UNIVERSITEIT VAN AMSTERDAM

Circular ICT

The effect of the circular economy on the financial performance of ICT companies

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Date 25 June 2021

Version Final

Statement of Originality

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Abstract

Information and Communication Technology (ICT) is one of the world's fastest-growing sectors. It is considered a way to enable energy and resource efficiencies and with that reduce emissions and support a switch towards a more sustainable society. The other side of the coin, however, is the fastest-growing amount of waste that the ICT sector produces, annually worth billions. The Circular Economy (CE) offers a solution to this problem by detaching economic growth from resource use through lowering the use of virgin material resources and energy, decreasing the output of waste and emissions, and regenerating natural systems. Since a consensus on the effect of CE on firm performance has not been reached, this study aims to discover whether circularity efforts have a positive effect on the financial performance of ICT companies. The relation between Return on Assets (ROA) and four separate CE actions, including increasing energy and water efficiency, perceiving waste as valuable, and decreasing emissions is examined to find an answer. By conducting a quantile regression analysis, the research offers thorough insights into the effect of four CE actions on different levels of financial performance. Findings show that high-performing ICT companies benefit from all four actions, while medium-performing companies solely benefit from increasing energy efficiency and perceiving waste as valuable, and low-performing companies do not benefit from CE actions.

1. Introduction

Information and Communication Technology (ICT) is one of the world's fastest-growing sectors. It is considered a way to enable energy and resource efficiencies and, with that, reduce emissions and support a switch towards a more sustainable society (Pohl et al., 2019). The other side of the coin, however, is the fastest-growing amount of waste that the ICT sector produces, which is annually worth $62.5 billion (World Economic Forum, 2019), as well as an extensive level of emissions which, if uncontrolled, will rise to a share of 14% of the total global emissions footprint by the time 2040 is reached (Belkhir & Elmeligi, 2018).

This is where the Circular Economy (CE) could offer a solution. CE is an alternative to the current "take, make, and dispose" linear business model (Ghisellini et al., 2016). Inspired by previous school of thought such as Industrial Ecology (Erkman, 1997), Cradle to Cradle (McDonough & Braungart, 2010), Performance Economy (Stahel & Reday-Mulvey, 1981), and Biomimicry (Benyus, 1997), CE aims to find ways in which end-of-life products and materials can remain valuable for alternative uses. This results in a reduction of the amount of virgin materials inputs and additionally a decrease in waste and emissions (Ellen MacArthur Foundation [EMF], 2015). The 3R principles of reduce, reuse, and recycle are commonly used to describe the idea behind CE (Ranta et al., 2018). By committing to these principles, it is possible to separate economic growth from resource and energy use, thus offering a win-win situation for ICT companies to keep growing while mitigating the environmentally damaging effects.

CE is said to be a driver of success for the United Nations Sustainable Development Goals (SDGs) 7 on affordable and clean energy, 8 on sustainable economic growth, 11 on sustainable cities and communities, 12 on responsible consumption and production, 13 on climate action, 14 on life below water, and 15 on life on land (United Nations, 2018). In

March 2020, the European Commission took on the circular economy action plan (CEAP) as part of the European Green Deal. The list of actions includes changes of legislation with regards to reporting on circular activities, facilitating circular efforts with laws such as "right to repair", motivating proper waste management, and stimulating circular innovations through cohesion policy funds (European Commission, 2020). International corporations have become strategic partners with the Ellen MacArthur Foundation to formulate ambitious but achievable goals which will enhance the incorporation of circularity into their businesses in the near future (Ellen MacArthur Foundation [EMF], 2017). These examples are a few of the many circularity initiatives that are currently being undertaken. Governments, NGOs, society, and businesses are all starting to become aware that the circular economy is a promising idea that will change the current state of the art.

Despite the growing attention for both the environmental and economic opportunities offered by CE, the adoption of this model in practice is still rather slow. In research on barriers to CE, Kirchherr et al. (2018, p. 267) have shown that cultural barriers such as a "hesitant company culture" are the most prevailing. Second are market barriers, with "high upfront investment costs" mentioned as one of the roadblocks to CE. Besides that, Ranta et al. (2018) found "business impact of CE is perceived as low" as one of the main barriers to CE. In another research results showed that companies were "not committed to environmental issues because they do not think it would increase their profits and competitiveness" (Ormazabal et al., 2018, p. 157). The barriers mentioned above can be considered to be caused by a lack of knowledge about the effect of CE on the financial performance of a company. Since a worsening financial performance could cause a company not to be able to pursue the current way of business anymore, it is essential for a firm to be assured that CE efforts do not negatively affect the financial performance (Blasi et al., 2021). Therefore, it is necessary to find a consensus on whether it pays to become circular.

Even though considerable research has been done on the relationship between CE and financial performance (e.g. Ranta et al., 2018; Zhu et al., 2010; Rosa et al., 2019), there has not been a study in which quantitative analysis is applied to find more robust results. Moreover, most attention has been on manufacturing companies, which leaves ICT an interesting, relatively untouched sector yet to be analysed. With that in mind, this study aims to find an answer to the following question: *Does being circular positively affect the financial performance of ICT companies?* To answer this question, results will be acquired through a quantile regression analysis focusing on different quantiles of financial performance.

There is a strong belief that this work is both important for the academic field as well as for the development of practical implications. First, this study offers results from an analysis that has not been performed before. This adds to the current CE literature as it gives new insights into the effect of CE on financial performance. Second, by using a quantile regression analysis, an additional understanding is developed about how different levels of financial performance are affected by CE efforts. Third, it will have help managers in the decision-making process of what to focus on when committing to CE. Besides that, the outcome could help create more certainty about circularity, which in its turn could stimulate the adoption of a circular business model for ICT companies, and with that, provide a more sustainable solution for sustainability supporting technology.

In an effort to answer the question, a quantitative analysis is conducted, which is presented in the following five sections. The next section, "Theoretical Framework", focuses on defining CE and the principles and strategies surrounding the idea, as well as creating a framework that enables analysing CE in the ICT sector. Section three, "Methodology", explains how the research is conducted by providing information about the data sources used, the variables chosen to analyse the relationship between CE and financial performance, and the type of regression analysis used. This is followed by the section "Results", which provides a thorough overview of the results obtained from the analysis. Section five, "Discussion", focuses on explaining and discussing the insights derived from the results, after which both academic and managerial implication are discussed, ending with limitations and ideas for future research. The last section, "Conclusion", provides an overview of the main findings and several concluding remarks.

2. Theoretical Framework

In order to understand the relation between a circular business model and the financial performance of companies within the ICT sector, it is essential to define a circular economy. Furthermore, the mechanisms of value creation through circular efforts should be discovered, which is done by reviewing various frameworks. This is followed by the exploration of the ICT industry and specific circularity efforts. The relation between CE and financial performance is discussed last.

2.1 Circular Economy

2.1.1 Circular versus Linear

The circular economy is increasingly being recognised by governments, companies, and society as an alternative to the linear economy. In the linear economy, resources are taken from the earth and turned into products that are thrown away once not needed anymore. This mechanism, referred to as the “take-make-dispose” system (Ellen MacArthur Foundation [EMF], 2015), causes several negative externalities. The extraction of resources from the earth and the disposal of waste back onto the earth are causing detrimental effects on the earth's ecosystems, such as "biodiversity loss, water, air and soil pollution, resource depletion, and excessive land use" (Geissdoerfer et al., 2017, p. 757). The linear economy is not only harmful to the environment, however. Price volatility is rising, companies suffer from the increased vulnerability due to the risks associated with the declining accessibility of resources, and supply disruptions are becoming a more common phenomenon, which makes it difficult to keep up with the increasing demand for products (EMF, 2015).

The circular economy aims at minimising waste production, energy usage, and extraction of natural resources by promoting the use of products and materials for as long as these are valuable. Consequently, the ultimate goal of CE is to separate resource extraction and environmental degradation from economic growth (Liu et al., 2009; Xue et al., 2010). It can be defined as “a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017, p. 759).

During the past decade, numerous scholars have made an effort to describe and analyse CE according to several different methods, including CE origins and principles (e.g. Ghisselini et al., 2016; Ranta et al., 2018; Kirchherr et al., 2017: Prieto-Sandoval et al., 2018), CE business models (e.g. Bocken et al., 2016; Lüdeke-Freund et al., 2019; Rosa et al., 2019; Heyes et al., 2018), drivers and barriers of CE (e.g. Zhu et al., 2010; Kirchherr et al., 2018; Gue et al., 2020), and circularity metrics (e.g. Rossi et al., 2020; Moraga et al., 2019; Vinante et al., 2021). As the objective of this research is to find the effect of circular activities on the financial performance of a company, the focus will be on CE principles as a starting point to discover the relevant circular strategies and on CE business models to grasp the ways in which companies can capture the value created by the circular strategies.

2.1.2 Principles of Circular Economy

A commonly used approach to CE is the 3R principles of reuse, reduce, and recycle (e.g. Ghisellini et al., 2016; Ranta et al., 2018). *Reuse* describes the act of using products, components, or materials numerous times for the same purpose for which they were created without having to alter anything. *Reduce* refers to increasing the efficiency of production and consumption processes in order to minimise the input of energy and raw materials and the output of waste and emissions (EU, 2008). The increase of efficiency can be reached by, for instance, the introduction of new technologies (Su et al., 2013). *Recycle* describes the act of repurposing obsolete components or materials, i.e., "waste", by reprocessing it into new products, materials, or substances (EU, 2008).

Besides the 3R principles, scholars have tried to create a more extended and detailed version to describe CE, resulting in, for instance, the 4R and 6R frameworks. *Remanufacturing* is a principle that is added to form one version of the 4R-principles (Bressanelli et al., 2020). This describes the act of using components from discarded products to create a new product with the same function and with the quality of a brand new product (Morseletto, 2020). In another study, *recover* is the fourth principle and describes the act of disassembling and preparing components from obsolete products, so these can become part of a new product (Yang et al., 2017). *Repair* is the principle that completes the 6R framework and describes the act of making minor necessary improvements to products to make these functional for use again (Ghisellini & Ulgiati, 2020).

An important aspect of CE that is not explained by the R-principles is that circularity starts at the design phase of a product or service. Redesigning a product of service such that the use phase is extended and repairing, remanufacturing, refurbishing, and recycling can be done more easily fosters a more circular business (EMF, 2015). Besides promoting the eco-efficiency of production and consumption, it is important to make a switch from the use of finite resources to renewable resources, and with that promote eco-effectiveness (Heyes et al., 2018; EMF, 2015).

2.2 Circular Strategies

CE actions revolve around the management of two types of material flows: *technological* nutrients, which are meant to provide as much value as possible without returning back to the biosphere, and *biological* nutrients, which are meant to safely return to the biosphere after the use phase as fuel for nature (William & McDonough, 2002). In the case of the ICT industry, technological nutrients will play the dominant role when considering circular efforts, which will therefore be the focus of this research.

CE actions can be described by use of the actions of closing the loop, slowing the loop, and narrowing the loop. *Closing the loop* describes the act of closing the material flow between the end-of-life and production, i.e., using waste as food. *Slowing the loop* describes slowing down the process from production to end-of-life, achieved by extending the life of a product or component. *Narrowing the loop* describes the increase in efficiency, with the aim to have the same level of productivity while using fewer resources (Bocken et al., 2016). Geissdoerfer et al. (2017) adds to this *intensifying the loop*, which highlights a more intensive use-phase, and *dematerialising the loop*, which describes software and service solutions as an alternative to product utility.

Lüdeke-Freund et al. (2019) highlight the main reverse cycles, i.e., the flow of products or materials back into the value chain, characterising CE business models whilst making a distinction between biological and technological nutrients. The reverse cycles are displayed in a diagram that shows the difference in "distance" between the end-user and the value chain. Three technological reverse cycles of interest for this study are explained in the order of the shortest distance to the longest distance. *Reuse and redistribution* comprises the exchange of a product between the end-user and a service provider that generates value by reselling the product without having to utilise a high amount of inputs and effort.

Refurbishment and remanufacturing explains the reverse cycle from the end-user back to the manufacturer. In this cycle, the product needs components to be replaced while part of the product is still good for use. This requires more input and effort than the first cycle, however not as much as for producing a brand new product. *Recycling* is the exchange between the end-user and the parts manufacturer, where separate components are sorted and prepared for use in a new production process. Even though this requires more inputs and effort, it still allows for lower use of virgin materials resources. "The power of the inner circle" is used by EMF (2012) to explain the difference in value creation of the three above-mentioned reverse cycles. The tighter the circle, the less amount of labour, energy, and input is needed, and at the same time, the lower the emissions and waste output. Moreover, a tighter circle will also prevent the linear supply chain inefficiencies from happening, resulting in overall savings on virgin material input. Another value creation mechanism described by EMF (2012) is "the power of circling longer". This mechanism explains the additional value creation due to an extended use of products and materials, which causes a lower need for virgin materials. The main lever for both these mechanisms is the rising resource prices due to the rising shortage of raw materials.

Besides "value created", CE brings along a new form of value, namely "value retained". As Lüdeke-Freund et al. (2019, p. 55) describe it, "the value created along forward supply chains is quite evident—raw materials are processed into products that are sold. In contrast, the "value retained" of a used product, its components, and its materials is not as easy to determine in the current linear economy". As such, in order for companies to capture new forms of value created, business model innovation is needed so that there is an alignment with the CE principles. Moreover, Pieroni et al. (2019) state that since CE is increasingly being recognised as a suitable alternative to the linear economy, CE business model innovation is essential for the companies' competitive advantage.

Remarkably, most of the CE business models focus on manufacturers and are thus more oriented towards the production of tangibles (Bressanelli, 2020). For instance, Bocken et al. (2016) identified six business models that support circular value creation, delivery, and capture of technological nutrients: a) *access and performance* model, which offers a product as a service rather than selling it; b) *extending product value* model, which prolongs the use period of a product by repairing or remanufacturing; c) *classic long life* model, which focuses on producing products with a high endurability which as a result can be reused multiple times; d) *encourage sufficiency* model, which facilitates a switch from a focus on quantity to quality and taking a "non-consumerist" approach; e) *extending resource value* model, which uses "waste" materials as input for other production processes; and f) *industrial symbiosis* model, in which "waste" materials from other companies are used as inputs for the productions process. As a reaction to literature mainly focusing on circularity within the manufacturing industries, Heyes et al. (2018) built on sustainable business models archetypes by Bocken et al. (2014) to point out four CE business models that are more suitable for service-oriented companies: a) *maximising materials and energy efficiency* model, which builds on the idea of using a lower amount of resources leading to less waste and emissions; b) *encouraging sufficiency* model, which, similar to above, decreases the amount of products in use by offering products as a service ; c) *creating value from waste* model, in which waste is used as inputs for other processes, for example by providing a take-back service; and d) *adopting a stewardship role* model, which entails taking business partners and other stakeholders along in the CE journey by for instance engaging with upstream suppliers.

Although the previously mentioned CE business models are a good starting point for identifying the possibilities to create value through circular efforts, it does not provide a clear view on how this could be applied to the ICT sector. For that reason, CE efforts in the ICT sector will be discussed next.

2.3 Circular ICT Sector

ICT companies are believed to play an essential role as a driver in the transition towards CE, both by dematerialising and by increasing energy and resource efficiency. What should not be ignored, however, is that ICT can cause negative effects, too. A growing number of companies and consumers are utilising ICT solutions – that need energy to function – as a tool for becoming more efficient, with an increase in the use of energy at the user level as an indirect result (Pohl et al., 2019). As a direct effect, the rising demand for ICT solutions causes an increase in the use of resources to produce the hardware and an increase in energy use to keep the back-end running (Horner et al., 2016). Consequently, if ICT companies do not join the transition towards a circular approach, ICT solutions could have a net negative environmental effect in the end. However, in order for this transition to be successful, it must improve ICT firm performance. In the following two sections, CE examples of the ICT sector are explored, after which several value creation mechanisms are identified to be on interest for the ICT sector. Due to the scope of this research, the focus will be solely on the CE actions of the companies that have an influence on the direct effects.

2.3.1 Examples from the ICT sector

Even though many studies have been dedicated to identifying CE business models for numerous specific industries, the ICT industry has not been touched upon yet. Nevertheless, by combining previous research on CE business models and specific examples of the ICT industry, this section develops a framework that can be used to discover how circular efforts within the ICT industry enable circular value creation. Fan and Fang (2020) stress the fact that at the micro-level, it is fundamental to distinguish between different types of companies to successfully interpret and develop CE strategies. With that in mind, a distinction is made between three subcategories within the ICT sector: manufacturing companies, trade companies, and service companies.

Apple's aim to make every product carbon neutral provides an illustrative example of how ICT manufacturing companies can deploy circularity principles and make a move towards a CE business model. Three levers are used by Apple to achieve circularity. *Sourcing and efficiency* focuses on using recycled and renewable materials alongside the aim of improving material efficiency in the production process. *Product longevity* is directed at prolonging the use of, on the one hand, products by designing durable products, offering repairs, and making use of software updates, and on the other hand, components by reuse and refurbishment. *Product end-of-life* aims to improve the collection of devices and the recycling process to use these as inputs for new devices and to address the e-waste challenge. Besides these three levers, Apple mentions two other goals that can be considered as part of a circular strategy. First is the goal of waste-free operations along the entire supply chain, where zero waste goes to landfill. Second is the commitment to use water efficiently and to look for alternative water sources (Apple, 2021). Of the above-mentioned CE business models, three are identified as concordant to Apple's CE strategy. Extending product value model, as both repair services and software updates enable the longer use of the products, classic long life model, which is in line with the aim to produce long-lasting devices that can be reused, and extending resource value model, since devices are collected such that recycled materials can be used as inputs for another production process.

WESCO International, a leader in supply chain solutions distributing electrical products, is chosen as an example for the ICT trade sub-sector. Even though the company does not explicitly mention a circular strategy, certain aspects of its sustainability strategy can be considered to promote circularity or as the first step towards a circular strategy. Since the company consists of approximately 500 distribution centres and around 2000 vehicles for distribution activities, increasing energy efficiency is one of the key components of WESCO's strategy. Emissions are another important aspect due to their distribution activities. By using renewable energy and carbon offsetting, the company aims to lower the level of emissions. The last aspect of the circularity strategy is reducing the waste stream the company generates by offering take-back services for clients and looking at opportunities to reuse and recycle both the taken-back materials and waste materials flows from internal operations (WESCO, 2019). In the case of WESCO, two of the above-mentioned CE business models are in line with its strategy. The maximising materials and energy efficiency model is consistent with the aim to increase energy efficiency and reduce the level of emissions, and the creating value from waste model covers the take-back services and the objective to reuse or recycle waste materials.

Google is selected to provide an example of the strategies that ICT service companies could execute to become a circular company. With the CE mission to CE mission to "accelerate the transition to a circular economy in which business creates environmental, economic, and community value through the maximum reuse of finite resources", Google (2019, p. 3) offers a thorough illustration of how an ICT service company can set goals to reach circularity. The CE action plan is split up into three parts, each focusing on one part of the business, including the data centres, the workplaces, and the consumer electronics. Since the aim is to find strategies for ICT service companies, the actions that are part of the first two categories will be discussed. The data centres are powered by renewable energy and work towards the aim to create zero-waste data centres by reusing, repairing, refurbishing and remanufacturing hardware, recycling materials, and ensuring that no waste goes to landfill (Google, 2019). Within the supply chain, new contracts are developed to use recycled materials. Besides that, each data centre is built to maximise energy and water efficiency (Google, 2020). Similarly to the data centres, the workplaces are powered by renewable energy and aim to minimise the office waste streams. Next to that, regenerative strategies are designed for energy, water, and waste (Google, 2019). In the same way as WESCO, Google's strategy is pursuant to the maximising materials and energy efficiency model, as both data centres and workplaces are powered by renewable energy and because there is an aim to regenerate and achieve maximum efficiency on water and energy. By reusing, repairing, refurbishing and remanufacturing hardware and recycling waste materials, Google's CE strategy is in coherence with the creating value from waste model.

The CE business models help grasp the way in which, within different ICT sub-sectors, value can be generated through CE actions and strategies. However, the effect of CE on the bottom line requires an understanding of the added value that CE can offer in the value creation, delivery, and capture processes.

2.3.2 Circular Economy and Financial Performance

CE is regarded as an opportunity to simultaneously improve the financial performance of the company and enhance its environmental responsibility. Since prior results on the relation between financial performance and CE are mainly based on qualitative research, these will differ from the results presented in this study. As such, the following section highlights the key mechanisms through which CE is expected to have an effect on firm performance, which are based on a combination of findings from CE studies and quantitative results from studies that are related to the different mechanisms. Expected negative effects of CE on financial performance are discussed first, which is followed by positive effects.

As mentioned before, the adoption of CE principles by the business sector is still rather slow, partly due to uncertainty about the effect on the firm performance. In a study towards CE barriers, Kirchherr et al. (2018) found two market barriers that cause companies to hold back from CE actions. First and foremost are the low virgin material prices, which make it unattractive for companies to switch to either renewable or recycled materials. As long as prices for virgin materials are low, it will not be beneficial for the performance of a company to switch to secondary materials. High upfront investment costs are mentioned to be the other barrier resulting from the lack of knowledge about CE that still persists amongst the business sector. Similar to the first barrier, the high costs make switching to a CE business model unattractive as it does not have a positive effect on financial performance. García-Quevedo et al. (2020) mention the high costs related to a transition towards a green business, which is specifically the case for small to medium enterprises. This is supported by the findings of Ormazabal et al. (2018) that show the restraint on CE is caused by the lack of convincement for companies that the CE benefits (e.g. cost reduction, revenue generation) outweigh the costs. Ghisselini et al. (2014) added to this that reducing negative externalities seems to have higher costs than benefits, making the CE action to reduce emissions not financially attractive.

Barnett and Salomon (2012) found the relationship between corporate social performance and financial performance neither to be negative nor positive. Rather, from their analysis, they concluded the relationship to be U-shaped, meaning that companies that invest little to none or a high amount in social responsibility are financially better off than companies that invest a medium-level amount. This shape is attributed to the aggregating trust of stakeholders in the capability of the firm to do good, which for which companies are rewarded financially.

The main component of a positive effect of CE is cost efficiency (Ranta et al., 2018), which is also considered to be an important part of the “circular advantage” (Accenture, 2014). Through material and energy efficiency, companies are able to deliver the same amount of products or services with a lower amount of inputs, which decreases the costs of production, operations, logistics, and transportation (Bocken et al., 2014; Rosa et al., 2019).

Moreover, working with recycled or reused materials leads to a reduction in materials purchasing costs compared to new materials (Nelen et al., 2014). A simple decrease in the use of energy, water, and raw materials also adds to the lowering of production costs (Ormazabal et al., 2018; Ghisetti & Rennings, 2014). Thus, the combination of resource efficiency, utilization of secondary materials and components, and a decrease in the use of resources and energy will lead to an overall cost reduction for companies pursuing CE strategies, which will eventually have a positive effect on the financial performance.

The strengthening of a company's competitive position can be seen as another effect emerging from a commitment to CE. As a consequence of lower production costs, a company can offer a price of its products or services that provide an advantageous competitive position compared to companies that do not commit to CE (Bocken et al., 2014). Not only does competitive pricing create a relative advantage, enhancement of a company's reputation as a result of CE efforts also contributes to this. Focusing on the reduction of negative externalities, i.e., waste, emissions, and pollution, a company could enhance its reputation (Rosa et al., 2019) with an increase in financial performance as a result (Sroufre et al., 2019; Bressanelli et al., 2020).

Extra revenue generation, or the creation of new profit pools, is regarded as another positive effect of CE. With the circularity principles in mind, companies can generate extra value by offering new products such as "waste" materials and components, more durable products, and new services that promote circularity, such as take-back services or repair services. Ormazabal et al. (2018) mention the commercialization of sub-products to be an important determinant of the financial CE success of companies. Similarly, Bressanelli et al. (2020) identified selling recycled materials and recovered components to be a source of financial value for companies. With a specific focus on the ICT sector, Park et al. (2010, p. 1497) stress the fact that "there are many unrealized opportunities to reuse, reclaim, and recycle ICT products and materials, while the financial value generated from these streams can be substantial". The creation of new products or services opens up previously untouched markets, too, allowing the number of profit pools to increase in size (Nußholz, 2018). Moreover, when a manufacturer offers durable products, extra revenues can be made by asking for a premium price and by acquiring an increased market share (Bocken et al., 2014; Bressanelli et al., 2020).

2.4 Hypotheses

CE actions are assumed to both negatively and positively influence financial performance. However, when looking back at the arguments presented above, the negative effects can all be summarised into one possible cause for harming the financial performance, namely high costs. The positive effects, however, are based on several thoroughly backed arguments, consisting of a combination of decreased costs, increased revenues, and an enhanced reputation. Consequently, there is sufficient evidence to believe that CE will positively influence the financial performance of ICT companies.

Cost reduction due to resource and energy efficiency is believed to be the main driver for CE value generation. Since water is an important factor in the CE strategies of two of the ICT cases mentioned above, this is the “resource” that will be focused on in the current study. As such, the following two hypotheses are proposed.

H1*: Increasing energy efficiency will positively affect the financial performance of ICT companies.*

H2*: Increasing water efficiency will positively affect the financial performance of ICT companies.*

By changing the perception of “waste is trash” to “waste is food”, ICT companies can enhance their performance by both retaining current and creating new value. Through the reuse of products and components, companies decrease the inputs costs as fewer new materials are needed. Besides that, products or materials that are not of use in production anymore can be sold to third parties, which creates a new value stream. With this in mind, the following hypothesis is proposed.

H3*: Reducing, reusing, recycling, treating, or phasing out waste, including e-waste, will positively affect the financial performance of ICT companies.*

As part of the *reduce* principle of CE, reducing emissions is an important aspect for companies committing to circularity. As previous studies have shown, focusing on decreasing negative externalities, in this case emissions, will enhance a company's reputation. The enhanced reputation will, in its turn, have a positive effect on the financial performance by allowing a company to ask for a premium price and increase market share. Having said the above, the following hypothesis is proposed.

H4*: Reducing the level of environmental emissions will positively affect the financial performance of ICT companies.*

3. Methodology

3.1 Sample and Data

For the analysis performed in this research, data will be gathered from two sources: ORBIS and Thomson Reuters Refinitiv Eikon. ORBIS is a dataset created and updated annually by Bureau van Dijk and provides in-depth financial and general information about over 400 million companies worldwide, both private and listed. The data from this dataset is used for the dependent variable that measures the firm performance, as well as the control variables. Thomson Reuters Refinitiv Eikon is a desktop that provides real-time access to financial information, including environmental, social, and governance (ESG) performance indicators for companies worldwide. The scores, composed of company-reported information, are not based on what is defined as "good"; rather, peer groups are used to create relative scores. Two types of data from Thomson Reuters Refinitiv Eikon are used. First are dummy variables that assign the value 1 if a question can be answered with “Yes” and the value 0 if the answer is “No” or if insufficient information for the question is found. Second are percentile ranks, which provide a relative score based on the industry of the company in question. These scores give an overview of how well the company is performing in certain aspects compared to its peer group. As this score is based on a rank, it has a low sensitivity to outliers (Refinitiv, 2021). As the latest updated information from ORBIS is from the year 2020, the selected year of the information from Eikon is 2019. This allows a cross-sectional analysis of the effect of CE actions on the financial performance of the company.

The building of the database starts with selecting all companies that are part of Thomson Reuters Refinitiv Eikon, which is 56,846 companies. As the focus on the analysis is the ICT sector, the first step is followed by selecting a relevant sample of companies using NACE codes provided by Mas et al. (2012). They composed a complete list of all NACE codes that are regarded as part of the ICT sector, guided by the OECD ICT sector definition. NACE codes allow the results to be compared at a world level (Eurostat, 2008), which is useful for this study as the sample will represent ICT companies from around the world. An overview of the NACE codes belonging to the ICT sector can be found in Appendix 1. The number of ICT companies in the database is 2,797, including ICT trade companies and ICT service companies. As the database consists of 793 variables, the next step is to select the variables that can be used to measure circularity, as well as to drop duplicates and variables that have a high number of missing observations. After merging the cleaned dataset with the ORBIS dataset, the number of companies is 456. The sample is finalised by selecting the companies on which information is available from ORBIS for the year 2020. The final number of companies that are used for the analysis is 353, of which 15 ICT trade companies and 338 ICT service companies.

3.1.1 Dependent variable

Financial performance is the dependent variable in this research. Agreement in the CE literature on the right measure for financial performance has not been reached yet. In this case, Return on Assets (ROA) is used to measure financial performance (Bassetti et al., 2021; Elsayed & Paton, 2005; Rossi et al., 2020). This variable is calculated by dividing net income before taxes by total assets. ROA is an appropriate measure to use when analysing firms within the same sector (Al-Tuwaijri et al., 2004), which is in line with the sample used. For this analysis, the log transformation of ROA is used to ensure a non-skewed measure.

3.1.2 Independent variables

The environmental scores from Thomson Reuters Eikon Refinitiv are used to create independent variables. As different circularity efforts create value in a different way, it is of the essence to use a separate variable for each category of efforts. This allows identifying the effects of CE on financial performance in a more comprehensive way. With this in mind, the four independent variables are created by selecting corresponding dummy variables and percentile scores and using STATA software to perform a factor analysis. Following Ormazabal et al. (2018), the Varimax algorithm was used to employ an orthogonal rotation of the components' matrix. To ensure a non-skewed measure, log transformations are used. An overview of the composition of each independent variables can be found in Appendix 2.

Energy measures the efforts of the company to lower the level of energy used by increasing energy efficiency and switching to renewable energy. This variable has been used in multiple studies as a CE indicator. For instance, Rossi et al. (2020) identified the use of renewable energy as one of the CE indicators, whilst mentioning the financial benefits of energy reduction, too. Korhonen et al. (2018) highlight energy efficiency to be one of the key objectives of CE, while Li et al. (2010) described energy efficiency and energy conservation to be the basic element of the CE policies proposed by the Chinese government.

Water measures the efforts of the company to decrease the amount of water used by increasing efficiency through both targets and policies. Bocken et al. (2016) identify resource efficiency to be part of the CE action of narrowing the loop. Next to energy efficiency, Korhonen et al. (2018) mention the reduction of raw materials to be another key element of CE.

Waste measures the efforts of the company to reduce the amount of e-waste and waste in general by initiating actions including recycling, reusing, reducing, and phasing out waste. As e-waste poses a significant challenge for the ICT sector, it is essential to take this along in the analysis. Heyes et al. (2018) emphasise the importance of this matter, as e-waste is the largest source of waste in the world and because it consists of a lot of scarce materials which are still valuable for other purposes. Treating waste, in general, is another aspect that should be taken along. Amongst others, Ormazabal et al. (2018) mention this to be the key element of "recover", the CE strategy focused on the last phase of a product.

Emissions measures the efforts of the company to set targets and create policies with the aim to reduce environmental emissions generated by the company. Considering the high amount of greenhouse gasses that the ICT sector emits (Arushanyan, Ekener-Petersen, & Finnveden, 2014; PWC, 2020), it is imperative to include this in the analysis. Heyes et al. (2018) identified reducing emissions to be a common CE action on a micro-level.

3.1.3 Control variables

As the dependent variable in this research is the financial performance of a company, it is essential to control for factors that could have an effect on this. Previous studies that have identified these specific variables are used as a guide for selecting the appropriate controls.

Age is the first control variable, which is the number of years the company exists. It is calculated by deducting the year of constitution of the year of data acquisition. Age is shown to have a positive effect on financial performance due to the increased capacity to acquire profitability growth from sales growth and an increase in productivity as a result of a higher level of experience both internally and within the industry (Mallinguh et al., 2020; Blasi et al., 2021).

Size is calculated by the log transformation of the total assets of the company. This variable is included as a control since it is proven to have an effect on the financial performance; due to economies of scale that are a result of size, size can positively influence the capacity of the firm to invest, especially for environmental investments (Basetti et al., 2021; Duque-Grisales & Aguilera-Caracuel, 2019; Ghisetti & Rennings, 2014; Elsayed & Paton, 2005).

EBITDA is used as a proxy for the competitive position of the company within its industry. Following Blasi et al. (2021), this control is a dummy that assigns the value 1 if the EBITDA of the company is greater than or equal to the industry's average and 0 if the EBITDA is below the industry's average.

CapEx, or capital expenditures, is calculated using the formula $Total\ Assets_t - Total\ Assets_{t-1} + Depreciations_t$ and measures the resources of the firm to promote future growth and the ability to invest (Amir et al. 2007; Mak & Kusnadi, 2005). This variable is included to control for the positive effect it has on financial performance.

Leverage is used as a proxy to control for the risk of a firm, as this can negatively influence the financial performance (McWilliams & Siegel, 2000; Elsayed & Paton, 2005). For this research, leverage is calculated as the ratio of total liabilities to total shareholder equity.

AdvertisingIntensity is calculated as the ratio of total intangible assets to total sales of the company, following the formula of Chapple et al. (2001). This control included as it has been shown that marketing capabilities can be financially rewarding for a firm (Barnett & Solomon, 2012). Besides that, advertising can help increase consumers awareness about the environmental efforts of a company, which could have a positive effect on the financial performance (Elsayed & Paton, 2005; McWilliams & Siegel, 2000).

Table 1 presents a summary of the descriptive statistics of the variables that are used to test the hypotheses.

Table 1
Descriptive statistics.

Variable	N	Mean	SD	Min	Max
ROA	265	1.760209	1.040495	-3.101092	4.442957
Energy	351	-.5669274	1.185834	-2.046293	.968878
Water	351	-.1285404	.4327213	-.4304578	1.067927
Waste	351	-1.029754	1.796979	-3.164228	.7193825
Emissions	351	-.3361785	.813752	-1.17033	.8172765
Age	352	28.15057	25.17262	1	168
Size	353	14.91712	1.733959	11.39748	20.08036
EBITDA	353	.1869688	.3904399	0	1
CapEx	350	1315597	5254576	-3686675	5.13e+07
Leverage	350	2.813596	50.10171	-499.6744	772.5
AdvertisingIntensity	349	.8313741	1.277344	0	10.86322

3.2 Regression Model

For this analysis, a nonparametric quantile regression analysis is utilised, which is a more comprehensive alternative to the classical ordinary least squares (OLS) regression analysis. Whilst the OLS regression provides an estimate of the conditional mean change of the dependent variable as a result of a change in the independent variable, the nonparametric quantile regression offers the possibility to estimate the change of the dependent variable at any selected distribution (Arshad et al., 2018). This allows for a more thorough analysis of the complex relationship between the dependent and independent variables and more nuanced insights. As mentioned by Blasi et al. (2021), for environmentally orientated studies, an OLS regression could omit certain essential factors that would not be missed when doing a quantile regression analysis. Applying this analysis could add another layer of insights since it could expose a difference in the effects of CE on different levels of financial performance of a firm, which could likely foster motion towards reaching a consensus. To provide a comparative baseline, an OLS regression will be included in the analysis, too. The following linear regression models are estimated:

H1: $ROA_{i,t} = \alpha + \beta_1 Energy_{i,t-1} + \beta_2 Age_{i,t} + \beta_3 Size_{i,t} + \beta_4 EBITDA_{i,t} + \beta_5 CapEx_{i,t} + \beta_6 Leverage_{i,t} + \mu_{i,t}$

H2: $ROA_{i,t} = \alpha + \beta_1 Water_{i,t-1} + \beta_2 Age_{i,t} + \beta_3 Size_{i,t} + \beta_4 EBITDA_{i,t} + \beta_5 CapEx_{i,t} + \beta_6 Leverage_{i,t} + \mu_{i,t}$

H3: $ROA_{i,t} = \alpha + \beta_1 Waste_{i,t-1} + \beta_2 Age_{i,t} + \beta_3 Size_{i,t} + \beta_4 EBITDA_{i,t} + \beta_5 CapEx_{i,t} + \beta_6 Leverage_{i,t} + \mu_{i,t}$

H4: $ROA_{i,t} = \alpha + \beta_1 Emissions_{i,t-1} + \beta_2 Age_{i,t} + \beta_3 Size_{i,t} + \beta_4 EBITDA_{i,t} + \beta_5 CapEx_{i,t} + \beta_6 Leverage_{i,t} + \mu_{i,t}$

To estimate the effect of CE on the financial performance of the companies, lagged measures for *Energy, Water, Waste,* and *Emissions* are used. This provides extra certainty to grasp the causal relationship between the CE actions and ROA.

4. Results

Table 2 presents the correlation matrix for the dependent, independent, and control variables used in the analysis. Results show two significant correlations between the dependent variable and the control variables (*Size* -0.174, $p < 0.05$; *Advertising* -0.310, $p < 0.01$). The four independent variables all have either strong or moderate correlations that are all significant with a p-value 0.01, which can be understood as an effect of the interrelatedness between the four different CE measures. For instance, the correlation coefficient between *Waste* and *Emissions* is 0.664 can be explained by the fact that efforts aimed at reducing the amount of waste will lead to less waste being incinerated and ending up in landfills, two circumstances that generate emissions of their own (Nakamura, 1999). Brouwer et al. (2018) identified "the Nexus of energy-water-food-land-climate" to depict the interrelatedness between all five components and stresses the fact that putting pressure on one can cause pressure on the others. Similarly, does this work in the opposite manner. Thus, reducing the amount of energy used will lead to a lower level of emissions (Brouwer et al., 2018). As a result of the high, significant correlations between *Energy, Water, Waste*, and *Emissions,* a decision is made to perform four separate analyses. What can be seen as well is that there are several significant correlations between the independent and control variables. However, the highest correlation, between *Size* and *Energy,* is 0.444 ($p < 0.01$), which is considered a low correlation. Consequently, multicollinearity is not seen as an issue in this research.

Table 3 presents the estimations for *Energy* and includes both results for the quantile regression analysis as well as the OLS regression analysis. The OLS regression is included to compare the estimates on the simple mean of ROA and the other distributions of ROA. Remarkably, the estimates from the quantile regression are different for each quantile and are significantly different from the OLS estimate. This points out the necessity and validity to apply a quantile regression analysis. Looking at the quantile regression estimates, the effect of *Energy* on *ROA* is positive and significant ($p < 0.1$) for the medium- and high-performing (Q50: 0.0750 and Q75: 0.0778) ICT companies. For the low-performing ICT companies, the effect is negative and insignificant. As such, the effect of the CE efforts to increase energy efficiency has the largest positive effect on the performance of high-performing ICT companies and is followed by a positive effect on the performance of medium-performing ICT companies.

Table 3
Model estimation with *Energy* as the independent variable.

Variables	*Quantile Regression*			*OLS*
	Q25	Q50	Q75	
	ROA	ROA	ROA	ROA
Energy	-0.0130	0.0750*	0.0778*	0.0491
	(0.0461)	(0.0446)	(0.0411)	(0.0608)
Age	0.00545***	0.00144	-0.000346	0.00120
	(0.00177)	(0.00172)	(0.00158)	(0.00190)
Size	-0.169***	-0.146***	-0.219***	-0.187***
	(0.0443)	(0.0429)	(0.0395)	(0.0604)
EBITDA	0.303*	0.254*	0.345**	0.563***
	(0.156)	(0.151)	(0.139)	(0.183)
CapEx	5.10e-09	-8.17e-09	-4.73e-09	-7.38e-09
	(9.14e-09)	(8.85e-09)	(8.16e-09)	(1.10e-08)
Leverage	0.00177*	0.00104	0.000488	0.00119***
	(0.000962)	(0.000931)	(0.000858)	(0.000230)
AdvertisingIntensity	-0.224***	-0.274***	-0.239***	-0.224***
	(0.0401)	(0.0389)	(0.0358)	(0.0654)
Constant	3.927***	4.279***	5.858***	4.639***
	(0.644)	(0.623)	(0.574)	(0.900)
Observations	262	262	262	262
Pseudo R2	0.082	0.088	0.134	
R-squared				0.146

NOTE: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2
Correlation matrix.

Variable	ROA	Energy	Water	Waste	Emissions	Age	Size	EBITDA	CapEx	Leverage	Advertising
ROA	1										
Energy	0.00976	1									
Water	0.0719	0.539***	1								
Waste	0.0407	0.712***	0.436***	1							
Emissions	0.0635	0.769***	0.558***	0.664***	1						
Age	0.0697	0.211***	0.0624	0.158*	0.203***	1					
Size	-0.174**	0.444***	0.410***	0.407***	0.434***	0.167**	1				
EBITDA	0.0229	0.362***	0.408***	0.310***	0.381***	0.163**	0.700***	1			
CapEx	-0.109	0.188**	0.211***	0.164**	0.219***	-0.0242	0.530***	0.432***	1		
Leverage	0.0600	0.0716	0.0646	0.0895	0.0139	0.0289	-0.0282	-0.0173	0.0600	1	
Advertising	-0.310***	-0.0234	0.00300	0.0758	-0.000959	-0.153*	0.157*	-0.00667	0.0538	0.0266	1

NOTE: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

In the case of the control variables, several remarkable results are found. *Age* solely has a significant positive effect on the financial performance of low-performing ICT companies (0.00545, $p < 0.01$). With regards to *Size,* the results show a significant negative impact on the ROA of all ICT companies ($p < 0.01$), which contradicts the expected effect. The strategic position, determined by the *EBITDA* dummy variable, shows to have a significant positive effect on all three distributions of the ICT companies' performance, while capital expenditures, *CapEx,* do not significantly affect company performance, and *Leverage* only has a significant small positive effect (0.00177, $p < 0.1$) on performance. What stands out are the results for *AdvertisingIntensity,* which have a significant ($p < 0.01$) negative effect on firm performance for all three levels of performance (Q25: -0.224; Q50: -0.274; Q75: -0.239). This contradicts the expectation of the positive effect that advertising was expected to have on firm performance. The results are, however, in line with Bublitz and Ettredge (1989), who have found that the positive effect of advertising is short-lived and that the eventual effect of advertising on the market value of a company is negative.

Table 4 present the results for *Water* for both the OLS regression analysis and the quantile regression analysis. Similarly to the results for *Energy*, there is an evident difference between the mean estimate and the estimate for the different quantile, confirming the need to use a quantile regression analysis. The results show that increasing water efficiency has a positive effect for all three levels of performance; however, the estimate is significant only for the high-performing companies (0.293, $p < 0.01$).

When comparing the control variables of this analysis with the analysis discussed above, it shows that most estimates are comparable. There is a slight difference for the *EBITDA* dummy variable, of which the effects for the low- and medium-performing companies are not significant. Likewise, for *Leverage,* the estimate for low-performing ICT companies is not significant.

Table 4
Model estimation with *Water* as the independent variable.

Variables	*Quantile Regression*			*OLS*
	Q25	Q50	Q75	
	ROA	ROA	ROA	ROA
Water	0.121	0.162	0.293***	0.275**
	(0.135)	(0.103)	(0.0988)	(0.135)
Age	0.00543**	0.00153	0.000459	0.00158
	(0.00212)	(0.00162)	(0.00155)	(0.00194)
Size	-0.174***	-0.114***	-0.202***	-0.194***
	(0.0520)	(0.0398)	(0.0381)	(0.0596)
EBITDA	0.287	0.155	0.242*	0.502***
	(0.190)	(0.145)	(0.139)	(0.179)
CapEx	6.80e-09	-6.85e-09	-4.42e-09	-7.21e-09
	(1.10e-08)	(8.40e-09)	(8.04e-09)	(1.20e-08)
Leverage	0.00172	0.000927	0.000396	0.00106***
	(0.00116)	(0.000886)	(0.000848)	(0.000230)
AdvertisingIntensity	-0.214***	-0.287***	-0.253***	-0.222***
	(0.0482)	(0.0368)	(0.0353)	(0.0588)
Constant	3.983***	3.857***	5.601***	4.751***
	(0.749)	(0.573)	(0.548)	(0.877)
Observations	262	262	262	262
Pseudo R2	0.084	0.087	0.137	
R-squared				0.155

NOTE: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5 presents the results for *Waste.* Once again, the OLS regression analysis is included as a benchmark for the quantile regression analysis results. Different from the results for *Energy* and *Water*, it can be seen that the mean effect of CE efforts focusing on waste is positive and significant (0.0726, $p < 0.1$). Nonetheless, when comparing the mean estimate with the estimates resulting from the quantile regression analysis, there is still a noticeable difference in the values. For low-performing ICT companies, the effect of *Waste* on *ROA* is positive yet not significant. The effect on the financial performance of medium- and high-performing ICT companies is positive and significant, however not as high as the mean effect. Noteworthy is that the uppermost quantile enjoys the greatest positive effect (0.0678, $p < 0.01$), followed by a positive effect for the median (0.0482, $p < 0.1$). With this, it can be validated that the quantile regression analysis is required to provide in-depth results.

The control estimates are mostly similar to the results of the two analyses discussed above. When compared to the analysis with *Water* as the dependent variable, the results for *Leverage* differ for the lowest percentile (Q25) since the effect is positive and significant.

Table 5
Model estimation with *Waste* as the independent variable.

Variables	*Quantile Regression*			*OLS*
	Q25	Q50	Q75	
	ROA	ROA	ROA	ROA
Waste	0.0380	0.0482*	0.0678***	0.0726*
	(0.0247)	(0.0277)	(0.0212)	(0.0424)
Age	0.00554***	0.00161	-0.000355	0.00102
	(0.00152)	(0.00170)	(0.00130)	(0.00196)
Size	-0.121***	-0.145***	-0.200***	-0.202***
	(0.0377)	(0.0422)	(0.0323)	(0.0623)
EBITDA	0.121	0.239	0.298***	0.555***
	(0.133)	(0.149)	(0.114)	(0.180)
CapEx	1.82e-09	-7.44e-09	-4.75e-09	-6.63e-09
	(7.84e-09)	(8.79e-09)	(6.72e-09)	(1.11e-08)
Leverage	0.00161*	0.000987	0.000507	0.00111***
	(0.000825)	(0.000925)	(0.000708)	(0.000234)
AdvertisingIntensity	-0.236***	-0.244***	-0.309***	-0.230***
	(0.0344)	(0.0385)	(0.0295)	(0.0652)
Constant	3.265***	4.265***	5.654***	4.920***
	(0.549)	(0.615)	(0.471)	(0.939)
Observations	262	262	262	262
Pseudo R2	0.083	0.088	0.142	
R-squared				0.156

NOTE: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 presents the results for the analysis with *Emissions* as the independent variable. When comparing the quantile estimate for high-performing companies (Q75) with the mean estimate, it is notable that these are close to similar. However, the estimate resulting from the quantile regression analysis is has a higher level of significance (0.154, $p < 0.01$). For the low- and medium-performing ICT companies, the effect is positive yet not significant. Therefore it can be stated that including the results for a quantile regression analysis is valid and gives more thorough insights.

Table 6
Model estimation with *Emissions* as the independent variable.

Variables	*Quantile Regression*			*OLS*
	Q25	Q50	Q75	
	ROA	ROA	ROA	ROA
Emissions	0.0752	0.0807	0.154***	0.157*
	(0.0606)	(0.0690)	(0.0584)	(0.0836)
Age	0.00502***	0.00152	-0.000156	0.000879
	(0.00166)	(0.00189)	(0.00160)	(0.00196)
Size	-0.150***	-0.127***	-0.226***	-0.198***
	(0.0409)	(0.0465)	(0.0394)	(0.0606)
EBITDA	0.231	0.154	0.320**	0.532***
	(0.146)	(0.167)	(0.141)	(0.178)
CapEx	2.75e-09	-8.29e-09	-4.45e-09	-7.77e-09
	(8.55e-09)	(9.73e-09)	(8.24e-09)	(1.09e-08)
Leverage	0.00159*	0.000927	0.000377	0.00103***
	(0.000904)	(0.00103)	(0.000871)	(0.000245)
AdvertisingIntensity	-0.221***	-0.288***	-0.231***	-0.223***
	(0.0375)	(0.0427)	(0.0362)	(0.0636)
Constant	3.703***	4.055***	5.956***	4.840***
	(0.593)	(0.674)	(0.571)	(0.905)
Observations	262	262	262	262
Pseudo R2	0.084	0.086	0.138	
R-squared				0.155

NOTE: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Results for the control variables are similar to the estimates discussed above and do therefore not need to be elaborated.

5. Discussion

Does being circular positively affect the financial performance of ICT companies? The above analysis of the effect of four specific CE actions on the financial performance of ICT companies has resulted in several findings that provide an answer to this question. From the quantile regression analysis, it has become clear that a distinction can be made between the effects that CE has on the different levels of companies' performance.

Table 7
Overview of hypotheses.

Hypothesis	*Quantile Regression*			*OLS*
	Q25	Q50	Q75	
H1: Increasing energy efficiency will positively affect the financial performance of ICT companies.	X	✓	✓	X
H2: Increasing water efficiency will positively affect the financial performance of ICT companies.	X	X	✓	✓
H3: Reducing, reusing, recycling, treating, or phasing out waste, including e-waste, will positively affect the financial performance of ICT companies.	X	✓	✓	✓
H4: Reducing the level of environmental emissions will positively affect the financial performance of ICT companies.	X	X	✓	✓

Table 7 presents an overview of the answers to the hypotheses proposed prior to the analysis. As can be seen, all four hypotheses are partially supported by the results. Whilst the mean effect of increasing energy efficiency does not show a positive relationship with company performance, the effect on medium- to high-performing ICT companies is positive. The positive effect of increasing water efficiency on financial performance is supported by the mean effect as well as the effect on high-performing companies. This is similar in the case of reducing the level of environmental emissions. Reducing, reusing, recycling, treating, or phasing out waste is shown proven to both have a positive effect on the financial performance of medium- to high-performing ICT companies and of the average ICT company.

In a comparison between the different CE actions, it becomes evident that increasing water efficiency has the highest positive effect on the ROA, followed by a reduction of emissions. Hereafter comes the positive effect of increasing energy efficiency, and last is perceiving waste as valuable. The highest effect of water efficiency can be explained by the fact that of the sample, most companies were ICT service companies that require a high amount of water to cool their hardware allowing the business to function (Oltmanns et al., 2020). Thus, if these companies pursue strategies to become water-efficient, this will most likely end up in a significant cost reduction and, with that, a positive effect on the financial performance. Not having manufacturing companies in the sample could also explain why perceiving waste as valuable has the lowest positive effect on financial performance. Since ICT trade and service companies do not manufacture products as part of the value creation process, the number of by-products will be lower too. Consequently, the effect of reusing or recycling waste for ICT trade and service companies will be little compared to the other three CE actions.

When looking at CE actions in total, it can be concluded that committing to circularity has an overall positive effect on the financial performance of high-performing ICT companies. These results are in line with the majority of the studies that predicted positive returns from CE (e.g. Rosa et al., 2019; EMF, 2012; Ghisetti & Rennings, 2014; Bressanelli et al., 2020; Park et al., 2010). Taking into consideration research that focused on sustainability and firm performance, there are more studies that found similar results. For instance, in their quantitative analysis, El-Sayed and Paton (2005) found that environmental performance had a significant positive effect on firm performance.

Between medium-, and high-performing companies, results show that high-performing companies benefit more from CE actions. The difference in the effect of CE on financial performance between different performance levels has not been thoroughly discussed in the literature yet. Coad and Rao (2008) looked into the relationship between innovation and firm growth and found that high-performing high tech companies benefitted most from innovative actions. Since switching to a more circular business model can be regarded as an innovation, these results are interesting to take into consideration. The U-shaped relationship described by Barnett and Salomon (2012) could partially explain the difference in effects of CE on financial performance between the different levels of ROA. In their research, it was concluded that companies that most actively invest in enhancing sustainability performance enjoy the highest returns. These results must be compared to the current results with caution, however, since the analysis does not show the effect on different levels of the dependent variable but the effect of different levels of the independent variable. Still, the results found by Barnett and Salomon could point out that companies with a higher ROA are capable of investing more in CE efforts, which in its turn could lead to more significant positive results.

With regards to medium-performing companies, the CE strategies that focused on increasing energy efficiency and perceiving waste as valuable have a positive effect on ROA, while increasing water efficiency and reducing emissions do not have a significant effect. The effect on the financial performance of low-performing ICT companies is not significant for any of the four CE actions. The fact that all CE actions have a positive relationship with the financial performance of high-performing firms, while merely two actions positively affect medium-performing companies, and zero actions affect low-performing companies, could be explained by the high costs related to switching towards a more circular approach (Kirchherr et al., 2018). Companies that have a high financial performance are most likely able to invest a high amount in CE. Lower-performing companies do not have the same amount of resources to invest in CE, which could lead to either investing an insufficient amount or even not investing at all and thus not reaping the benefits related to CE strategies. Ghisetti & Rennings (2014) found that in the case of reducing environmental externalities, i.e., emissions, the costs of the actions related to this are rather high and will outweigh the benefits. This conclusion can provide an explanation as to why emissions merely positively affect the financial performance of companies with a high ROA.

5.1 Academic Implications

The implications of this research for the academic world are twofold. First, this study addresses a current gap of not having verified the expectations resulting from exploratory research since this is one of the first attempts to perform a regression analysis on an N-sample for finding a relationship between CE and financial performance. The results confirm the expected positive effects of CE on firm performance of prior exploratory research whilst revealing a variation in the effect of CE on different levels of firm performance. This shows the importance of looking into possible variables that play a decisive role when analysing the effect of CE on financial performance.

Second, this study answers previously mentioned avenues for future research by touching upon a sample rarely discussed in prior academic work. As mentioned before, most of the micro-oriented exploratory work dedicated to CE has been focused on manufacturers. Besides that, even though the ICT sector is being recognised to contribute to a substantial part of the growing waste output as well as the high level of emissions, this sector does not receive quite as much attention when looking into possible circular solutions for these problems. Most academic work that looked into the ICT sector focuses on manufacturers of hardware, while ICT service providers are an important group to be taken into consideration, too. Since business, government, and society are relying more and more on technology as a means to solutions for efficiency, and thus solutions to environmental problems too, the need for ICT services is rising at a fast pace. Recognising the importance of finding ways in which circularity could help the move towards a more sustainable way of offering these services, this study made an effort to create a framework that explains ways in which this industry can commit to circularity and with that create financial benefits. It has become clear that more exploratory research is necessary to create more awareness about CE possibilities for the ICT sector. With this first attempt, the aim is to motivate scholars to become aware of this gap and to use this research as a starting point for future research.

5.2 Practical Implications

There are several practical implications of this research. The first implication takes into consideration the importance for companies to adopt circularity actions that enhance business performance since the main aim of this research was to depict whether investing in CE actions would have a positive effect on financial performance. This study shows that committing to CE can have a positive effect on the financial performance of a company and thus contributes to the certainty for companies considering a switch to a more circular business model. The results refute a commonly mentioned barrier to CE is the perceived high upfront costs that possibly outweigh the benefits and could thus serve as motivation for companies to commit to CE. For ICT companies planning to commit to circularity, this research provides insights regarding the prioritization of CE actions. Considering the high upfront costs of CE, focusing on one aspect of circularity at a time could be a way for companies to become more circular while not having to invest a high amount at once.

Second, the difference in the effect of CE actions on financial performance between the different levels of firm performance could help companies in making a decision as to whether to invest in circularity initiatives. Since the findings show that a positive effect of CE is more common for high-performing companies, a decision could be made to focus on firm performance before addressing circularity. However, it should not be ignored that the sample included ICT companies, so for companies in another sector, these results should be taken into consideration with caution. With regards to policymakers, the combinations of a perceived hurdle of high upfront costs and the outcomes of this study showing the difference in positive effects of CE, it could be of interest to consider subsidies promoting CE adoption, especially for low- and medium-performing companies.

5.3 Limitations and Future Research

Despite the efforts to conduct reliable and valid research, this study has several limitations that offer viable opportunities for future research. The aim of this research is to find the effect of CE actions on the financial performance of a company. Due to time constraints, the decision was made to perform a cross-sectional analysis and use lagged CE variables. However, as stated by Elsayed and Paton (2005), for analysing the relationship between environmental measures and financial performance, it would have been more appropriate to make use of panel data. This way, a distinction could have been made between the short-term and long-term effect of CE on firm performance, as it could take a significant amount of time before investing in CE has an effect on firm performance (Coad & Rao, 2008). In line with this limitation, a proposal for future research would be to perform a longitudinal analysis using a quantile regression approach.

The use of secondary data poses a limitation in that the data was not gathered with circularity as the main theme. As such, a lot of time and effort went into finding and selecting appropriate variables to measure circularity efforts of the companies from the sample. Even though the selected variables are believed to be an appropriate measure of CE for this research, having access to information specifically focused on circularity could improve the analysis. As such, this presents an opportunity for future research to use a circularity focused database when performing quantitative analysis to assess the relationship between CE and financial performance.

Another limitation related to the use of secondary data is that there was not sufficient data available on the research and development (R&D) expenses of the companies included in the sample. As stressed by McWilliams and Siegel (2000), R&D intensity is an important determinant when analysing the effect of environmental performance on financial performance. Yet, due to the limited available data on this component, there was no opportunity to include this in the analysis. For future research, this could be taken into consideration when selecting data for the analysis.

As this study focuses on ICT companies and ICT trade and service companies, in particular, the results should be treated with caution when applying to other industries. Even though using a probability sampling method would have made generalizability of the results possible, this would not be a proper method based on the nature of this study, as Fan and Fang (2020) state that it is important to distinguish between different types of companies to successfully interpret CE strategies. Based on this, a future research opportunity would be to apply the current research methodology to different industries in order to add to the knowledge base about the effect of CE on firm performance.

6. Conclusion

The aim of this paper is to find an answer to the question *Does being circular positively affect the financial performance of ICT companies?* By means of conducting a quantile regression analysis, this research adds new quantitative insights to the somewhat unanswered question of whether it pays to commit to circularity. Since it is essential for companies to get positive returns from investments made, and there is still substantial uncertainty as to whether CE will have a positive effect on firm performance, finding an answer to this question could help stimulate the adoption of a circular business model.

By looking at the effect of four CE actions, including increasing energy efficiency, increasing water efficiency, perceiving waste as valuable, and decreasing emissions on the different percentiles of the ROA of 262 ICT trade and service companies, the cross-sectional analysis was able to provide a thorough answer to the research question. The findings showed that for high-performing ICT companies, CE efforts have a positive effect on financial performance. For medium-performing ICT companies, however, two CE efforts, increasing energy efficiency and perceiving waste as valuable, contribute positively to financial performance. For low-performing companies, none of the four CE efforts had a significant positive effect on financial performance.

The current study contributes to the academic world by confirming previous outcomes of exploratory work that CE is expected to have a positive effect on the financial performance of companies. Besides that, it offers new insights into the relationship between CE and the ICT industry, which is a topic rarely discussed. The findings offer ICT companies considering investing in CE an enhanced understanding of how CE actions can have an effect on financial performance. Besides that, it could help the companies prioritise actions and consider whether the company is in a good financial position to think about circularity. With regards to policymakers, the results address the fact that financial support for low- and medium-performing companies could promote the adoption of CE.

Even though CE has been a hot topic for both research and business in the last two decades, a full consensus on the definition, strategies, and effects has not been reached yet. What scholars and managers can agree on, however, is the fact that ICT is an enabler of efficiency and as a result of circularity; and that the use of ICT is increasing at a rapid pace. Consequently, by ensuring that the growth of the ICT sector is detached from resource use, a state can be reached in which the move towards a more sustainable future will become more sustainable.

7. References

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8. Appendices

Appendix 1 - NACE Codes Belonging to the ICT sector

The 2007 OECD ICT Sector Definition

ICT Manufacturing Industries	
261	Manufacture of electronic components and boards
262	Manufacture of computers and peripheral equipment
263	Manufacture of communication equipment
264	Manufacture of consumer electronics
268	Manufacture of magnetic and optical media
ICT Trade Industries	
4651	Wholesale of computers, computer peripheral equipment and software
4652	Wholesale of electronic and telecommunications equipment and parts
ICT Service Industries	
582	Software publishing
6110	Wired telecommunications activities
6120	Wireless telecommunications activities
6130	Satellite telecommunications activities
6190	Other telecommunications activities
6201	Computer programming activities
6202	Computer consultancy activities
6203	Computer facilities management activities
6209	Other information technology and computer service activities
6311	Data processing, hosting and related activities
6312	Web portals
9511	Repair of computers and peripheral equipment
9512	Repair of communication equipment

Source: OECD (2011) as cited in Mas et al. (2012)

Appendix 2 - Composition Independent Variables

Variables used in the Factor Analysis

Independent variable	Variables from Thomson Reuters Refinitiv Eikon		
Energy	Policy energy efficiency score: *Does the company have a policy to improve its energy efficiency?*	Energy efficiency targets score: *Has the company set targets or objectives to be achieved on general resource efficiency?*	Renewable energy use dummy: *Does the company make use of renewable energy?*
Water	Policy water efficiency score: *Does the company have a policy to improve its water efficiency?*	Water efficiency targets dummy*: Has the company set targets or objectives to be achieved on water efficiency?*	
Waste	E-waste reduction score: *Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out e-waste?*	Waste reduction dummy: *Does the company report on initiatives to recycle, reduce, reuse, substitute, treat or phase out total waste?*	
Emissions	Policy emission reduction score: *Does the company have a policy to reduce emissions?*	Emission reduction targets score: *Has the company set targets or objectives to be achieved on emission reduction?*	

Source: Thomson Reuters Refinitiv Eikon database