource (over)exploration or imports; direct taxes to firms, depending on their supply chain and production methods; grant positive financial incentives and subsidies to firms implementing circular methods; or even grant some benefits regarding bank loans for sustainability investments. It is important to note however, that the most suitable type of policy will depend on the level of development/maturity of the market in question, and the heterogeneous regional properties of firms. Therefore, policies must not only discuss their practical value, but also implement said policies in adapted and customized ways, considering the sector, type of product or firms in question, or at the very least complement general policies with regional policies.

Nonetheless, it is still important that governments announce their policies in a clear and transparent manner and present a (monetary/fiscal) value strong enough to change the market, but not excessive to the point of risking to destroy the market. As a means of achieving such a value, basic Cost and/or Profit functions can prove to be helpful in assessing “how much” a positive incentive or how high a direct tax benefit should be given to circular economy methods, to promote sustainable development on the market in question. Governments and other legally related institutions may also prove to be the most pertinent entities to inquire and gather the necessary information of firms, to compute a real practical value from such theoretical models. Therefore, even if such simple models only calculate basic and provisional values, they are still crucial as a means to discuss the practical implementation of taxes or incentives as suitable policies of government intervention. In the example of plastic sectors, sustainable change may occur if circular economy firms have at least as much or more profit than their linear production methods counterparts, at current market prices. To achieve this, tax benefits could assist in reaching similar costs directly associated with the level/amount of production between linear and circular methods, while positive incentives can cover for the fixed costs that may pose a barrier to change (such as cost in research and development) as well as compensate firms for the expected level of losses due to the unstable nature of recycled plastics.

In the econometrics model testing conducted in this study, statistical evidence was found supporting that direct Taxes and positive Incentives are government intervention tools that can indeed promote sustainable development, as well as other drivers of circular economy such as social pressures and environment commitment intrinsic to firms. Results also show that the higher such environment commitment is, then it will generate more sustainable development. Similarly, the higher the social pressures, then the better the results in achieving efficiency goals as well. In terms of positive Incentives, the more a government supports circular firms, then the more sustainable their development will be. Meanwhile, the higher a Tax, then the lower will be the environmental efficiency of a firm, thus justifying implementing higher Taxes on linear methods (to dissuade their production) while granting benefits/lower taxes towards promoting circular systems. These results are in line with the solutions proposed by the theoretical model, and serve as solid proof that using Incentives and Taxes to shift the markets towards circular economy can indeed bring positive results, when policies are properly implemented.

In theoretical terms, it may be justifiable to improve such models with other basic economic theories and methodologies, such as considering market structures, marginal analysis or even other behavioral variables/trends. If suitable data can be accessed, then these models can also be applied in practical case studies rather than being constructed in a purely theoretical method. Regarding the econometrical models, these may still be studied with more suitable and up to date databases, which may better represent the desired theoretical variables. Further access to or creation of experimental data could also allow studying this economic reality with other pertinent model types such as vector autoregressions (VAR), stochastic frontiers or program evaluations.

However, if such policies are inaccurately implemented, then they can prove to have neutral or even negative results. In terms of behavior, if firms have their own intrinsic values, then it is essential that the applied policies do not instrumentalize and take away from these intrinsic environmental concerns. What kind of message does this Tax convey? Does this Incentive give a wrong public image that firms do not care about the environment? Will firms stop their own investments and depend only on these incentives? Will firms respect these policies because conserving the environment matters, or only because the taxes force them to do so? Do these policies imply that past individual firm efforts were too insignificant? Do firms or households trust the governmental decisions? Such are examples of pertinent questions that must be asked, just as they affect human behavior, to some degree, they may also affect firms. Even when the government grants an incentive towards circular economy, if they take away intrinsic moral values and turn them into a simple cost and benefit analysis, then while one driver increases, the other decreases, so the total effect may be neutral. Or even worse, once the incentive is removed, as it was not achieving the desired results, the intrinsic values may not increase to their past value, which may controversially result in a negative impact in sustainable development.

Careless promotion of circular economy may also present other undesirable trade-offs, even if the government intervention tools reached their target results. Such trade-offs could consist in the increase on production of goods that can be reused (in the same or another production system), but also cause the production of environmentally friendly durable and reusable final goods to decrease. Or even worse, circular economy may increase resource usage and efficiency, but damage other sustainability goals, by causing deforestation, increasing toxic gas emissions, polluting oceans or possibly even polluting the very blood of the human population. These are serious undesirable "trade-offs" that must be prevented by further investing in innovation of new circular production methods.

With the basic theoretical models, any policy maker should be able to estimate a general value for a Tax or Incentive. Nevertheless, when considering all of the previously stated issues, any government or entity trying to implement such a policy will also face costs of gathering any missing required data, costs of adapting the policy implementation to each case correctly, or will even have to support further costs in research and innovation of new circular methods. Even if we assume that scientific progress is always possible with the due financial investment, there may be cases where implementing circular economy may simply be too costly, and thus conclude that there are better available alternatives that should instead be invested on. Circular economy proves to have a great potential, nonetheless, it naturally has limitations and measuring these limitations as costs (even if just by general estimations) is crucial to determine which is the best solution to promote a greener economy. After all, Recycling and Reusing materials are important solutions, but in many cases Reusable final products or simply Reducing production for other alternatives may bring better results or simply be more feasible.

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7. Appendix A

Computed Stata code and comments:

"

```
* just to get a general idea on the data

sum RPI

sum EPSI

sum TGMA

sum ERTR

sum GEEG


*solving currency and country scale issues turning them to % of gdp

gen gdpall = GDPALL / 1000000


gen tgma = (TGMA / GDPUSD) * 100


gen geeg = (GEEG / gdpall) * 100


sum tgma

sum geeg


*each country requires an identification number or entry

gen N = 1


 replace N = 2 if Country == "Belgium"
```

replace N = 3 if Country == "Czech Republic"

replace N = 4 if Country == "Denmark"

replace N = 5 if Country == "Finland"

replace N = 6 if Country == "France"

replace N = 7 if Country == "Germany"

replace N = 8 if Country == "Greece"

replace N = 9 if Country == "Hungary"

replace N = 10 if Country == "Ireland"

replace N = 11 if Country == "Italy"

replace N = 12 if Country == "Netherlands"

replace N = 13 if Country == "Poland"

replace N = 14 if Country == "Portugal"

replace N = 15 if Country == "Slovak Republic"

```
replace N = 16 if Country == "Spain"

replace N = 17 if Country == "Sweden"

replace N = 18 if Country == "Switzerland"

replace N = 19 if Country == "United Kingdom"


*using panel data

xtset N Year

xtdescribe

describe

xtsum

*Hausman test to determine if a Fixed Effects or Random Effects model should be used

xtreg RPI EPSI tgma ERTR geeg, fe
```

```
estimates store fe

xtreg RPI EPSI tgma ERTR geeg, re

estimates store re

hausman fe re

* Using random effect estimators
* Pooled OSL

regress RPI EPSI tgma ERTR geeg, vce(cluster N)

* Between effects estimator

xtreg RPI EPSI tgma ERTR geeg, be

* Random effects estimator

xtreg RPI EPSI tgma ERTR geeg, re vce(cluster N)

* External instrument estimator, results already excluded this option

xtivreg RPI (EPSI = ERTR) tgma geeg, re
```

```
xtivreg RPI (EPSI = ERTR) tgma geeg, re vce(cluster N)

xtivreg RPI (EPSI = ERTR) tgma geeg, be

* Dynamic panel data model Instrumental variance estimators

*Anderson-Hsiao

xtivreg RPI (L.RPI = L2.Y) EPSI tgma ERTR geeg, fd

*Arellano-Bond

xtabond RPI EPSI tgma ERTR geeg, twostep vce(robust)

estat abond, artest(3)

quietly xtabond RPI EPSI tgma ERTR geeg, twostep

estat sargan

xtabond RPI EPSI tgma ERTR geeg, maxldep(1) twostep vce(robust)

estat abond, artest(3)
```

```
quietly xtabond RPI EPSI tgma ERTR geeg, maxldep(1) twostep

estat sargan

*Blundell-Bond

xtdpdsys RPI EPSI tgma ERTR geeg, twostep vce(robust)

estat abond, artest(3)

quietly xtdpdsys RPI EPSI tgma ERTR geeg, twostep

estat sargan

xtdpdsys RPI EPSI tgma ERTR geeg, maxldep(1) twostep vce(robust)

estat abond, artest(3)

quietly xtdpdsys RPI EPSI tgma ERTR geeg, maxldep(1) twostep

estat sargan
"
```

End of code file.