An In-Depth Investigation into The Relationship Between Municipal Solid Waste Generation and Economic Growth in the City of Cape Town

by

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Thesis presented in fulfillment of the requirements for the degree of Master of Commerce at Stellenbosch University

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December 2020

Declaration

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Abstract

Issues of landfill scarcity are propelling cities and countries to direct policy instruments towards waste management. An objective of achieving a green economy, of which there is decoupling of waste, has become the forefront of policy design in many cities around the globe. The City of Cape Town (CCT), facing similar landfill scarcity issues, has begun taking steps towards waste minimisation. To determine whether it is possible for the City to rely on economic growth to achieve absolute decoupling of waste, this study investigates the long- and short-run relationship between economic growth and municipal solid waste generation. This is done using both time series regression analysis and decoupling calculations.

Furthermore, the Waste Kuznets Curve is investigated. Socio-economic and policy drivers of waste generation are included in the investigation to inform policy design. This study finds that the CCT has been experiencing long-run relative decoupling of waste, with short-run fluctuations of absolute decoupling during economic recessions. No strong long-run relationships between socio-economic variables and MSW generation for the CCT are found, however, in the short run it is deduced that population density is positively related to per capita MSW generation. The Think Twice waste minimisation programme, as a potential policy driver of MSW generation, is evaluated using a segmented linear regression. It is found that the Think Twice programme only has had temporal effects of reducing MSW generation, and that much of the reduction in MSW generation is rather explained by exogenous economic shocks, such as the 2008/2009 economic crash.

Keywords: *Decoupling, Waste Kuznets Curve, waste management, City of Cape Town, Waste economics*

Opsomming

Aangeleenthede rakende die tekort aan stortingsterreine dwing stede en lande om hulle beleidsrigtings sterker op afvalbestuur te vestig. Doelwitte met die oog op die bereiking van 'n groen ekonomie, waarvan afval ontkoppel kan word, het die voorpunt van beleidsontwerp in talle stede regoor die wêreld geword. Die Stad Kaapstad (CCT), wat met soortgelyke probleme rakende die tekort aan stortingsterreine te kampe het, het begin om stappe te doen om afval te minimaliseer. Om te bepaal of dit vir die stad moontlik is om op ekonomiese groei staat te maak om sodoende algehele ontkoppeling van afval te kan bewerkstellig, ondersoek hierdie studie die lang- en korttermynverband tussen ekonomiese groei en munisipale generering van vaste afval. Dit word met behulp van die analise van tydreeks-regressie en ontkoppelingsberekeninge uitgevoer.

Voorts word die Waste Kuznets-kurwe ondersoek. Sosio-ekonomiese en beleidsdrywers van afvalgenerering word by die ondersoek ingesluit om beleidsontwerp aan te vul. Hierdie studie se bevinding dui daarop dat die CCT relatiewe ontkoppeling van afval op langtermyn ervaar, met fluktuasies op die korttermyn van absolute ontkoppeling tydens ekonomiese resessies. Geen stewige langtermynverhoudings tussen sosio-ekonomiese veranderlikes en generering van munisipale vaste afval (MSW) vir die CCT is gevind nie, maar op die korttermyn is afgelei dat die bevolkingsdigtheid positief verband hou met die generering van MSW per capita. Die Think Twice-program vir die minimalisering van afval, as 'n potensiële bestuurder van MSW-generering, word aan die hand van 'n gesegmenteerde liniêre regressie geëvalueer. Die bevinding is dat die Think Twice-program slegs ’n tydelike effek opgelewer het om MSW-generering te verminder, en dat 'n groot deel van die vermindering van MSW-generering eerder voor die deur van eksogene ekonomiese skokke, soos die ekonomiese ineenstorting in 2008/2009, gelê moet word.

Sleutelwoorde: Ontkoppeling, Afval Kuznets-kurwe, afvalbestuur, Stad Kaapstad, Afvalekonomie

Acknowledgements

First and foremost, I would like to thank my supervisor, Professor Martin de Wit of the Stellenbosch University's School of Public Leadership, for offering valuable feedback and for encouraging me to apply advanced critical-thinking skills throughout the analysis.

I would like to extend my gratitude towards Professor Daan Nel of the Stellenbosch University's Statistics Department and Gideon Du Rand of the Stellenbosch University's Economics Department for offering their assistance in the statistical component of this study.

I would like to thank all persons involved in the data collection process, including the Research Department and the Solid Waste Department at the City of Cape Town and Duduzile Mazibuko and Gae Tshwaro at Statistics South Africa.

A big thank you to Mrs. J. Saunders for assisting with the technical editing component of this thesis. I must thank my parents, Marius and Louise, for providing the means to enroll in this course and for their continuous support throughout this year.

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List of Acronyms

ADF: Augmented Dickey-Fuller

ARDL: Autoregressive Distributed Lag Model

ARTS : Athlone Refuse Transfer Station

CAC: Command and Control

CCT : City of Cape Town

CEA: Clean Energy Africa

CGE: Computable General Equilibrium

CSIR: Council for Scientific and Industrial Research

EKC: Environmental Kuznets Curve

EI : Economic Instrument

DEA: Department of Environmental Affairs

DEFF: Department of Environment, Forestry and Fisheries

Defra: Department for Environment, Food and Rural Affairs

DRS: Deposit-refund schemes

DVR: differential and variable rate

ECM: Error Correction Model

EPR: Extended Producer Responsibility

EFCA: Environmental full-cost accounting

GBT: Garbage Bag Tax

GTWR: geographically and temporally weighted regression model

GVA: Gross Value Added

GW: General Waste

HW: Hazardous Waste

ISWM: Integrated Solid Waste Management

IIWTMP: Integrated Industry Waste Tyre Management Plan

IWM: Integrated Waste Management

IWEX: Integrated Waste Exchange

IDC: Industrial Development Corporation

KIWMF: Kraaifontein Integrated Waste Management Facility

LCA: Life Cycle Analysis

MBT: Mechanical Biological Treatment

MFA: Material Flow Accounting

MRF: Material Recovery Facilities

MSW: Municipal Solid Waste

MWI: Municipal Waste Intensities

NAFTA: North American Free Trade Agreement

NEMWA: National Environmental Management: Waste Amendment Act

NPSWM: National Pricing Strategy for Waste Management

NWMS: National Waste Management Strategy

OLS: Ordinary Least Squares

PAYT: Pay-As-You-Throw

PP: Philips-Perron

PRO: Producer responsibility organisation

SANS: South African National Standard

SoWR:	State of Waste Report
SWD:	Solid Waste Department
TP:	Turning Point
VAT:	Value Added Tax
WEEE:	Waste electrical and electronic equipment
WKC:	Waste Kuznets Curve
WIO:	Waste Input-Output model

Chapter 1: Study overview

This chapter introduces the research problem regarding waste generation for the City of Cape Town (CCT) in Section 1. In Section 2, a preliminary literature review evaluates the foundation of research into the field of Environmental Economics with reference to waste, the economy, and the Environmental Kuznets Curve (EKC). The purpose of this study is highlighted in Section 3, followed by the problem statement and research objectives in Section 4. Lastly, the methodologies and data sets are briefly introduced in Section 5.

1.1) Research problem

The severity of landfill scarcity, as discussed in subsequent sectionsis propelling action towards waste minimisation, with the first goal of the National Waste Management Strategy (NWMS) being to "Promote waste minimisation, re-use, recycling and recovery of waste" (Department of Environmental Affairs, 2019: 6). Per the 3rd Generation Integrated Waste Management Plan (2017), the issue of landfill scarcity is elevated by the lack of waste collection services to informal and back yard dwellers, which, in turn, results in illegal dumping of waste and limited landfill airspace (CCT, 2017: 2).

Solid waste management, in traditional views, has been considered an engineering problem, requiring a technical solution. More recently, problems associated with waste management has been identified to be economic in nature (Goddard, 1995). Solid wastes are the remnants of consumption and production processes, which are primarily determined by economic variables such as prices and income (Goddard, 1995: 188). The problem of waste management is therefore economic in nature, meaning it is characterised by resource scarcity and governed by choice. This economic problem requires economic solutions which achieve allocative efficiency through cost-effective options. For the CCT, solid waste management solutions are required to address the issues of resource (landfill airspace) scarcity through the employment of solutions that allow for maximum flexibility for consumption and production decisions, subject to the costs that need to paid (Goddard, 1995: 189).

The CCT faces challenges of landfill scarcity and resource management in the waste sector. According to the latest available GreenCape Market Intelligence Report (GreenCape, 2020: 2), of the 25 municipalities in the Western Cape, 22 municipalities have an estimated 5 years of landfill airspace left. The estimated remaining airspace for the CCT's landfills is more than 5 years, but less than 15 years (GreenCape, 2020: 18). The consideration of municipal and external costs of landfill expansion, transportation of waste and waste flow leakages (plastic pollution, littering and illegal dumping) increase the difficulty in finding a solution to appropriate waste management in the City. There is a need for economic policy guidance on waste management to allocate resources to achieve a socially optimum and sustainable solution. To prepare for such policy guidance, appropriate information is needed on the relationship between the socio-economic trends and municipal waste in the City. This study attempts to fill the gap by determining the current state of the economy and waste, investigating whether decoupling (or delinking) exists between these two variables, and to what extent. This is conducted using two approaches; firstly, using economic theory surrounding the Environmental Kuznets Curve (EKC) for waste and analysing parameter elasticities under regression analysis and, secondly, using a decoupling factor equation as introduced by the Organisation for Economic Co-operation and Development (OECD, 2002).

The investigation of the relationship between socio-economic and policy variables against waste generation statistics will aid in providing guidance on how to structure economic policy to achieve a possible scenario of decoupling of waste generation from socio-economic development and a growth in income. Moreover, the efficacy of current waste minimisation initiatives (the Think Twice recycling programme) is empirically assessed. The ultimate purpose of the study is to contribute to improved decision-making on municipal waste management by identifying targeted economic policy instruments that reduce the societal costs, that is both the municipal and the external costs, of municipal waste, with a specific consideration of the socio-economic conditions for the CCT.

1.2) Preliminary literature review

This study is informed by empirical literature that investigates the relationship between waste and the economy by considering the scenarios under which decoupling takes place in an economy. A study by OECD (2002: 43) investigates decoupling scenarios of municipal waste going to final disposal, against private final consumption. The research shows that all the 23 OECD countries investigated (except for Hungary, Portugal, and Spain), exhibit waste decoupling. Similarly, Inglezakis *et al*. (2012), plot Municipal Waste Intensities (MWI), derived from dividing Municipal Solid Waste (MSW) by GDP, over time for European countries to examine whether decoupling exists. The authors conclude decoupling exists for all 27 European countries investigated and for the EU-27 on average.

More commonly in the economic literature on waste management, statistical regression analysis is conducted to determine the relationship between waste and the economy and the state of decoupling of waste generation (Madden, Florin, Mohr & Giurco, 2019; Mazzanti & Zoboli, 2009 and Mazzanti, 2008). Mazzanti and Zoboli (2009) and Mazzanti (2008), conduct their analysis on 25 and 15 European Union countries respectively, whilst Madden *et al.* (2019) considers Local Government Areas (municipalities) that fall within the New South Wales state. These authors all find evidence of relative decoupling as shown by the Waste Kuznets Curve (WKC) hypothesis[1]. The scholarly debate surrounding the EKC has gained traction since its popularisation in the 1990s by Shafik and Bandyopadhyay (1992), Grossman and Krueger (1991, 1995), Panayotou (1997)

[1] Explanations of how to deduce absolute and relative decoupling from the Waste Kuznets Curve is discussed in subsequent chapters.

and the World Bank (1992). According to Ozokcu and Ozdemir (2017:640), the EKC describes the relationship between environmental degradation and economic growth. The hypothesis suggests that at early stages of economic development, environmental degradation increases with real GDP per capita. At a certain level of development, a turning point is reached and the trend reverses, such that increases in real GDP per capita correspond with decreasing environmental degradation. If accepted, the EKC hypothesis implies that economic growth is environmentally rewarding in the long run, however it may adversely affect the environment in the short run. Research in waste economics often investigates the waste-economy relationship in conjunction with testing the WKC hypothesis. The WKC employs waste (typically, waste generation) as the environmental pressure component in EKC literature.

The WKC literature can be broken down on a scalar level by study area. This breakdown will commonly yield WKC hypothesis results as follows; cross-national level studies often find no existence of the WKC and find that waste generation has a monotonically increasing relationship with income (Cole, Rayner & Bates, 2007; Johnstone & Labonne, 2004; Mazzanti & Zoboli, 2009; Karousakis, 2009). Sub-national or single-country level studies, although in their infancy, do reveal existence of the WKC curve (Berrens, Bohara, Gawande & Wang, 1997; Mazzanti, Montini & Zobili, 2008 and Alajimi, 2016). Municipal or city-level studies often accept the WKC hypothesis, however only certain municipalities in these studies reach the turning point of the estimated curve (Ercolano, Lucio Gaeta, Ghinoi & Silvestri, 2018; Madden *et al.*, 2019; and Trujillo Lora, Carrillo Bermúdez, Charris Vizcaíno & Iglesias Pinedo (2013). Barring this breakdown, the literature investigating the waste-economy relationship can be further compartmentalised by data, methodologies and variable categories. This compartmentalisation approach is adopted for the literature review undertaken in Chapter 2.

1.3) Study purpose

The ultimate purpose of the study is to inform the design of economic policy instruments for managing MSW. With landfill scarcity being a predominant issue in the Cape Town region, it is important to understand how waste generation and economic growth are connected and how sensitive this relationship is, which economic sectors are more wasteful, and if there is a possibility of relative or absolute decoupling between economic growth and MSW with specific policy, technological and behavioural interventions.

The analysis proposed in this study is expected to inform policy decisions regarding waste minimisation efforts from a city-wide economic perspective. The research is focused on determining which socio-economic variables result in relatively greater changes to waste generation and then to target the largest contributing variables through economic policy interventions, supported by awareness campaigns or other appropriate projects, processes, and policy instruments.

1.4) Problem statement and research objectives

The problem of landfill scarcity in the Cape Town region necessitates an analysis of physical waste flows and categorisations, of the broader economy and of waste management options. The primary objective addresses this problem though answering the question of how responsive MSW generation in the CCT is to changing economic conditions. The secondary objectives include (i) testing the WKC hypothesis for the Cape Town municipal solid waste sector, which simultaneously informs the status of decoupling, (ii) identifying the main socio-economic and policy drivers that need to be managed to decrease MSW and to determine how effective current waste minimisation initiatives are in reducing MSW generation. This is a city-level study that focuses on the CCT[2].

It is hypothesised that MSW generation is positively correlated to economic growth (as measured by change in GVA) in both the short and long run. It is further hypothesised that a WKC for the CCT exists, but that only relative decoupling is observable in the long run, with temporary absolute decoupling taking place during economic recessions. The socio-economic drivers identified by the Department of Environmental Affairs' (DEA) State of Waste Report (SoWR) (2018), which include population growth, population density, Gross Value Added (GVA) and GDP growth, will all most likely have a positive impact on MSW generation (DEA, 2018: 3). The study aims to investigate alternative drivers that may impact MSW generation such as those that have been identified for other countries. These include socio-economic drivers such as tourism flows, share of the population older than 60 years and share of the population unemployed. The Think Twice waste minimising initiative[3], as included in the Integrated Solid Waste Management policy, is hypothesised to have an immediate effect of reducing per capita MSW generation. Both a level change of per capita MSW generation and a trend change of per capita MSW generation are investigated.

1.5) Research design, methodology and method

The research conducted in this study is undertaken through both qualitative and quantitative analysis. This study combines primary and secondary data to compile a dataset of the above-

[2] A city, or municipal, approach is adopted as opposed to a regional, national, or international approach, to ensure context-specific considerations are made for policy decision-making. This is further reasoned in Chapter 2, Section 2.4.1.

[3] The Think Twice programme is a kerbside collection programme allowing for separate collection and processing of recyclable materials.

described variables[4]. This dataset is used for empirical analysis using time-series regression techniques.

The method-selection process follows the format provided by Shrestha & Bhatta (2018). The method-selection process is simplified in the flow diagram (see Diagram 1.1). To determine the waste-economy relationship, the WKC and to determine the validity of various socio-economic drivers on waste-generation, both an Ordinary Least Squares (OLS) and an Autoregressive Distributed Lag Model (ARDL) approach is applied. These models are commonly applied in waste and EKC literature (Alrajhi & Alabdulrazag, 2016; Madden *et al.*, 2019; Miyata, Shibusawa, & Hossain, 2013; Shuai Chen, She, Jiao, Wu & Tan, 2017; Islam, Shahbaz & Butt, 2013; Köhler & de Wit, 2019 and Yang, 2019). However, unlike most EKC and WKC time-series regression literature, this study considers an array of explanatory variables. Harbaugh, Levinson & Wilson (2002:541) find that, with the inclusion of control variables, the relationships between the environmental pressure variable and the economic (income) variable exhibit vastly different shapes. This is attributed to the omitted variable bias increasing the explanatory power of parameters when no explanatory variables are included in the model. This study makes use of natural logarithm transformations. As argued by Shahbaz, Jalil & Dube, (2010), Cameron (1994) & Ehrlich (1975, 1996), log-transformations provide more appropriate and efficient results relative to simple level-level regression models. Moreover, the log transformation is preferred since coefficients can be directly interpreted as elasticities. However, it is noted that log-transformations imply that only correlation can be inferred from reduced-form equations and that reduced-form equations have been shown to influence results (Moosa, 2017:4936). This study duplicates the appropriate regressions using levels to assess differences in parameters.

[4] The dataset and variables are further described in Chapter 4.

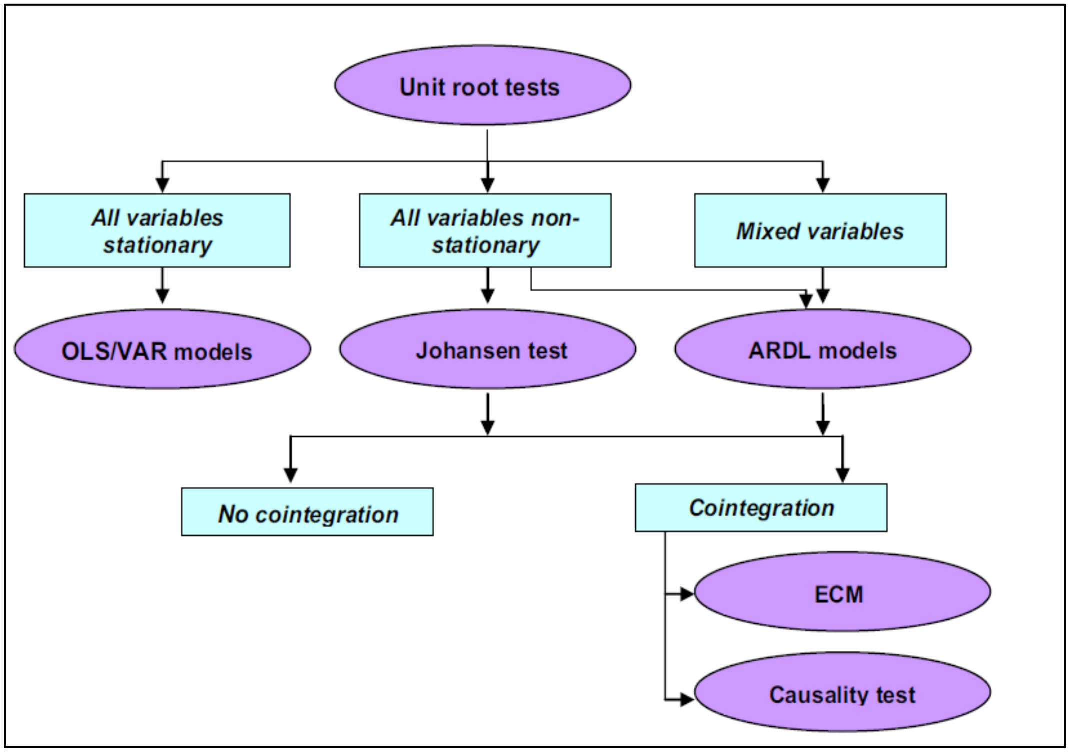

Diagram 1.1: Method Selection Process

(Source: Shrestha & Bhatta, 2018: 76)

The choice of the accepted modelling approach is dependent on the results of Unit Root and Cointegration tests. Unit Root tests are applied to determine the stationarity of the variables. Should variables be non-stationary, the OLS regression results could be 'spurious', implying that the estimates cannot be used for policy decision-making (Nkoro & Uko, 2016: 68). Cointegration tests analyse whether there are long-run cointegrating relationships between variables. If all variables are I(1)[5], and if they are cointegrated, an OLS estimation can be applied (Shuai *et al.*, 2017; Madden *et al.*, 2019). If any variables are integrated of a higher order, they are differenced and then included in the regression. Three cointegration analysis techniques are available; the

[5] Indicating that they are stationary after first differencing.

conventional Granger (1981) and Engle and Granger (1987) procedure, the Johansen and Juselius (1990) procedure and the Pesaran and Shin (1999) and Pesaran, Smith and Shin (2001) ARDL cointegration bounds test. Under the Engle-Granger (1987) cointegration procedure, all series must be of the same order. Under the Johansen (1988) and the ARDL cointegration procedure, this limitation does not apply (Nkoro & Uko, 2016: 69). Should all variables be integrated of the first order, both an Engle-Granger cointegration procedure and a Johansen cointegration procedure will be applied before computing OLS estimations. As noted by Kohler (2013: 1045), there are several advantages of using the ARDL bounds cointegration test. The ARDL bounds test avoids endogeneity problems and is superior for small samples. This study computes the ARDL bounds test before running the ARDL model.

There are notable issues when computing OLS time-series regressions. For a non-stationary stochastic process, which is a Difference Stationary Process, to be used in an estimation for an econometric model, the traditional diagnostic statistics for OLS model validation (such as the adjusted R^2 and Fishers-Ratio), can become misleading and inappropriate for policy and forecast (Nkoro & Uko, 2016: 67-68). To avoid these issues, an ARDL model will be computed. Moreover, the ARDL model is appropriate to determine short-run dynamics and long-run relationships when reparamitised into an Error Correction Model (ECM).

To evaluate whether the results from the OLS and ARDL-ECM models are correct in determining the existence of a WKC and the state of decoupling, the decoupling factor is calculated for the long run (for 1997-2019). To examine annual changes of decoupling (absolute or relative) for the CCT, a similar methodology process to that of Inglezakis *et al.* (2012) is applied. An index for per capita GVA and per capita MSW, with the base year 1997 being equal to 100 is used and graphically presented and analysed. Here, absolute decoupling occurs when the growth rate of MSW per capita is zero or negative and relative decoupling occurs when the growth rate of per capita MSW is positive, but less than the growth rate of GVA. No decoupling is experienced when the growth rate of per capita MSW is greater than the growth rate of GVA (Inglezakis *et al.*, 2012: 2362-2363).

For the secondary objective, of determining the success of current waste policies and waste minimising initiatives in the CCT, a segmented linear regression is applied. This empirical technique is applied to determine the short- and long-run impacts of the Think Twice recycling campaign *ex-ante* and *ex-post.* This type of methodology is often applied in medical research to determine the effects of health interventions; however, it has been applied to broader research fields, including the field of waste economics (Park & Lah, 2015). As noted by Evangelos, Doran, Springate, Iain, & Reeves (2015), there are three assumptions that apply to segmented linear regression analysis. The first is that the pre-intervention trends are linear – this assumption can be confirmed through graphical representation of the outcome variable. Secondly, it is assumed that the population characteristics remain unchanged throughout the period. This assumption is mostly applied for medical research, whereby population characteristics include sample patients' age and sex, therefore, this assumption is omitted in this analysis (Evangelos *et al.*, 2015: 3). Thirdly, there are no other interventions that influence the outcome variable at the time that the intervention is employed. Should all these assumptions be met, this methodology is considered the "next best" procedure for analysing intervention impacts when trial data are not available (Evangelos *et al.*, 2015: 1). For this analysis, all assumptions are met and further discussed in Chapter 4.

1.6) Conclusion

This study contributes to previous literature considering the linkage between MSW generation and economic growth and other drivers of MSW generation, as focused on the CCT for the period 1997-2019. In conjunction to this, the investigation of the EKC hypothesis for waste is used to determine whether income growth can resolve high waste generation rates in the longer run, whether there is evidence of decoupling in the City and whether it will be possible to achieve absolute decoupling. These findings are compared to the decoupling factor indicators to provide credible results. Furthermore, secondary objectives of determining socio-economic drivers that influence the rate of waste generation, provides information that can be used in the design of economic policy instruments that can be implemented by the CCT Metropolitan Municipality. The efficacy of CCT waste policies are analysed both quantitatively, by applying a segmented linear regression to observe the impacts of the Think Twice recycling campaign on per capita MSW generation, and qualitatively, by combing empirical findings from this study and waste literature to provide suggestions for appropriate implementation of economic policy instruments for the CCT waste sector.

Chapter 2: Literature Review

Existing literature in waste economics considers issues facing landfill scarcity and how to achieve an economy that decouples from waste. In recent years, public policy agendas have made considerations for the size and composition of solid waste and how to control for problems arising with increasing waste quantities (Goddard, 1995: 183). Before developing effective and appropriate policy options for waste management, an in-depth understanding of the waste economy is needed. For this reason, it is important to, firstly, define and discuss relevant economic and waste-related concepts before reviewing existing empirical literary findings. Once these concepts have been defined, the most relevant literature with regards to the chosen explanatory variables, methodologies and data can be discussed.

The sections in this chapter are presented as follows: Section 2.1 outlines and discusses relevant waste-related and economic concepts. Section 2.2 introduces current global and local waste management strategies that employ the concepts as discussed in Section 2.1. Section 2.3 discusses existing literature pertaining to this study's objectives and begins with a review that analyses both the WKC and broader waste-economy relationships. This section further provides insights of existing literature on an array of appropriate explanatory variables (socio-economic and policy variables) that have been shown to influence the rate of waste generation and discusses the appropriateness of these variables for the CCT case study.

2.1) Definitions and relevant concepts

The definition and description of important waste and economic concepts are crucial for the development of this study. The concepts discussed in this thesis include (i) sustainability and sustainable development, (ii) the green and circular economy, (iii) waste generation and waste landfilled, (iv) the Environmental Kuznets Curve (EKC), (v) decoupling and (vi) elasticities. Furthermore, this section briefly explains macro-economic theory surrounding waste management.

Definitions regarding waste types and streams are context-specific and will be discussed in Chapter 4, when considering the CCT case study.

2.1.1) Sustainability and the circular economy

The concept of sustainability can be used under three base categories - economic, environmental and social. Broadly defined, "sustainability" and "sustainable development" is the ability for the present generations' needs to be met without compromising the ability of future generations to meet their needs (Brundtland, 1987: 15). Within a waste-related context, sustainability can be applied to the type of waste economy which is envisioned. A more sustainable waste sector can be conceptually described as a green economy (Greyson, 2006: 1383).

A green economy, according to the Department for Environment, Food and Rural Affairs (2011: 4) exists if all-natural resources are managed sustainably whilst maximising economic growth and value. A green economy in a South African context is defined as *"a system of economic activities related to the production, distribution and consumption of goods and services that result in improved human well-being over the long term, while not exposing future generations to significant environmental risks or ecological scarcities"* (DEFF, 2020: para. 3). Material recirculation, encompassed within a circular waste economy, enables the development of new products by recycling used products. Under this approach, waste is viewed as a resource. This circular waste economy is described as a more sustainable alternative as opposed to the current linear waste system that exists for most countries and cities (Singh & Ordoñez, 2016: 342). Under economic assessment, the adoption of circular economies can be enhanced through ex-ante evaluation. Evaluation methods include Cost-Benefit Analysis, Life Cycle Assessments, Full-Cost Accounting, and other Circular Economy indicators. These methods are briefly discussed in Section 2.2.

2.1.2) Waste-related activities

Waste generated is the number of materials or products that enter the waste stream prior to any waste diversion or landfilling (Pipatti, Sharma & Yamada, 2006: 25). Waste diversion is the amount of waste that has been recycled, reused, and treated. Ultimately, a circular economy allows for the efficient use of products by ensuring products and materials are used more than once

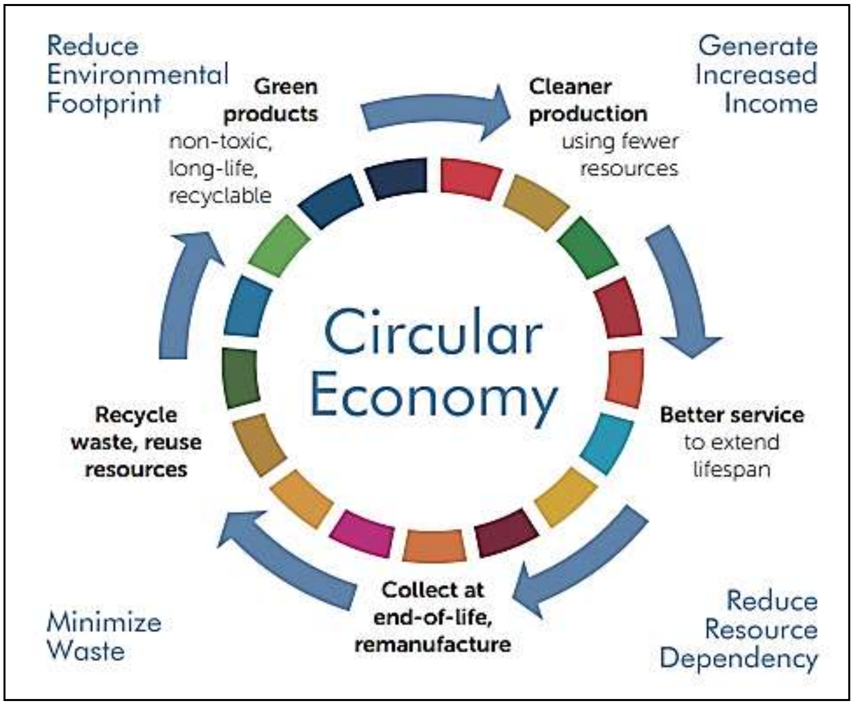

Diagram 2.1: The Circular Economy
(Source: United Nations Industrial Development Organisation, 2020)

through improved design and maintenance and transferring waste from the end of the supply chain to the beginning (United Nations Industrial Development Organisation, 2020: 3). Diagram 2.1 depicts the circular economy for waste. The approaches that should be employed under a circular economy for waste include the use of green products, cleaner production methods, better servicing of products and production lines, remanufacturing of old products and recycling and reusing of waste products.

2.1.3) Environmental Kuznets Curve (EKC)

The EKC is a theoretical tool that can be used to investigate the relationship of environmental indicators and the economy and to determine if decoupling between the respective variables exist. In 1955, the Kuznets economic hypothesis had been developed, through which Simon Kuznets argued for an inverted U-shaped relationship between economic growth and income inequality (Kuznets, 1955). This concept had been developed further to encompass an environmental perspective. In the 1990's, Grossman and Krueger (1991, 1995) initially examined the Environmental Kuznets Curve (EKC) by considering the impact of the North American Free Trade Agreement (NAFTA) on the environment. The EKC argues that at low levels of income, environmental degradation is low and, as income begins to increase, environmental degradation increases until a turning point is reached. From this turning point, as income increases (and countries become more developed) environmental degradation decreases due to advanced technologies and financial resources that are employed to address environmental issues.

The EKC hypothesis acts as a tool to determine whether long-term economic growth can combat environmental degradation. As noted by Raymond (2004: 328), caveats do exist when using or testing the EKC. On an empirical level, disagreements exist on the accuracy of such models in their ability to describe the full environmental impact of economic growth (Raymond, 2004: 328). On a theoretical level, there is disagreement on whether the EKC precisely depicts real-world scenarios, and, consequently, whether it can fully inform policy-making decisions. Arrow, Bolin, Costanza, Dasgupta, Folke, Holling, Jansson, Levin, Mailer, Perrings and Pimentel (1995), note that considering EKC results alone for environmental policy is not recommended for several reasons. Firstly, the assumption of infinite per capita income growth is unjustified and, secondly, only considering macro-level relationships (i.e. Gross National Product) omits measuring true economic performance, such as the flow of environmental services and the value of net changes in stock values of natural capital.

2.1.4) Decoupling of waste and elasticities

Decoupling of waste, according to the WRAP report (2012: 3), involves the generation of less waste per unit of economic activity. There are four states of decoupling; *Absolute* decoupling, whereby waste generation remains constant or decreases as economic activity increases, *Relative* decoupling whereby economic activity increases whilst waste generation increases, but at a greater rate, *Coupled* decoupling whereby there is a one-on-one rate increase of waste generation and economic activity and *Negative* decoupling whereby an environmental pressure indicator such as waste generation increases at a faster rate than the rate of increase of an economic indicator. Waste decoupling essentially considers the relationship between waste generation and economic growth, with the goal to generate less waste per unit of economic activity.

There are two indicators used in the literature to determine the state of decoupling. Elasticities, as the first indictor, are the calculated ratio of the percentage change in one variable to the percentage change in another variable. Empirical studies often include a series of elasticity indicators to investigate the correlations between environmental impacts and their influencing indicators (Wang, Hashimoto, Yue, Moriguchi & Lu, 2013: 619). Elasticities, as decoupling indicators, can be calculated using the following formula:

$$E = \frac{\%\Delta Environmental\ Pressure}{\%\Delta Economic\ Indicator}$$

where E is the economic indicator elasticity of the environmental pressure (Wang *et al.*, 2013: 619). From an empirical standpoint, where decoupling between economic growth and waste exist, an inverted U-shaped curve or WKC is found between waste generation and the economic performance indicator (Madden *et al.*, 2019: 675). This relationship is graphically summarised in Diagram 2.2. Under the WKC framework, absolute decoupling exists if the economic variable is situated on the descending segment of the WKC, implying that regression coefficients (elasticities) must show evidence of a plausible turning point. A plausible turning point exists where the estimated economic turning point (TP) lies within the range of the economic indicator for the area under investigation. For example, when the $estimated\,TP < Average\,Income$ of a study period, absolute decoupling is present (Madden *et al.*, 2019: 675). Relative decoupling, whereby the estimated TP is larger than the range (or the average actual income) of the economic indicator for the study area, exists on the ascending segment of the WKC. This curve, when plotted, is often used to observe whether the implementation of structural changes or policy reform influences the state of decoupling. Diagram 2.2 summarises this relationship.

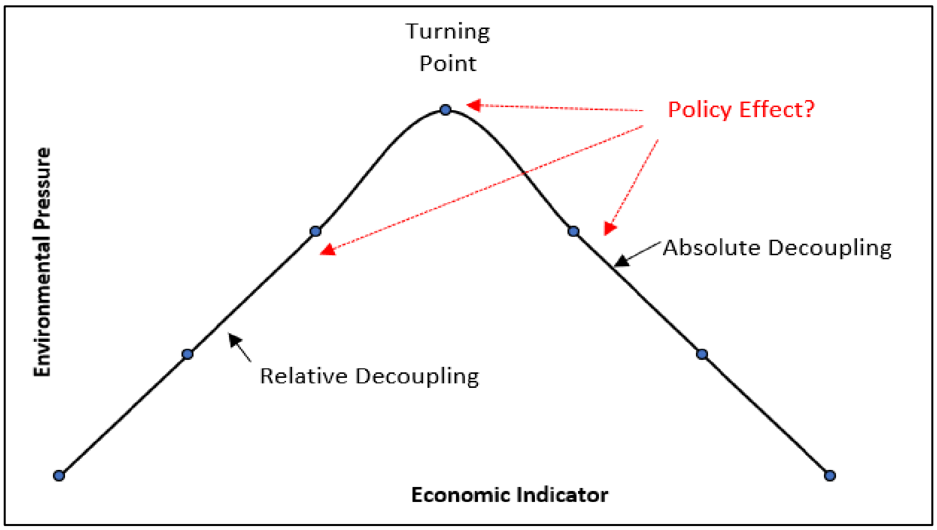

Diagram 2.2: Environmental Kuznets Curve and Decoupling

(Source: Constructed by author, adapted from Mazzanti & Zoboli (2009: 6))

In the case of econometric analysis, the Beta coefficients are an indicator of the responsiveness of waste generation to certain independent variables. If the Beta coefficient is equal to 1, the elasticity is described as "unit elastic", meaning a one-unit change in the independent variable would lead to a unit change in the dependent variable (MSW). If the Beta coefficient is larger than 1, there is “elasticity”, meaning that a one-unit change in the independent variable would lead to a larger than one-unit change in the dependent variable. If the Beta coefficient is smaller than one, there is "inelasticity", which implies a one-unit change in the independent variable would lead to a smaller than one-unit change in the independent variable. Typically, with small time-series datasets, it is not plausible to deduce strong causal relationships. This means that the regression coefficients cannot be interpreted as casual elasticities (such that a $\%\ \Delta\ in\ X$ results in a subsequent $\%\ \Delta\ in\ Y$), but rather, these coefficients are used to determine the general relationship between variables.

The policy explanatory variables (i.e. the service charges for waste management) will indicate how a change in price may impact a change in waste generated, this is termed the price elasticity. Several municipal-level studies show a negative price elasticity for waste generation not exceeding -0.286 (Dijkgraaf & Vollebergh, 2003; Han, Zhang & Xia, 2016; Jenkins, 1993). This means that price increases of waste-related taxes (i.e.: variable volume-based waste taxes), result in a subsequent decrease in the amount of waste generated, however, given that these are less than 1, the price elasticity of demand is inelastic and there is generally a low responsiveness of MSW generation changes to a price increase in waste taxes. The income variable (i.e. GVA, GDP, GNP etc.) indicates how a change in income over time may impact a change in waste generated, this is termed the income elasticity. International studies have shown that waste generation has a positive income elasticity, but that these were less than one (Beede & Bloom, 1995). This means that if there is an increase in income[6], there is a less than proportionate increase in the amount of MSW generation. One of the reasons mentioned is the shift away from goods to less waste intensive services. It is also generally accepted that MSW generation is positively associated and close to being unit elastic with respect to population size (Beede & Bloom, 1995: 119).

Alternatively, as determined by the OECD (2002), decoupling can be calculated by obtaining a decoupling factor using the following formula:

$$D_f = \frac{(EP/DF)_{end\ of\ period}}{(EP/DF)_{start\ of\ period}}$$

[6] If calculated on a country level, GDP can be used as an income proxy. This can be calculated on a city level with GVA being an income proxy, and on a household level with household income being adopted as the income variable.

D_f is the decoupling factor, EP is the environmental pressures, and DF is the driving force (Wang *et al.*, 2013: 675). D_f is equivalent to the decreasing rate of resource use per unit of GDP (t). When the decoupling indicator is larger or equal to one ($D_f \geq 1$), absolute decoupling is observed. When the decoupling indicator is between the interval 0 – 1 ($0 < D_f > 1$), relative decoupling exists and if the decoupling indicator is below or equal to 0 ($D_f \leq 0$), there is no decoupling (Wang *et al.*, 2013: 620). Decoupling, whether absolute, relative, or non-existent, can also be graphically analysed by plotting the environmental index and the economic index against the time series (Inglezakis *et al.*, 2012). The state of decoupling and the ascertainment of the WKC can be used to inform waste management decisions.

2.2) Waste management and economic policy

When considering management options and the deployment of policy instruments in the waste sector, there are various economic concepts to consider. These concepts include (i) policy-mix options, (ii) crowding out effects, (iii) external, internal and opportunity costs, and (iv) Full-Cost Accounting. This section briefly explains what policy-mix options are available and the crowding out effects that may arise. Furthermore, this section highlights modelling options that encapsulate the external, municipal and opportunity costs of waste and waste management options.

In most countries, local authorities are often tasked with evaluating and implementing a mix of policy instruments aimed at targeting the issues at hand. There are three identified types of policy instruments for waste management. These are regulatory, economic, and informational instruments (Montevecchi, 2016: 4). Regulatory instruments, or commonly called ‘command and control’ (CAC), are the norms and standards governing the actions of economic agents. These instruments focus on standards, permits, recycling and final disposal within the waste sector. Examples of such regulations include height restrictions on landfills and regulations of what waste materials may or may not be recycled. Typically, there penalties are issued for non-compliance with regulatory instruments.

Economic Instruments (EI's) internalise the environmental degradation costs into the production and consumption processes. EI's, according to the United Nations Environment Programme (UNEP) (2005:5), can be defined as:

"a policy, tool or action which has the purpose of affecting the behaviour of economic agents by changing their financial incentives in order to improve the cost-effectiveness of environmental and natural resource management".

Unlike CAC's, EI's are far less rigid and are non-prescriptive to actions. EI's are acknowledged for their ability to incentivise or disincentivise economic agents to go beyond what laws and regulations require. EI's can be categorised as revenue raising instruments[7], which involve user charges for the provision of waste services; revenue providing instruments, that are targeted at rewarding desired consumer and producer behaviors, such as efforts of waste minimisation; and non-revenue instruments which include the combined incentive effects of the former two categories (UNEP, 2005: 7-8). The latter, non-revenue instruments, include deposit-refund schemes as well as property-rights based instruments. Lastly, informational instruments are aimed at deploying resources to educate economic agents about the responsibilities and actions that can be taken towards minimising the amount of waste generated. These include awareness-raising programmes on composting and recycling (Montevecchi, 2016: 10 and Oosterhuis, Bartelings, Linderhof & van Beukering, 2009: iii).

A study by Nahman & Godfrey (2010), which had used survey answers provided by waste management authorities in South Africa, found that 67% of authorities believed the recyclable

[7] This thesis does not expand the discussion around revenue-raising instruments, as these are instruments intended to cover administrative costs of waste management and are not tools that influence the rates of MSW generation.

waste stream must be targeted by EI's. Fifty percent (50%) of respondents opted for EI's targeting construction and demolition waste, and 33% found the organic waste streams as an important EI target. Eighty three percent (83%) found the industrial waste stream to be an important target; while 56% believed that hazardous waste should be targeted.

In South Africa, respondents of the Nahman & Godfrey's (2010) study believe that the most appropriate EI for reduction waste generation are deposit-refund schemes. Deposit-refund schemes combine two types of EI'S; a product tax on consumption with a subsidy provided for the return of the product or its packaging. Deposit-refund schemes (DRS) target several waste sectors by allowing for the return of different waste stream materials, which are then either recycled or disposed of appropriately. These materials include general waste products (such as glass bottles, paper, and cardboard), household E-waste, hazardous waste (such as batteries) and PET waste.

Walls (2011:1) argues that there are several advantages of implementing a deposit-refund scheme over Pigouvian taxes. The first advantage is that these schemes tend to circumvent the issues of illegal dumping associated with Pigouvian taxes[8], due to the rebate offered which incentives economic agents to return waste. Secondly, the issues of monitoring and enforcing of taxes are avoided in many scenarios. For example, DRS systems encourage litter to be picked up and recycled, whilst, with Pigouvian taxes, it is often difficult to hold individuals accountable for littering. Thirdly, issues of tax evasion under the DRS system are avoided.

Moreover, it is important to consider the capacity of local, regional, and national authorities in implementing the above-discussed instruments. There is a need for stringent controls to keep the regulations in place with CAC's. With limited capacity to ensure these controls are implemented,

[8] These are taxes which are imposed on businesses or individuals that engage in activities that produce negative consequences on society and the environment (Kagan, 2020).

developing countries often find these instruments difficult to execute alone (UNEP, 2005: 2). EI's can incentivise or disincentivise polluters to go beyond what is formulated by regulation. In developing countries, it is recommended that a policy-mix between EI's and CAC's be implemented (UNEP, 2005: 2). Montevecchi (2016: 2) notes that, when compared to a single policy instrument that is employed in isolation, policy mixes tend to yield a higher performance towards given policy objectives. Policy mixes are preferred over stand-alone policy instruments since they are better at achieving the two objectives of solid waste management; to cover costs and thus improve service delivery, and to influence behaviour by means of the pricing mechanism aimed at waste minimisation, avoidance of negative impacts (e.g. from landfilling) or to strengthen resource recovery and recycling (Federal Ministry for Economic Cooperation and Development, undated: 5). This is reinforced through empirical findings discussed in subsequent paragraphs. It is recognised that, by implementing policy instruments, costs are incurred by municipalities. To ensure that costs are balanced at the margins, waste-producing sectors that produce higher marginal benefits and lower marginal costs must be identified and targeted by waste management. Economic instruments for environmental management aim to correct market failures, reinstate full-cost pricing, and realign resource allocation with societal objectives.

Another important consideration made by governments seeking to implement alternative waste management strategies and policies, is the issues faced by crowding-out. Crowding-out is a problem induced by excess government or external intervention. Studies investigating crowding-out effects often consider pricing (economic) instruments, such as Pay-As-You-Throw (PAYT) schemes[9] (Berglund, 2003: 6). Crowding-out theory proposes that, should households feel morally and innately inspired to partake in separation-at-source activities, economic instruments may crowd out this intrinsic motivation and can cause less recycling activity to be undertaken.

[9] PAYT schemes are variable policy instruments that ensure individuals pay for the waste that they discard (U.S. Environmental Protection Agency, 2016). This is done through weighing households' waste or by charging households per waste-bag or can they use

Similarly, this applies when economic agents are offered extrinsic rewards (i.e.: recycling subsidies or tariff reductions) to perform desired tasks, such as recycling, which can undermine intrinsic motivation and cause a reduction of waste minimisation actions.

When considering the existing empirical evidence on policy instrument mixes, there have been varying results on the effectiveness of various policy instruments employed by waste management authorities. Whilst Jenkins, Martinez, Palmer and Podolsky (2003) and Parks & Berry (2013) conclude that recycling programmes are more impactful in increasing the recycling rate compared to unit pricing systems, Sidique, Joshi & Lupi (2010) and Lakhan (2015) find that both pricing mechanisms and recycling programmes prove effective in increasing the rate of recycling.

Han *et al.* (2016: 2) contribute to this debate by arguing that it is insufficient to consider these policies as independent instruments that produce independent effects. Rather, they claim that these instruments interact with one another and have implications on the underlying intrinsic motivations of economic agents by inducing crowding-out effects. Han *et al.* (2015) employ a static panel data model to assess the policy mix of subsidised source separation and garbage fees on waste generation on 36 major Chinese Cities during the period 1998-2012. They conclude that, when paired with the garbage fee, the waste separation program tends to crowd out the intrinsic motivation for economic agents to sort waste at the source and instead has the opposite effect on source separation.

A meta-analysis conducted by Tojo (2008), which considers the European case study, also investigates the effectiveness of various policy mixes in achieving waste management objectives. This meta-analysis considers three case study areas – Italy, Poland, and Denmark. The study finds that, in Italy, where a Door-to-Door collection system had been implemented (similar to the Think Twice programme), there had been a 50%-60% improvement in source separation between 2003-2005. This system had been accompanied by an information campaign, which is said to have reinforced the success of the Door-to-Door system (Tojo, 2008: 24).

In Poland, Tojo (2008) analyses the effectiveness of the softer waste management instruments introduced by the 2002 National Waste Management Plan objectives. The analysis notes that most of the objectives set out by this Plan had not been achieved, especially in the areas of proper waste collection, source separation of recyclables, biodegradable waste, and hazardous substances. The lack of success had mostly been attributed to the financial mechanisms and over-preference of the free market, implying there was no consideration for the employment of complementary policy instruments which are aimed at incentivising waste-minimising behaviour. Lastly, in Denmark, Tojo (2008, 52) notes that, under the weight-based pricing system, which had been introduced in 1993, and a Door-to-Door collection system, the amount of residual waste was halved. It is, however, found that the amount of residual waste collected at households had been increasing, and that the proportion of organic waste, between the two fractions from 2000 to 2004, subject to door-to-door collection has been decreasing, implying that it is difficult to assess the actual impact of the weight-based pricing system on source separation. Evidence from this meta-analysis indicates that the success of policy instruments in reducing waste generation and improving source separation, is largely dependent on the mix of instruments employed.

An economic analysis conducted by Choe & Fraser (1999), employs a comprehensive model of household waste management policy incorporating the possibility of waste reduction effort by the firm and the household, and illegal waste disposal by the household. This model's findings, as will be seen in Chapter 3 during the discussion of the CCT's waste management system, can be considered for the CCT, given the issues of illegal dumping. Within this context, the study finds that the optimal policy combines an environmental tax imposed on the firm by a regulator, a household waste collection charge, and monitoring and fining of illegal waste disposal. The optimal policy found in this study, once again, reiterates the importance of implementing policy packages in achieving desired waste management objectives. From the above-discussed studies, Choe & Fraser (1999), Han *et al*. (2016), Lakhan (2015), Sidique, Joshi and & Lupi (2010) & Tojo

(2008) conclude that policy packages are effective in achieving objectives set out by waste management authorities.

Besides the consideration of the interactive outcomes of policy mixes, it is important to consider all costs and benefits derived from different waste management schemes. To reach a cost-effective solution for waste management, all costs, including externalities, must be balanced at the margins (Goddard, 1995: 189). The municipal costs (internal costs), are the direct monetised costs that are incurred by an organisation or person undertaking an activity.

Externalities are the nonmarket costs or benefits that arise when the social and economic activities of individuals or firms or in this case municipalities unintendedly impact others (Eshet, Ayalon & Shechter, 2006: 336 and Goddard, 1995: 189). Negative externalities, which arise from market failures, can be observed as environmental disruptions (i.e.: pollution, littering, marine debris and climate change), negative health effects or damages to property and agriculture. In the waste sector, negative externalities associated with landfilling include the release of landfill gasses (CO_2 and CH_4) and leachate which causes groundwater contamination (Eshet *et al.*, 2006: 337). Negative externalities associated with incineration include the release of air pollutants such as NO_x, SO_2 and dioxins. Landfills and incinerators typically induce welfare costs (i.e.: exposure to odour, dust, noise, and wind-blown litter) to households living near these facilities. Moreover, the transportation of waste to these sites create further negative externalities such as airborne emissions, accidents, and noise. Positive externalities (external benefits) of landfilling occasionally include energy generation obtained from methane, and the external benefits of incineration include avoiding external costs from conventional electricity production through energy recovery (Eshet *et al.*, 2006: 337).

Policymakers can make use of cost-benefit analysis (CBA) to calculate whether the benefits of waste management systems outweigh the social (external and municipal) costs (Eshet *et al.*, 2006: 337). In practice, however, challenges are found when accurately estimating the monetary values of externalities. Fortunately, there is an extensive range of literature in the field of environmental economics that estimate monetary values for externalities using various valuation methods (Dijkgraaf & Vollebergh 2003; Kim, Phipps & Anselin, 2003; Miranda & Hale 1997; Rosendahl, 1998; and Schall, 1992).

Full-Cost Accounting methods is a systematic approach used to calculate the direct and municipal costs associated with projects, policies, and actions. This includes Environmental Full Cost Accounting (EFCA)[10]. D'onza, Greco & Allegrini (2016) apply the 'full cost' classifications to determine the full costs of the MSW collection process for a sample of municipalities in Italy for four types of waste. Life Cycle Analysis (LCA)[11] and Waste Input-Output (WIO) models are also considered useful when analysing waste policies. Mali & Patil (2016) compute a LCA of MSW management to devise a more feasible treatment scenario for waste in Kolhapur city, India.

The study concludes that, on one side of the spectrum, open dumping is the most environmentally damaging scenario, and on the other side of the spectrum, pyrolysis–gasification, with energy recovery potential and composting is an environmentally preferable option for MSW management. Nakamura & Kondo (2002) had developed an extension of the WIO model. The model indicates the flow of various waste types that are generated by productive and waste treatment sectors (as a positive entry) and additionally shows the use of waste by productive sectors (as negative entry) towards the respective waste treatment option. Nakamura & Kondo (2002) apply this model to Japan, which faces similar issues of landfill scarcity. The WIO model results suggest that the preferred waste management for Japan is to concentrate incineration in a small number of large facilities with efficient energy recovery. Material Flow Analysis (MFA) is helpful in providing

[10] EFCA is an accounting method that includes both the direct costs (such as operating costs), and the indirect costs (costs to the environment, society, and human health) (Jasinski, Meredith & Kirwan, 2015: 1124).
[11] LCA assess the environmental impact of a product throughout its life cycle (from "cradle" to "grave") (Haggar, 2005)

visual aid in understanding the flow of materials in a specific waste system. Once these material flows are identified, the costs of processing these materials can be determined (Wilson, Rodic, Scheinberg, Velis & Alabaster, 2012: 242). An example study of MFA is conducted by Masood, Barlow & Wilson (2014). The study evaluates the MSW management system in Lahore, Pakistan and deduces that, despite the amount of investment being directed towards waste services, such as waste collection, the current state of waste management in Lahore is poor due to gaps in planning and physical infrastructure.

Waste management, under the FCA approach, considers three main types of costs, namely, up-front costs, operating costs, and back-end costs. These three cost types, according to the United States Environmental Protection Agency (EPA, 1997:3), account for the "life cycle" activities of Municipal Solid Waste, whereby the up-front costs, such as initial investments needed to execute waste services, account for the "cradle" segment of LCA. Back-end costs, involving the costs incurred to wrap up operations of waste facilities, account for the "grave" segment of LCA. The full-cost pricing formula, which determines at what price certain waste taxes or EI's should be set, is given as:

$$P = MPC + MUC + MEC$$

P is the price, MPC is the marginal production costs, MUC is the marginal user (depletion) cost and MEC is the marginal environmental cost (Panayotou, 1994: 3). Economic instruments aim to establish full cost pricing by accounting for scarcity costs associated with resource depletion and environmental degradation.

Under public theories of regulation, which assumes that regulators have access to full information, and that the regulative actions contribute towards promoting public interest and that market failures exist, one method of achieving allocative efficiency of resources is government intervention (den Hertog, 2010: 5). This theory postulates that the greater the intervention, the lower welfare losses will be. This has been critiqued for various reasons. One critique considers that government intervention is efficient and can be implemented without undergoing great costs (den Hertog, 2010: 9). Given the extent to which external and municipal costs need to be managed under waste management, as previously discussed, this is evidently an issue needed to be considered by solid waste managers and regulators. Whilst these costing approaches are not formally calculated in this study, they are highlighted in this section to determine the relevance of economic policy suggestions offered later in this study.

2.3) Waste management in practice

Whilst it is important to have a fundamental understanding of the theories of waste economics to support waste management decisions, waste management is often conducted under a context-specific framework. This section highlights the current global perspective on waste management and the circular economy. Furthermore, global case studies are considered to inform later findings.

Finite natural resources, a major contributor towards economic growth and development, should be appropriately managed to enable a shift towards a sustainable environmental growth path and, in the long run, towards a green economy. To propel action towards reaching a green economy, policy measures need to be implemented, which address existing market failures and prevent inefficient consumption of resources. Within the waste sector, policies should be aimed at creating incentives for economic agents, to not only invest in waste-minimisation technologies, but to simply make more efficient choices (Department for Environment, Food and Rural Affairs (Defra), 2011: 5).

Generally, waste policies and management systems are implemented to assist the transformation from current linear waste economies to circular waste economies. Material recirculation, which enables the development of new products, is described as a more sustainable alternative as opposed to the current linear waste system (Singh & Ordoñez, 2016: 342). Since its adoption in 1975, the waste hierarchy has been used as a tool to guide long-term waste policies towards achieving a circular waste economy. The waste hierarchy, provided by the South African State of Waste Report

(SoWR), as depicted in Figure 2.1, displays the levels of waste management activities from the most desirable to the least – with avoidance and reduction of waste generation being the most desirable and treatment and disposal of waste (landfilling and incineration without energy recovery) is the least desirable (DEA, 2018: 66). It should be noted that such a hierarchy is used in a broad context for management policies and is not necessarily applied or is useful for every country or city. The application of such a hierarchy may impede the socially optimum solution by reducing revenue streams and increasing costs for the waste sector. For example, it may not necessarily be cost-efficient to construct new recycling plants, or transport wastes to these recycling plants, due to the external and municipal costs incurred. Whilst the waste hierarchy is used as a fundamental global guiding tool for integrated waste management, a more intricate understanding of waste management strategies is needed to find cost-efficient approaches. To do this, global case studies of various waste management strategies, and their respective rates of success, is required.

Figure 2.1 : Waste Hierarchy
(Source: DEA SoWR, 2018: 66)

Comparisons can be drawn on waste management techniques under an integrated and sustainable (solid) waste management approach (ISWM)[12]. Wilson *et al.*'s (2012) study is a prime example of such a comparison[13]. For ease of analysis, Wilson *et al.* (2012: 238), separates the ISWM into two 'triangles' - the physical and governmental components. For comparative purposes, 7 benchmark indicators had been used to capture the two triangles of ISWM. The first, physical triangle, considers three key drivers of developments in waste management, and the benchmark indicators included here are: public health, the environment and resource management. The governmental component analyses the strategies implemented to deliver a well-functioning waste system. This includes three inter-related criteria (benchmark indicators) for effective governance: inclusivity, financial stability, and sound institutions.

The Wilson *et al.* (2012:238) study compares data for 20 'representative' cities globally. The first trend noted is that per capita waste generation increases with income levels[14]. The second trend,

[12] Integrated Waste Management is the current approach to waste management in South Africa.
[13] This study is summarised from a developing city perspective to draw comparisons to the CCT.
[14] The income proxies considered are the Human Development Index (HDI) and Gross National Income (GNI)

although acknowledging the issues surrounding waste definitions and measurement strategies, determines the composition of waste per income-level. Levels of organic waste are relatively higher for lower income countries than higher income countries. The composition percentages for paper are relatively low for lower income countries and plastic levels are generally high for all income-levels.

The findings related to the 7 benchmark indicators are summarised as follows. The public health driver is measured by the collection coverage in cities. It is found that, despite previous assumptions by the World Bank (undated), which claim that, in developing world cities, less than 50% of waste is collected, middle-income cities have a collection coverage in the range of 70–90% and low-income cities in the range of 45-60% (Wilson *et al*., 2012: 246). This implies that waste collection and service delivery in the developing world is a priority of waste management. The second indicator; environmental control is measured by the waste disposal methods and standards. Wilson *et al.* (2012: 247) finds that developing cities had an average 51% of controlled disposal, with a noted distortion towards zero, due to the city of Bamako reporting 0 controlled disposal, but high recycling rates. This implies that there are municipal efforts aimed at redirecting investments towards waste facilities in developing cities. It is speculated that this is a responsive waste management solution employed due to the high rates of illegal dumping in developing cities brought (Wilson *et al.*, 2012: 247).

The resource management indicator is measured by the share of materials recovered. Wilson *et al.* (2012: 248) find that middle- and low-income cities report significantly larger shares of recovered waste being handled by the informal sector relative to high-income cities[15]. This finding is in line with Simatele, Dlamini & Kubanza's (2017) study that investigates the importance of the informal waste sector for the recycling initiatives in the city of Johannesburg, South Africa. Simatele *et al.* (2017) conclude that the informal waste sector (specifically, waste pickers) play a significant role

[15] High-income cities are fully dependent on the formal sector for waste recovery

in solid waste management, particularly in waste collection and recycling. This study finds that, in 2016, informal waste pickers had been responsible for retrieving an approximated 53% of recyclable glass (or glass bottle) and 64% of scrap metals received at Maningi recycling plants. The authors further argue that, given this significant contribution of informal waste pickers in waste diverting activities, there should be a greater alignment of the informal waste sector into the ISWM framework (Simatele *et al.*, 2007).

When comparing governance strategies, the first driver considered by Wilson *et al.* (2012: 249-252) is inclusivity. Inclusivity, in this context, is whether government strategies includes equitable service delivery and inclusivity on decision-making. Only 2 of the 20 cities score highly for user inclusivity and provider inclusivity – Adelaide (high-income city) and Belo Horizonte (upper-middle income city). The second driver considered is financial stability which had been calculated from the percentage of the population using and paying for waste collection services. Evidently, high-income countries are shown to have the highest financial stability levels. However, for the remaining income levels there are sporadic results. The authors did, however, note that expenditure levels for solid waste management in low- and middle-income cities were lower than that of high-income cities and that there is space for these expenditures to increase before affordability problems would take place. Finally, the last driver considered is 'sound institutions', which had been measured by the degree of institutional coherence. Wilson *et al*. (2012:252) had found all cities to have medium to high levels of institutional coherence except for Dehli (lower-middle income city), Nairobi (low income city) and Bamako (low income city). The degree of institutional coherence had been measured using a composite score on a set of quality indicators. The first four indicators assess policy and the degree of municipal control, while the last two assess the degree to which the solid waste budget is directly controlled by one responsible department within the city, and the degree of departmental management control over waste management.

From this study, conclusions can be drawn that cities around the world are making a concerted effort to address issues surrounding solid waste management. Developing (low-middle and low-income) cities are directing resources towards improvement of waste services, recycling of waste and improving government strategies. Evidently, each city has specific parameters guiding the ability of waste management. This study aims to consider these parameters for the CCT and provide guidance on how to manage waste in a cost-effective manner by analysing the City's waste and economic relationship and the identifying the indicators that drive solid waste generation.

2.4) Empirical evidence on the relationship between waste and the economy

Whilst the theoretical and applied understandings of waste management strategies are important, it is crucial to consider the empirical findings of waste management. This section summarises the empirical findings related to the objectives of this study. In section 2.4.1, a description of the various methods for obtaining empirical results investigating the relationship between waste and the economy is provided. In section 2.4.2, literature investigating the WKC hypothesis is summarised. Lastly, in section 2.4.3 and 2.4.4, a breakdown of the explanatory variables (policy and socio-economic variables) used in empirical literature are discussed and summarised.

2.4.1) Research methods

Literature that investigates the relationship between waste generation and the economy and the effect of influencing drivers on waste generation has been making headway, however, there exists differences between methodologies, data and definitions used in the literature (Grazhdani, 2016: 4). Nevertheless, researchers undertaking this type of study consider one (or more) of five broad control variable categories; socio-economic, demographic, household-related, waste management measures and policy variables, either under a qualitative or quantitative framework (Grazhdani, 2016: 4). For this study, the literary focus is on research that considers socio-economic and policy variables.

Furthermore, the methods within the existing literature act as an important guiding tool for this study. According to Grazhdani (2016:5), methodologies used by researchers investigating the waste-economy relationship include regression analysis, group comparison trend analysis using historical data, systems dynamics, input-output analysis, gray fuzzy models and an artificial intelligence model. This study makes use of regression analysis, which can be further compartmentalised into a model using municipal-level data. Regression modelling is widely employed in EKC analysis due to the availability of developed theory and simple algorithms (Grazhdani, 2016: 5).

This study utilises municipal (city) -level time-series datasets. Time-series regression is widely employed in research investigating environmental degradation and its relation to the economy in an individual study area. Predominantly, the environmental component of these studies is greenhouse gas (GHG) emissions (Abid, 2015; Jalil & Mahmud, 2009; Ozturka & Al-Mulalib, 2015; Shuai *et al.*, 2017[16]; Tutulmaz, 2015; and Yang, Yuan & Sun, 2012).

Whilst it is more common to investigate delinking of waste using a panel data regression, there are studies investigating the WKC hypothesis using time-series regression (Magazzino, Mele & Schneider, 2020; Miyata *et al.*, 2013; Wu, Zhang, Xu & Che, 2015; and Yang *et al.*, 2012). Despite the drawback of having to account for serial correlation and individual heterogeneity when using time-series linear regression, there are benefits in using time series data. As highlighted by Jalil and Mahmud (2009: 5168), using time series data on a single country or city level can provide a better framework for understanding the relationship between the economy and environmental degradation. Moreover, this type of analysis allows for the examination of various policies and other exogenous factors that may apply singularly to the country or city of study, thus allowing for more appropriate and targeted policy suggestions (Jalil & Mahmud, 2009: 5168). This is further reinstated by Chang and Lin (1997: 167), who argue that these models are flexible enough to allow for policy intervention adaptions. With panel data, this may not be possible since not all cities employ the same policy interventions. Wu *et al.* (2015), an exemplar study in this regard, initially

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[16] Shuai *et al.* (2017) investigates the EKC using both panel and time series data.

regresses pooled data for an entire region within China under two models – the first model only considering per capita GDP and per capita GDP^2 as independent variables, and the second including a proxy for environmental policy (domestic garbage harmless treatment rate). The researchers then regress time-series data for single city analysis. They consider three Chinese cities, Chongqing, Zhongshan and Taipei, and include a policy explanatory variable that had been implemented in each city, respectively. They find evidence of a WKC for two of the three cities examined.

The secondary objective of this study is to identify indicators that influence waste generation rates. These indicators, namely socio-economic and policy variables, can be included in time series models, however, caution is drawn when including too many variables due to greater chances of autocorrelation (Simonoff, 2020). This study investigates explanatory variables in a step-by-step process, by adding each variable, by order of which variable is considered most influential to least influential, to provide a set of models of which conclusions can be drawn. The time-series study by Miyata *et al.* (2013) considers two additional explanatory variables apart from GDP, which are the city expenditure for waste treatment (CE) and population. Their data set spans from 1980-2005. Their findings conclude that there is a positive relationship between economic growth, MSW generation and city expenditure for waste treatment. Similarly, Magazzino *et al.* (2020), who consider the relationship between waste generation, GHG emissions and GDP, include an additional explanatory variable into their model, namely waste recovery generation. They run two time-series models; the first model only includes GDP and Total Municipal Waste generation, of which they find a bidirectional causal relationship; the second model includes the remaining two independent variables (GHG emissions and waste recovery), of a significant causal link from waste recycling to greenhouse gas emissions is concluded. Further results investigating the WKC and explanatory variables, using both panel and time-series regression is discussed in the following sections.

2.4.2) Empirical findings on the WKC

Several studies have investigated whether economic growth can ultimately resolve the issue of increasing waste generation by testing the WKC hypothesis. Typically, economic studies geared around waste management investigate three primary objectives; the general relationship between waste and the economy, testing of the WKC, and testing which socio-economic and policy indicators impact waste generation rates the most.

It can be shown that the scale of the empirical data used for investigating the relationship between waste and the economy often informs the findings reported by authors. Table 2.1 summarises these results. Ercolano *et al.* (2018) note that cross-national studies show evidence of a monotonically increasing relationship between waste generation and the economy. For instance, Johnstone and Labonne (2004) analyse cross-national OECD data on municipal solid waste from 1980 to 2000. They include three socio-economic variables (household size, household composition and population density) as regressors and find a monotonically increasing relationship between waste and the economy. Furthermore, the findings reported by Cole *et al.*, (1997), investigating cross-national municipal waste data collected in 13 OECD countries over the period 1975–1990, follow suite and show the same result as Johnstone & Labonne (2004). A comparable result is found by Mazzanti & Zoboli (2009), based on data from 25 European countries for years 1995-2005, which show a monotonically increasing relationship between waste and the economy. Although the cross-country results of a non-existent WKC is presiding, these conclusions are not unequivocal. Raymond (2004) finds evidence of a U-shaped WKC when investigating empirical evidence provided by 142 countries.

It should be addressed that cross-national research concerning the WKC hypothesis and the waste-economy relationship do have caveats that can result in ineffectual results. These results estimate “average” international curves and cannot always be applied to municipal administrative units, where, typically, this type of research is applied (Ercolano *et al*., 2018: 398). Moreover, cross-country studies often overlook cross-national heterogeneity, on which these studies are based, implying the WKC may not hold for all areas under investigation.

On a single-country level, case studies utilise more concise datasets that better inform sub-national administrative targets. An example of such a study is provided by Mazzanti *et al.* (2008), who apply a dataset of 103 Italian provinces from 2000 to 2004 to an empirical model. Their findings are in support of an inverted U-shaped WKC for waste and per capita added value. Similarly, Magazzino *et al.* (2020) confirm the existence of the WKC in Switzerland for the years 1990-2017. Wu *et al.* (2015) find the same result when using pooled data of 31 provinces in China, using data from 1997-2011.

Lastly, municipal-level studies, which are most appropriate for institutional contexts, whereby municipalities handle administrative and operational tasks surrounding waste management have been conducted in recent years. Ercolano *et al.* (2018) conduct panel regression analysis using a dataset consisting of 1,497 municipalities from the Lombardy region in Italy from 2005 to 2011. They find evidence that supports the WKC, however only several a few municipalities reach the turning point of the estimated curve. A study by Trujillo *et al*. (2013), observes 707 municipalities located in Colombia over the period 2008–2011. They conclude evidence for an inverted U-shaped WKC with a heterogeneous turning point across the regions of the country. Madden *et al.* (2019) use a geographically and temporally weighted regression (GTWR) model to investigate the WKC hypothesis for municipal waste from 2011 to 2015 and find mixed results for the WKC hypothesis. GTWR models, which are spatially varying coefficient models, extend an OLS regression such that regression parameters can adapt over space, therefore assuming relationships between variables may not constant over space (Madden et al., 2019: 676). The study finds that WKC-conforming municipalities have inferior waste management systems and waste disposal practices than those found in non-WKC conforming municipalities. This counter-intuitive argument is made because the WKC-conforming municipalities in the study area demonstrate higher per capita MSW generation rates and a significantly lower proportion of waste collected as recycling. Lastly, Wu *et al.* (2015) find evidence of two WKC-conforming cities from the three cities examined.

Given the findings from previous literature in this field, it is emphasised that the WKC results are dependent on the context of the study area. As per the theory discussed in relation to Diagram 2.2, only absolute decoupling of waste is observed when the study area, or municipality, reaches the turning point of the estimated curve. From the above-reviewed literary results, only a few study areas reach the turning point of the estimated curve, implying that it is more common to observe relative decoupling of waste as opposed to absolute decoupling of waste. Provided that this study investigates municipal-level data, and should it be found that the WKC hypothesis holds for the CCT and that the estimated turning point falls within the CCT's income range, absolute decoupling will be present. These results will be corroborated using calculations for the decoupling factor.

Table 2.1: Literature investigating the waste-economy relationship

	Level of Study			
Author(s)	Municipal	Single-country	Cross-national	Waste-economy Relationship
Cole, Rayner & Bates (1997)			✓	Waste generation monotonically increases throughout the income range examined
Berrens, Bohara, Gawande, & Wang (1997)		✓		Confirm an inverted-U relationship for two separate indicators of US hazardous waste
Johnstone & Labonne (2004)			✓	Waste generation monotonically increases with income
Raymond (2004)			✓	Waste/consumption stress indicator exhibits an inverted U-shape relation with income
Mazzanti, Montini & Zoboli (2008)		✓		An inverted U-shaped relationship exists with a turning point at very high levels of per capita income
Mazzanti & Zoboli (2009)			✓	Waste generation monotonically increases with income
Karonsakis (2009)			✓	Waste generation monotonically increases with income
Trujillo Lora, Carrillo Bermúdez, Charris Vizcaino & Iglesias Pinedo (2013)	✓			Quantity of landfilled solid waste exhibits a WKC relationship with economic development, whose turning point is heterogeneous across the regions of the country
Arbulú, Lozano & Rey-Maquieira (2015)			✓	Results accept the hypothesis for WCK for a panel of 32 European countries
Wu, Zhang, Xu & Che (2015)	✓	✓		WCK accepted for the pooled single region model, and WKC only accepted for two of the three cities analysed
Alajimi (2016)		✓		There is a long-standing relationship between the variables under examination, and that the EKC hypothesis is not valid for MSW in Saudi Arabia
Gardiner & Hajek (2017)			✓	No EKC hypothesis tested but causal relationships are tested. In the short run: bidirectional causal relation running from GDP to waste in Germany, bidirectional causality running from GDP and gross capital formation to waste for the UK. For France, causality running only from gross capital formation to waste was found. In the long run, the variables had no impact on waste in France and Germany. A unidirectional and bidirectional granger causality running from gross capital formation, GDP and employment to waste in the UK.
Ercolano, Lucio Gaeta, Ghinoi, & Silvestri (2018)	✓			Find evidence of an inverted U-shaped curve. However, only a few of the municipalities reach the turning point indicated by the estimated model.
Jaligot & Chenal (2018)	✓			Evidence of EKC cannot be confirmed as waste generation tends to stabalise as income increases.
Madden Florin, Mohr & Giurco(2019)	✓			Both WKC- conforming and non-conforming municipalities identified. WKCconforming municipalities had higher per-capita rates of waste generation, and lower mean incomes comparedto non-conforming municipalities.
Magazzino, Mele & Schneider (2020)		✓		WKC confirmed under time-series regression

Source: Own analysis, based on references as listed in the Table

2.4.3) Empirical findings on explanatory variables

Table 2.2 is a compilation of literature that employs empirical regression methodologies, the applied socio-economic and policy proxy explanatory variables and the fundamental conclusions drawn for the respective variables.

2.4.3.1) Socio-economic Indicators

It is evident that the chosen variables render mixed results. Population density, a common explanatory variable, often used as an urbanisation proxy for waste generation, most often has been shown to have a positively statistically significant relationship with waste in the Mazzanti *et al.* (2008) and Mazzanti and Zoboli (2009) studies[17]. In contrast, Jaligot and Chenal (2018) and Ercolano *et al.* (2018) find a negative relationship between waste generation and population density. Jaligot and Chenal (2018: 264) attribute this result to factors such as the differences of waste management strategies in urban areas (more densely populated) and rural areas. Other explanations include that higher population densities may imply a greater level of land resource scarcity; hence a more dedicated approach to preserve land may result in waste minimisation efforts (Mazzanti *et al.*, 2008: 60).

Another common explanatory variable often used in these studies include tourism proxies. Arbulú, Lozano, and Maquieira (2015) and Mazzanti *et al*. (2008) observe that tourism flows have a positive relationship with waste generation. Arbulú *et al.* (2015), exploiting the variables TUR (tourism arrivals) and TUREXPIND (expenditure per tourist index), concludes that tourism inflows exert a significant upward pressure on MSW generation until a turning point is reached, where more tourism arrivals contribute to lowering MSW. The turning point is argued for as follows: an increase in per tourist expenditure implies higher material consumption which subsequently suggests sophisticated preferences and, therefore, a greener demand that incentivises

[17] Mazzanti and Zoboli (2009) test 3 different dependent variables but this section only summaries the model which tests for MSW generation.

the implementation of greener management by tourism suppliers (Arbulú *et al.*, 2015: 633). Ercolano *et al.* (2018) observe a negative relationship between tourism flows and waste generation, which could be attributed to the above explanation provided by Arbulú *et al.* (2015).

Of the remaining socio-economic variables, which include the proportion of elderly persons, education and unemployment, Chen (2010) and Ercolano *et al.* (2018) report a negative statistically significant relationship between waste generation and the proportion of elderly persons. Chen (2010: 449) explains this result in that the elderly are more inclined to participate in recycling programs than the younger generation. Other authors who tested this hypothesis, such as Werner & Makela (1998), Mazzanti & Zoboli (2009), found no statistical significance between waste generation and proportion of elderly persons in the population. A study conducted by Struck & Soukopová (2016), who investigate the relationship between population age structure and waste reduction activities in Czech municipalities, also find that the eldest population group contribute the most to separation at source activities. Arbulú *et al.* (2015) are the only authors who found a statistically significant relationship between waste and education. They find a negative relationship between waste and education, which implies that higher education levels create environmental awareness and a tendency to recycle more. Chen (2010) finds a similar statistical result but only for the pooled data and not the regional data. Chen (2010) reports statistically significant results of the relationship between unemployment and waste disposal. This relationship is found to be negative, implying that an increase in unemployment reduces the rate of MSW. Chen (2010: 451) explains that, in rural areas, labourers are forced into tasks such as waste picking and recycling to generate income, thus reducing MSW disposal rates. Arbulú *et al.* (2015) observes that unemployment rates and MSW generation have a negative statistically significant relationship. The study argues that an increase in the unemployment rate reduces the consumption capacity, therefore reducing MSW generation rates.

2.4.3.2 Policy Indicators and Management Suggestions

Policy proxy variables are more complex since they are obtained by researching the specific waste management strategies used in respective study areas. Administrative units in one country rarely have the same waste management strategies and policies as another country. For these variables to best inform this study, it is argued that global case studies which analyse various policy strategies for waste management should be consulted. Table 2.2 offers a broad summary of literature that analyses various waste policy instruments. The literature of which Table 2.3 is compiled, includes research with quantitative (Carattini, Baranzinic & Lalived, 2018; Jaligot & Chenal, 2018; Mazzanti *et al.*, 2008; Massoud, Mokbel, Alawieh & Yassin, 2019; Sjöström & Östblom, 2010 and Wu *et al.* 2015), and qualitative (Greyson, 2006) arguments. Carattini *et al.* (2018), using a differences-in-differences model[18], Jaligot & Chenal (2018), using a fixed-effects regression model, Wu *et al.* (2015), using both a time-series and pooled regression, and Sjöström & Östblom (2010), using a Computable General Equilibrium (CGE) model all show that, at statistically significant levels, garbage bag taxes (GBT) are effective policy instruments for reducing waste generation.. A fixed tax is only appointed to middle- to high-earning income households (Jaligot & Chenal, 2018: 265). This implies that fixed taxes are only indirectly correlated to waste generation through income, and given South Africa's income inequality status, this type of tax may not be as appropriate in targeting the reduction of waste quantities.

A producer preventative policy approach to waste management is supported by Greyson (2006), arguing for a precycling insurance scheme[19] and Sjöström & Östblom (2010), contending for the implementation of producer-side waste taxes such as virgin material taxes. Although these upstream instruments are highlighted in South Africa's National Pricing Strategy for Waste Management (2008), the growth in the recovered aggregate sector is predominantly reliant on market-driven factors, rather than external factors (i.e. Extended Producer Responsibility schemes[20]), which is in contrast to global well-developed recovered aggregate markets

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[18] Difference-in-difference analysis is a statistical technique that controls for unobserved variables by estimating the causal effect of an intervention by modelling a 'control group' and a 'treatment group (Carattini *et al.*, 2018: 135).
[19] These are, according to Greyson (2006: 1384); "actions taken now to prepare for current resources to become future resources, rather than wastes accumulating in the biosphere".
[20] These are discussed in more detail in Chapter 3.

(GreenCape, 2019: 47). If it is found that the current waste policy instruments employed by the CCT do not have a significant effect in reducing waste generation rates, it is plausible that the CCT may consider adjusting the design of their instruments, preferably by using an array of complementary policy instruments (including CAC's, EI's and informational instruments) as part of a coherent policy package as discussed in Section 2.2[21].

Finally, Massoud *et al.* (2019) and Mazzanti *et al.* (2008) argue for organisational adjustments to achieve decoupling of waste. Massoud *et al.* (2019), interviewed environmental experts and concerned organisations and conclude that SWM strategies should shift towards a decentralised model, whereby all stakeholders should contribute towards the decision-making processes. The authors do acknowledge that, for this approach to achieve sustainable successful results, fiscal and political autonomy is paramount and that communication between all levels of authority (local, provincial, and national), should be superlative (Massoud *et al.*, 2019: 695). Mazzanti *et al.* (2008) show that the Cost-Recovery variable, which captures the effects of waste management movement towards an "enterprise approach", reduces the waste generation rates. This variable is another example of a variable tax.

[21] This suggestion is expanded in Chapter 6.

Table 2.2: Explanatory variables used in regression analysis

Author(s)	Socio-economic Explanatory Variables	Policy Proxy Explanatory Variables	Statistically Significant Relationship to Waste Variable
Mazzanti, Montini & Zoboli (2008)	Population density, separated waste collection, tourist flows	Tariff proxy and waste Cost-Recovery proxy	• Population density: positively statistically significant • Separated collection: negatively statistically significant • Tourist flows: positively statistically significant • Tariff proxy: positively statistically significant • Cost-Recovery proxy: negatively statistically significant
Mazzanti & Zoboli (2009)	Population density, urban population, household size, single households, age index, share of munufacturing value added.	Decentralised waste management policy drivers, Incineration directive, Landfill directive, Waste strategy policy index, landfill strategy policy directive	• Population density: positively statistically significant • Urban population: positively statistically significant (except REM model) • Share of munufacturing value added: negatively statistically significant
Chen (2010)	Population density (POPD), old age composition (OLD), unemployment (UNEMP), education (EDU)		• POPD: positively statistically significant • OLD: negatively statistically significant • UNEMP: negatively statistically significant
Arbulú, Lozano & Rey-Maquieira (2015)	International inbound tourists arrivals (TUR), Tourist expenditure index (TUREXPIND), Merchandise trade (TRADE), Dummy variable–tourism especialization (DX_Q1), Unemployment rate (UNEMP) Rural population (RURP), Government effectiveness (GOVEFF) & Education (EDU)		• TUR: positively statistically significant • TUREXPIND: negatively statistically expenditure • TRADE: positively statistically significant • DX_Q1*TUR: positively statistically significant • UNEMP: negatively statistically significant • EDU: negatively statistically significant
Wu, Zhang, Xu & Che (2015)		1) Regional level: Environmental Policy dummy; domestic garbage harmless treatment rate (HLT) 2) City level:Dummy of the waste charges policy (D): fixed disposal fee, potable water-based disposal fee and a plastic bag-disposal fee	• HLT: negatively statistical significant • Plastic bag-based disposal fee: negatively statistically significant
Alajimi (2016)	Population growth		• Population Growth: positively statistically significant
Gardiner & Hajek (2017)	Gross capital formation (CAPIT), employment (EMPL)		• CAPIT: positively statistically significant for France, Germany and the UK • EMPL: only negatively statistically significant for Germany
Jaligot & Chenal (2018)	Population density	Variable waste tax (BTAX) and a fixed waste tax (FTAX)	• Poor significance overall but finds that population density is negatively correlated to waste generation • BTAX: negatively statistically significant
Ercolano, Lucio Gaeta, Ghinol, & Silvestri (2018)	Population density, consumption by the elderly (OLDSHARE), tourist receptivity rate (ACCOMODATION) and share of foreign residents (FOREIGN)		• Population density: negatively statistically significant • OLDSHARE: positively statistically significant • ACCOMODATION: positively statistically significant • FOREIGN: negatively statistically significant
Madden Florin, Mohr & Giurco(2019)	Population density (POP.DENS), number of households (HHLDS), household size (HHLD.SIZE) and distance to urban areas (DIST.URBAN)	proportion of recycling (PROP.REC)	In their global model: • PROP.REC: positively statistically significant

Source: Various authors (2008-2019); Constructed by author

Table 2.3: Summary of literature that analyses various waste policy instruments

Author(s)	Geographical Area	Time period	Policies / Waste Management Suggestions	Policy Implications
Greyson (2006)	NA	NA	1) Precycling insurance scheme	1) Precycling insurance scheme: although newly implemented in China under the 'Law on the Promotion of the Development of Circular Economy', it claims to have several benefits for producers, the environment and society.
Mazzanti, Montini & Zoboli (2008)	103 Italian Provinces	1999-2005	1) Tariff proxy (Share of population living in municipalities that introduced a waste tariff substituting the former waste tax) 2) Waste Cost-Recovery proxy (tax or tariff revenues on variable service costs)	1) TARIFF is positively and significantly correlated to waste generation, showing a possible signal of endogeneity of policy cycles with regard to income: Richer areas show a stronger environmental policy commitment. 2) Cost-recovery, which captures the way the approach to waste management is moving toward an "enterprise approach", has a statistically significant and negative relationship with waste generation
Sjöström & Östblom (2010)	Sweden	2006-2030.	1) Preventative policy instruments (i.e.: virgin material taxes) 2) Household behaviour policy instruments	To achieve absolute decoupling: 1) Preventative taxes such as virgin material taxes can affect production techniques to reduce waste generation 2) Policy instruments must affect the pattern of household consumption such as a differentiation of the value added tax (VAT) in favour of goods and services, which reduce the waste intensity of household consumption.
Wu, Zhang, Xu & Che (2015)	31 provinces in mainland China	1997 - 2011.	1) Fixed disposal fee: charging a set amount per household per month 2) Potable water-based disposal fee: charging disposal costs based on potable water consumption per household per month 3) Plastic bag-based disposal fee: based on the weight / volume produced by households per month. Requires households to pack their waste in plastic bags sold by local government at a set price per month	1) the MSW policies implemented over the study period were effective in reducing waste generation, 2) the household waste discharge fee policy did not act as a strong driver in terms of waste prevention and reduction, and 3) the plastic bag-based disposal fee appeared to be performing well according to qualitative and quantitative analysis.
Jaligot & Chenal (2018)	Canton of Vaud, Switzerland	1996-2015	1) Variable waste tax (BTAX) 2) Fixed waste tax (FTAX)	1) BTAX is negatively and significantly correlated with MSW generation, which shows that specific charge policies are effective to reduce MSW generation.
Carattini, Baranzinic & Lalived (2018)	Canton of Vaud, Switzerland	2008 to 2015	1) Pricing garbage by the bag (PGB)	1) PGB is highly effective, reducing unsorted garbage by 40%, increasing recycling of aluminium and organic waste, without causing negative spillovers on adjacent regions
Massoud, Mokbel, Alawieh & Yassin (2019)	Lebanon, Western Asia	NA	1) Centralised approach to waste management 2) Decentralised approach to waste management	1) Delegation and the construction of centralised treatment facilities is recommended as it incentivises municipal cooperation and permits the installation of methodologies and technologies that reflect the limitations, public attitudes, and waste dynamics of each distinct geographical territory 2) Deconcentrating disposal would limit the number of landfills constructed and facilitate monitoring

Source: Various authors (2006-2019); Constructed by author

2.5) Conclusion

The scope of existing literature is unique to the context, the methodologies, the data, and the variables considered. The above-discussed literature provides a guiding tool for this study to consider relevant concepts and findings of municipal waste management strategies and the relationship between waste and the economy.

Section 1 discussed the relevant concepts about waste and the economy. These concepts include sustainability or, similarly, sustainable development, the green and circular economy, waste generation, waste landfilled, and waste diverted, the Environmental Kuznets Curve, decoupling, and elasticities. The concepts of WKC, decoupling of waste and elasticities are later applied in regression analysis to determine the short- and long-run relationships between the CCT's economy and MSW generation. This relationship is determined to assess what economic policy actions are required to achieve absolute decoupling and sustainable, long term, economic development.

Waste management theories and the relevant economic and policy instruments were discussed in Section 2. This section highlighted the importance of integrating regulatory and economic instruments to waste management. Moreover, this section discussed the empirical findings of literature that investigated the efficacy of policy instruments and policy packages. Environmental economic approaches such as LCA's, Full-Cost Accounting and Cost-Benefit Analysis, provide a framework for analysis of the costs and benefits involved when considering waste management systems. Although this study does not formally apply these techniques, they can be conducted in future research to determine whether the economic policy suggestions made in this study are socially optimal.

In practice, waste management is context-specific, and each city has pertinent parameters influencing waste generation and that are guiding waste management strategies. Section 3 discussed the findings of global and local waste management strategies. Recent research showed that developing cities are exploring options and adopting systems to waste services, recycling of waste and improving government strategies. This study determines the current state of waste management for the CCT, whether the CCT is exploring similar waste management options and adopting similar waste systems as per the research. To do so, the CCT's waste economy is investigated in Chapter 3.

Section 4 provided empirical literature investigating the objectives of this study. Municipal level studies investigating the WKC, using time-series or panel regressions, often find evidence of the WKC, however, only a few municipalities reach the turning point of the estimated curve. From the WKC literature, most studies only find relative decoupling of waste as opposed to absolute decoupling. This study will calculate a decoupling factor and analyse the MSW and GVA indices to reinforce the findings of the time series regression for the CCT.

Section 4 also summarised results obtained from studies investigating various socio-economic and policy proxies that influence waste generation. The most investigated socio-economic drivers that have been found to increase waste generation include population density and tourist flows. Socio-economic drivers found to decrease waste generation include education, the share of elderly persons within a population and unemployment. There are a range of policy variables considered in the literature due to the context-specific nature of policies and waste management systems. Variable economic instruments, such as Pay-as-you-throw (PAYT), seem to be working efficiently in most countries, however, it is reiterated that these instruments must be implement in conjunction with well-functioning regulatory instruments to be effective. Further waste management strategies argued for include precycling insurance schemes, preventative taxes (such as virgin material taxes), employing informational instruments and adopting a decentralised approach to waste management. An in-depth analysis of waste management strategies and economic instruments is undertaken in Chapter 4.

Chapter 3: City of Cape Town's MSW system and the economy

In the CCT, the current waste management costs and limited resource capacity provide incentives to seek out and implement alternative waste management practices (such as recycling), which is perceived to be more costly than landfilling (GreenCape, 2017: 13). As noted by GreenCape (2017:13), this perception is partially responsible for the slow infusion of alternative strategies. To address these issues, there is a need to determine cost-effective waste management solutions. Prior to implementing these options, it is important to consider the various drivers of waste to which the different economic, regulatory, and informational instruments must be targeted. The most wasteful sectors must also be identified to ensure policy responses are directed towards those areas in the waste system, which will not only achieve more efficient outcomes, but will prevent unnecessary cost burdens on the City.

This chapter introduces various descriptive statistics for the CCT. The sections are presented as follows; the study area of the CCT is described from a geographical, waste and socio-economic perspective in Sections 3.1, 3.2 and 3.3. In Section 3.4 the CCT's policy strategies for waste management are discussed. Waste management policies, legislation and by-laws are described and the relevance of these regulatory instruments for this study is briefly discussed. Furthermore, the current economic and informational instruments are described.

3.1) Study area description

To analyse the study area, the geography of the CCT, the CCT's waste sector and the CCT's socio-economy is described. It is important to understand the area of study when conducting econometric analysis under a waste-economy framework given that the findings are context-specific.

3.1.1) Geography & municipal solid waste overview

The CCT Metropolitan Municipality is located in the southern peninsula of the Western Cape Province. It is categorised as a Category A municipality, meaning that it contains more than 500 000 permanent residents that co-ordinate service delivery for the entire region (CCT, 2017: 13).

The CCT covers an area of approximately 2,445 km². North of the CCT is the West Coast District. The Cape Winelands Districts neighbours the CCT to the east and the Overberg District neighbors to the south-east, all of which are facing similar landfill scarcity problems, some more severe than others (GreenCape, 2020, 18). Figure 3.1 depicts a map of the CCT study area.

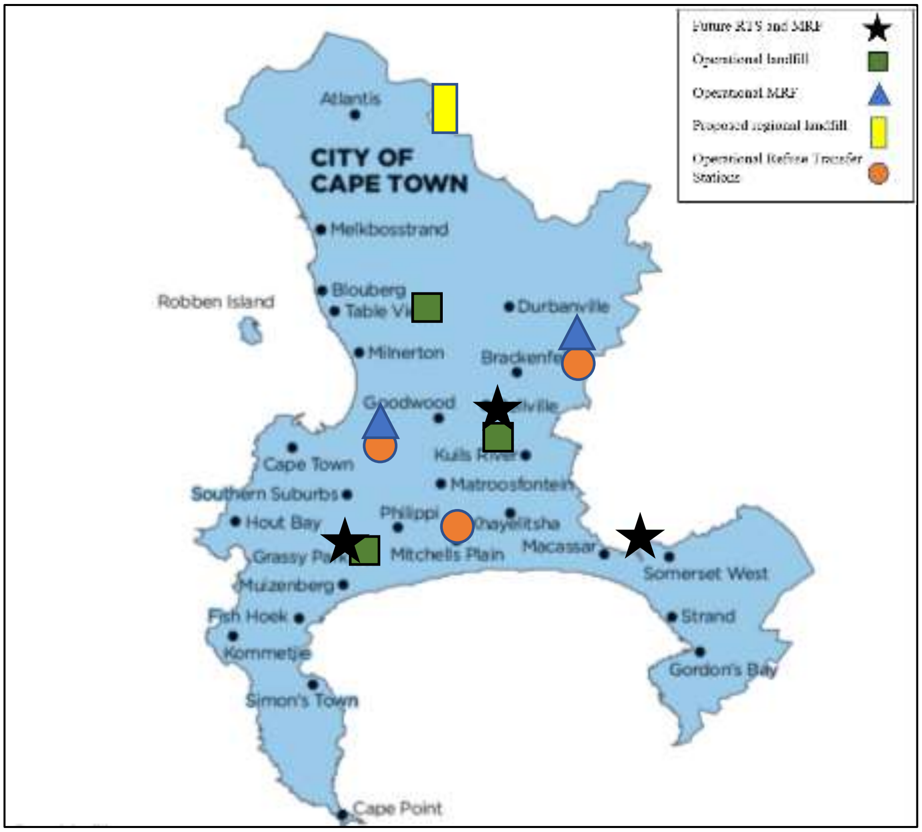

Figure 3.1 : Map of the City of Cape Town with waste infrastructure

(Source: adapted from Municipalities of South Africa and Morkel, 2018)

Currently, the CCT provides a 99.74% waste collection service in informal settlements and a 100% service in formal communities (CCT, 2018b: 23). According to GreenCape (2020: 18), the estimated remaining airspace for the CCT's landfills is more than 5 years, but less than 15 years.

Although the CCT has the highest household waste separation rates (23%) in South Africa, there remains a need for alternative waste management strategies to be employed to reduce waste generation and waste landfilled quantities (GreenCape, 2020: 9). In efforts to reduce landfilled waste, the CCT began operations of a R400 million Waste-to-Energy plant in Athlone in early 2017 (Cloete, 2017). Other waste-diverting and waste-processing facilities in the CCT include landfills, Material Recovery Facilities (MRF's) and Drop-offs. Waste Drop-offs provide individuals free access to drop off recyclables, as well as bulky garage and garden waste. The CCT has three operational landfill facilities; the Bellville South landfill and the Coastal Park landfill, both of which disposes of general waste and stockpiles garden waste and builder's rubble, and the Vissershok South landfill, disposing of general and medium to low hazardous waste (CCT, 2017: 13).

Athlone, Swartklip, and Kraaifontein transfer station, which had been commissioned in September 2010, are the three operational waste transfer stations in the CCT (CCT, 2017: 71). At these facilities, waste is temporarily stored and preferably sorted before being transported to other recycling facilities or landfills. The Athlone Refuse Transfer Station (ARTS) also functions as a dirty MRF, whereby various waste sources are being recovered and recycled. Provisions and plans for two additional transfer stations at Tygerberg and Helderberg are currently underway. In 2011, the Kraaifontein Integrated Waste Management Facility (KIWMF) had been commissioned to process mixed clean recyclables from the City's "Think Twice" kerbside recycling collection programme (CCT, 2017: 59).

The CCT has 25 waste drop-off facilities that offer residents free access to drop off recyclables, including garage and garden waste (CCT, 2020a). Contracts for the recycling and/or re-use of all recyclable/re-usable materials have also been introduced at 20 of these drop-off facilities. Moreover, to position itself as an actor in the green economy space, the CCT has signed a grant agreement with the United States Trade and Development Agency with a net worth of around R12,7 million to conduct a feasibility study on a natural gas distribution network for Cape Town (CCT 2018a: 67). Further information on the CCT waste sector is discussed in subsequent sections within this chapter.

3.1.2) City of Cape Town's Waste Sector

Although the amount of waste generated and waste landfilled presents an ongoing challenge to South Africa and the CCT, another issue facing the waste sector is the categorisation of waste, or lack thereof. Preceding the formation of the South African National Standard (SANS 10234) in 2013, and the publication of the State of Waste Report by the DEA in 2018, substantial amounts of waste had been categorised as "unclassified" (DEA, SoWR, 2018b: v). Accurate classification is important, not only to ensure waste is disposed of in the correct landfill sites but also due to the strict storage, treatment, and disposal measures required for hazardous waste (Lymer, 2016: 23). This study considers the definitions and categories of waste offered by the State of Waste Report and the SANS 10234. According to the DEA's SOWR (2018b: 15), "waste", as defined by the National Environmental Management: Waste Amendment Act, 2014 (59 of 2009) (NEMWA) is:

> *"a) any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, by the holder of the substance, material or object, whether or not such substance, material or object can be reused, recycled or recovered and includes all wastes as defined in Schedule 3 to this Act; or*
>
> *b) any substance, material or object that is not included in Schedule 3 that may be defined as a waste by the Minister by notice in the Gazette, but any waste or portion of waste, referred to in paragraph (a) and (b) ceases to be a waste -*
>
> *i. once an application for its re-use, recycling or recovery has been approved or, after such approval, once it is, or has been re-used, recycled or recovered;*
>
> *ii. where approval is not required, once a waste is or has been re-used, recycled or recovered;*
>
> *iii. where the Minister has, in terms of section 74, exempted any waste or a portion of waste generated by a particular process from the definition of waste; or*

iv. where the Minister has, in the prescribed manner, excluded any waste stream or a portion of a waste stream from the definition of waste".

Furthermore, waste is categorised according to its risk-factor as either General Waste (GW) or Hazardous Waste (HW). GW can be defined as waste that does not create an immediate threat or hazard to the environment or to health. HW, due to its inherent physical, chemical or toxicological characteristics poses a threat or hazard to health or the environment. Waste types per the broader waste categories (GW and HW) are depicted in Diagram 3.1. Figure 3.2 plots Cape Town's waste trends as per these broad categories. It is evident from Figure 3.2 that General Waste has a relatively higher generation rate compared to HW in the CCT. This trend, which depicts waste generation for total MSW, HW, and GW, is plotted for the years 2007 – 2019[22]. The result of relatively higher GW compared to HW, although seemingly accurate, could also be a consequence of miss-classification. As such appropriate classification and data values of waste are important when researching mechanisms to assist in the employment of waste management mechanisms.

A further concern regarding the waste industry is the amount of waste generated and the low recovery and recycling rates of waste. In 2017, South Africa had generated a total of 55.6 million tons of MSW, of which, an estimated 0.2% had been stockpiled or stored, 34.5% had been recovered or recycled, 0.1% had been treated and 65.2% had been landfilled (DEA's SoWR, 2018b: iv). According to GreenCape (2019: x), for 2018 the Western Cape province generates approximately 7.7 million tons of total waste per annum, with a substantial 48% (approximately

[22] These are the years for which primary data is available. Secondary data is not available for Hazardous Waste and General Waste, only total MSW.

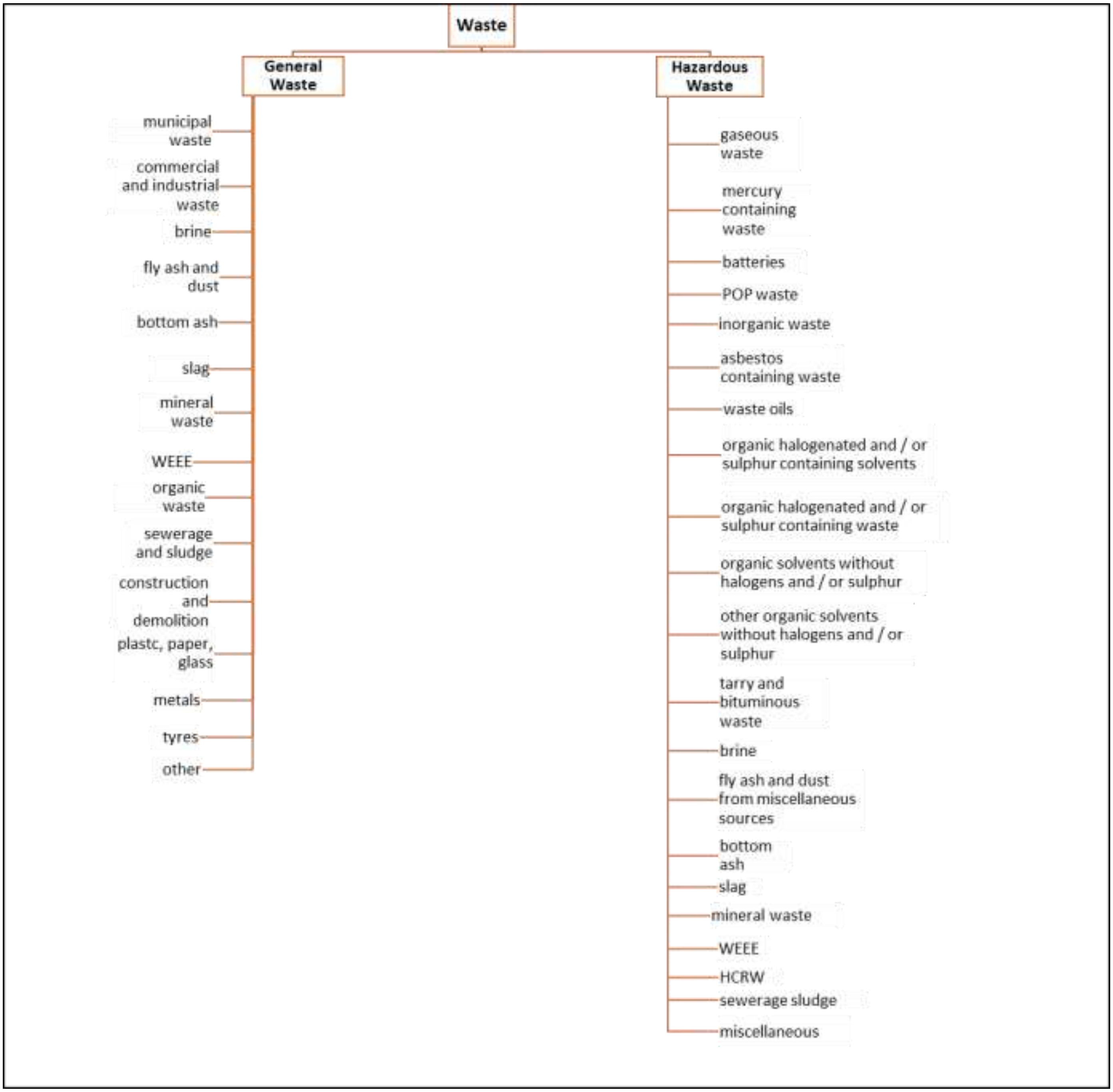

Diagram 3.1: Schematic Representation of Waste Categorisation in South Africa
(Source: Department of Environmental Affairs SoWR, 2018: 15-18, constructed by author)

3.6 million tons of total waste) of this provincial waste generation having come from the CCT. Both on a provincial and city (local) level, the MSW stream produces the largest waste quantities (2.4 million tons provincially and 1.7 million tons locally). For the CCT, within the MSW stream, the largest contributing waste sector is the construction and demolition waste stream, producing an approximated 1 million tons of waste per annum. Producing 0.6 million tons of waste, commercial and industrial waste is the second greatest waste stream, followed by 'other' waste streams, which contributes a further 0.3 million tons of waste. The lowest contributor towards solid waste generation is the agricultural and forestry sector, producing an approximated 0.07 million tons of waste (GreenCape, 2019: x). A plausible reason for such low municipal waste generation quantities reported from the agricultural waste stream is that the private sector generally services agricultural land as per the integrated standards and principles under the Integrated Waste Management Policy (CCT, 2017: 53).

Of the available private sector facilities licensed to process mixed organics, only 3 of these facilities can process more than 10 tons a day, which allows for a combined ~204,765 tons of organic waste to be processed by these facilities each year (GreenCape, 2020: 37). In the market for recyclables, the value of plastic waste is highest, ranging between R321.5 and R428.7 million/year in 2018 (GreenCape, 2019: x). The second highest value is assigned to the organic waste stream at R59 to R111 million per year, third highest for e-waste, valued between R34.9 million to R75.4 million/year. Another notable component of the CCT waste sector is the informal waste sector, particularly waste pickers, which, as briefly noted earlier, are undervalued for their services of waste diversion. A 2016 report published by the Council for Scientific and Industrial Research (CSIR), found that an estimated 80-90% (by weight) of paper and packaging is recovered by informal waste pickers in South Africa (Godfrey, Strydom, & Phukubye, 2016: 1). The impact of waste pickers and the informal waste sector on waste management in the CCT is notably underexplored and is an area of interest for MSW management for future research.

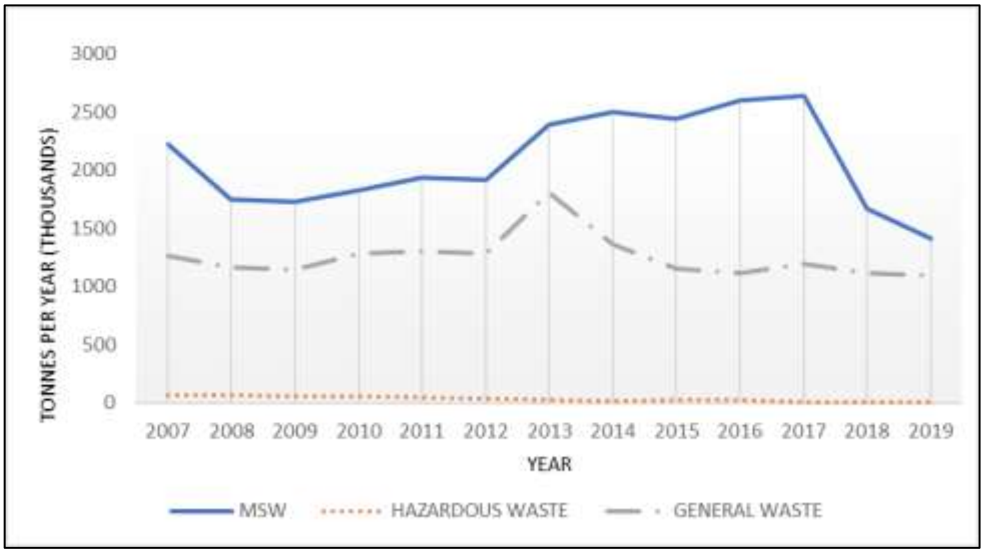

Figure 3.2 : CCT Waste Tonnages per Waste Category (2007-2019)

(Source: Primary Data Provided by the City of Cape Town, 2020b)

With reference to Figure 3.2, Cape Town's MSW has fluctuated over time. Between 2007 and 2009, MSW generation had decreased, and only began to increase again post-2013. Several indicators influence this waste generation trend. The various socio-economic indicators that influence the MSW generation rates are discussed below.

3.1.3) Socio-economic indicators

3.1.2.1) Gross Value Added

Value added is the (incremental) component of produced wealth that is ascribed to the geographical area (Mazzanti *et al.*, 2008: 65). Gross Value Added (GVA) accounts for the value of goods of services produced within a given area, minus all input costs and raw materials used in the production process. The CCT’s real GVA at basic prices, depicted in Figure 3.3, shows that there has been a steady increase in GVA from 1997 to 2019. The sector which contributes the least (an average of 1.5% per annum between 1997 and 2019) to total GVA is the primary sector. The primary sector consists of the agriculture, forestry and fishing sector and the mining and quarrying sector.

The second-largest sectoral contributor to total GVA, providing an average of 23.9% per annum of total GVA between the years 1997 and 2019, is the secondary sector. The secondary sector consists of the manufacturing, electricity, gas and water and the construction sectors. The largest contributing sector to the economy is the tertiary sector, which had contributed an average of 74.5% per annum towards total GVA between 1997 and 2019, implying the tertiary sector is the largest driver for the CCT's economy. The relationship between GVA and waste generation in the CCT is investigated in Chapter 4.

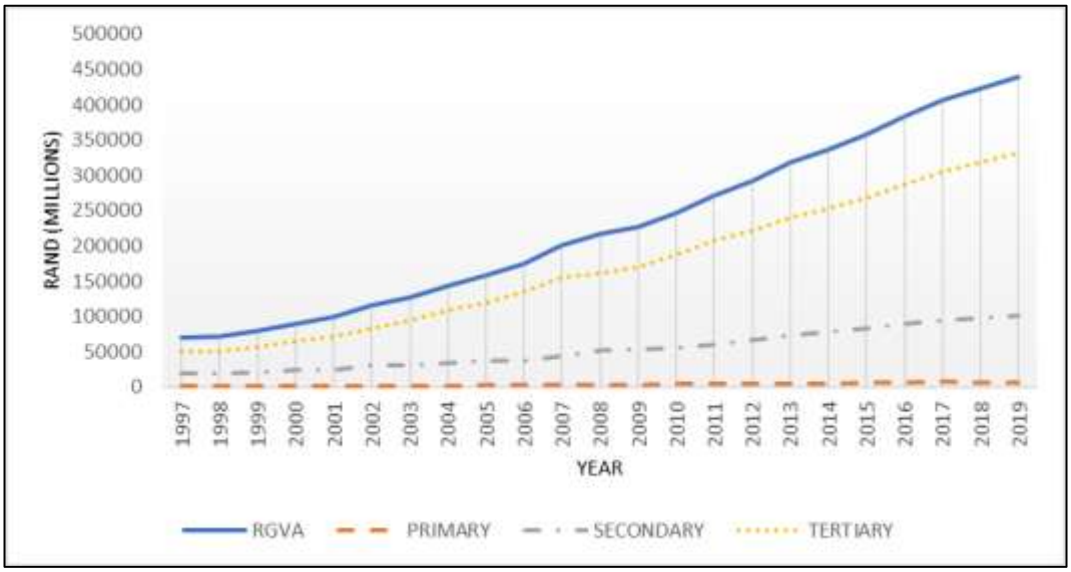

Figure 3.3: Total and Sectoral GVA Over Time

(Source: Own analysis based on Quantec 2020)

3.1.2.2) Population

Although the exact population values reported for the CCT vary between sources, all sources demonstrate an increasing population over time. CCT (2017) reports an annual population growth rate of 1.4% per annum whilst calculations using data from Quantec 2020 show an annual growth rate of 2.5%. The reportings from the CCT (2018: v) report show that the total population increased by 1.68% from 2015 to 2017, however, when calculations are cross-checked it shows a total population increase of 1.86%. Due to such differences in values, this section makes use of data provided either by the CCT itself or, where data have not been provided, by the Quantec EasyData portal (2020)[23]. The Quantec data sets used throughout this study had also been used to report economic findings by the CCT's (2018b) State of Cape Town report and in the Economic Performance Indicators for Cape Town (EPIC, 2017) report, and is therefore considered a reliable data source.

Figure 3.4 plots the population trend for the CCT for the years 1997 to 2019. Over time, the CCT population displays an evident positive linear trend. It is suggested by studies, such as Hiremath (2016), and by organisations such as The World Bank (2019), that population growth and waste generation often have a positive relationship. However, most studies that investigate variables that impact waste generation rates consider population density as a socio-economic indicator. Population density is used as a proxy for urbanisation within this context (Jaligot & Chenal, 2018; Madden *et al.*, 2019 and Mazzanti *et al.*, 2008). A higher population density, as a socio-economic indicator for waste generation, may result in either an increase in waste generation rates or a decrease in waste generation rates (Mazzanti *et al.*, 2008: 60 and Jaligot & Chenal, 2018: 262). An increase in population density may increase waste generation rates; a larger population, through economies of scale, will reduce waste collection costs, subsequently reducing incentives for waste minimisation or waste prevention strategies, resulting in an increase in MSW generation rates – this phenomena is known as density economies. In contrast, an increase in population density can decrease waste generation rates due to greater pressure being placed on land resources, resulting in more pressure to preserve land dedicated to waste disposal. The CCT's population density (Number of Persons per Square Kilometer) in 2018 was 1, 768 persons/km² (Quantec, 2020). Between 2005 and 2018, the population density has been increasing by approximately 37 persons per square kilometer each year. To determine whether this increase in population density has

[23] Unless stated otherwise.

increased or decreased waste generation rates, a regression analysis must be conducted with population density (degree of urbanisation) as an explanatory variable. This will be done in Chapter 4.

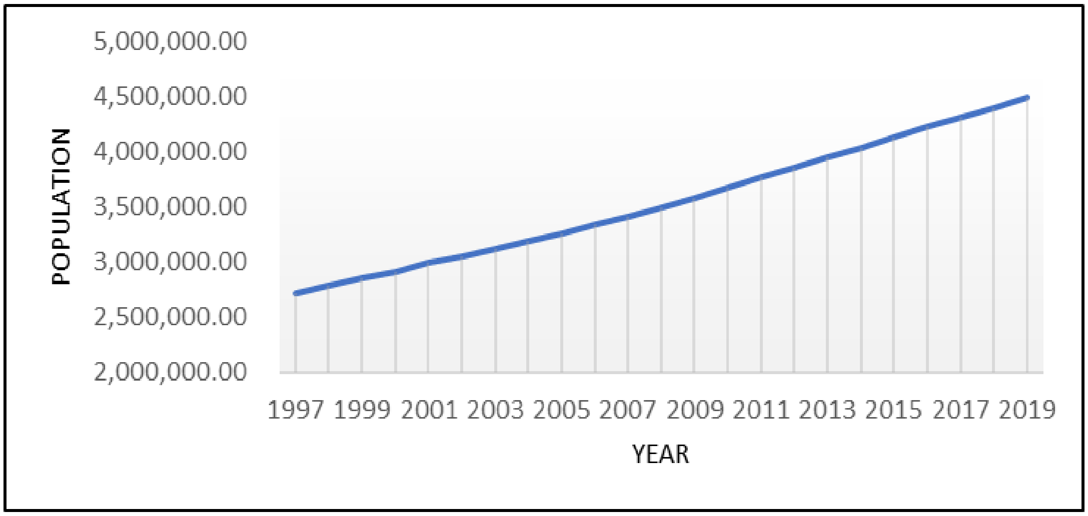

Figure 3.4 : City of Cape Town Population (1997-2019)

(Source: Own analysis based on Quantec, 2020 and City of Cape Town, 2020)

3.1.2.3) Tourism

Cape Town, according to CCT (2018a: 12), is one of the most visited tourist destinations on the African continent. Tourists do not only contribute greatly to the economy, but these flows also impact the number of natural resources that are consumed and waste that is generated. Several studies, including Mazzanti *et al*. (2008), Arbulú *et al.* (2015) and Mateu-Sbert, Ricci-Cabello, Villalonga-Olives and Cabeza-Irigoyen (2013), investigate tourism flows as a potential driver of waste generation. These studies find that tourism flows have a positive and significant effect on the rate of MSW generation. Tourism flows into the CCT have been shown to fluctuate intra-annually depending on seasonal changes and social events such as sporting tournaments. Figure 3.5 graphs the annual changes between international arrivals into Cape Town International Airport between 1999-2019.

Efforts have been made by the tourism sector to increase sustainability in Cape Town. For example, the Cape Town International Convention Centre – a popular tourist event venue which had hosted 504 events in 2015, and generated R209 million in revenue – had managed to recycle 85% of its waste in 2015 (Department of Tourism, 2015). However, due to the tourism sector enabling an influx of consumers, which typically deplete the availability of natural resources, it is important to investigate the effects of tourism flows on the waste sector. This will be done in Chapters 4 and 5.

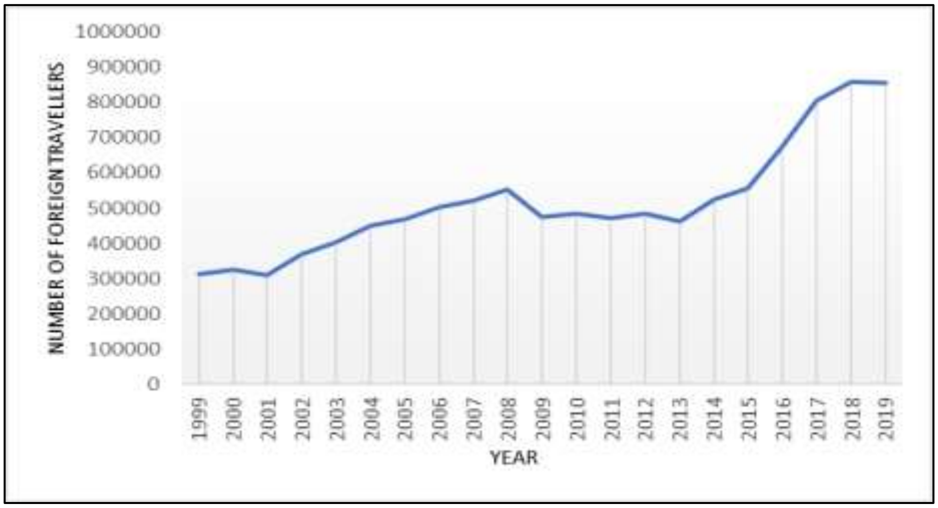

Figure 3.5 : Foreign Arrivals to Cape Town International Airport (1997-2019)

(Source: Own analysis based on StatsSA, 2020a)

3.1.2.4) Share of Elderly Population

As described in the literature review, some studies[24] argue that the greater the share of the elderly population, the more reduction is achieved in waste generation due to the elderly population partaking in more recycling programmes. An alternative argument is that the elderly may not have enough finances to consume as much as the younger population, therefore, resulting in less waste

[24] Chen (2010), Ercolano *et al.* (2018), Mazzanti & Zoboli (2009), Werner & Makela (1998), and Struck & Soukopová (2016).

produced. As can be shown from Figure 3.6, the elderly population in Cape Town constitutes the smallest proportion of the total population in 2011, at an estimated 6% (StatsSA , 2011).

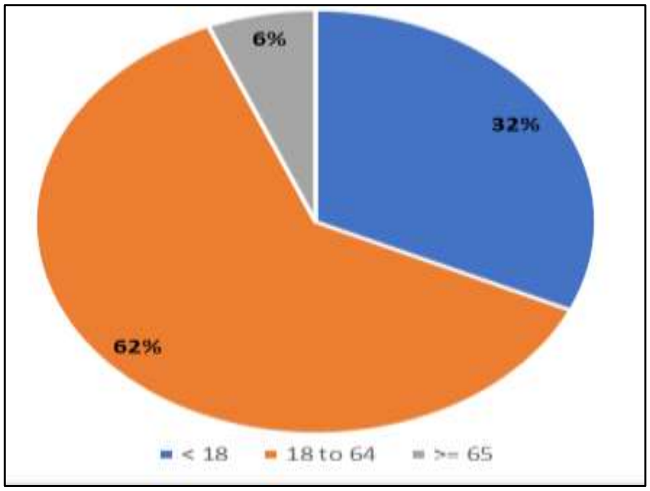

Figure 3.6: CCT Population by Age Group in 2011

(Source: StatsSA, 2011)

Moreover, the simultaneous growth of the elderly population and the total population is an important relationship to consider since these variables may have counterbalancing effects on MSW generation. In the CCT, over time, the share of the elderly population has increased from an approximated 7.25% in 1997 to 10.09% in 2019. This is trend depicted in Figure 3.7.

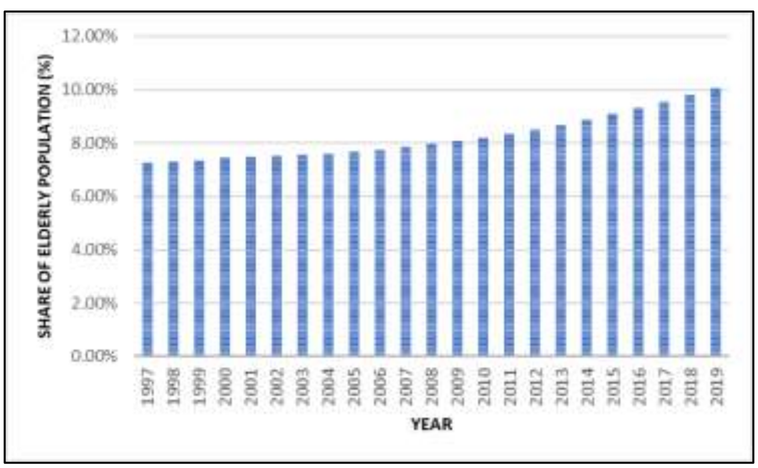

Figure 3.7 :Share of Elderly Population Over Time

(Source: Own analysis based on Quantec, 2020)

3.1.4) Policy Indicators

3.1.4.1) Regulatory Instruments

The CCT's Waste Sector is governed by national and provincial legislation and by local by-laws. This section begins by briefly discussing the development of national legislations directed at the waste sector. Moreover, existing policies, bylaws and strategic goals considered by the CCT waste department are discussed. The implications of these policies, bylaws and strategic goals on the research within this study are highlighted.

From a national perspective, Godfrey & Oelofse (2017: 2) discuss the development of the South African waste sector and summarise the promulgation of major waste legislation and policies. Initially, the amended Environmental Conservation Act (73 of 1989) (RSA, 1989) had outlined the requirements for waste management and provided the first legal classification of waste. This Act, although not providing a detailed enough definition of waste, did enable the Minister of Environmental Affairs and Tourism to regulate waste through reduction, reuse and recovery of waste (RSA, 1989). Between the years 1987 and 2007 minimal waste policy and regulation had emerged. However, since the publication of the 1st National Waste Management Strategy (NWMS) and the White Paper on Integrated Pollution and Waste Management for South Africa (RSA, 2000), the focus on waste management had become more pronounced. The publication of the National Environmental Management (NEM): Waste Act (59 of 2008) (RSA, 2008) and Waste Management (IP&WM) had encouraged a surge of new waste regulation between 2008 and 2017, including the NEM: Waste Amendment Act (26 of 2014) (RSA, 2014).

From a more theoretical perspective, Godfrey & Oelofse (2017: 2) define four stages of transition which the South African waste had undergone between 1987 and 2017. The first stage is the "The Age of Landfilling", beginning in 1989, whereby most of the waste had been landfilled without much consideration for waste minimisation. "The Emergence of Recycling"; the second stage, began in 2001 with the publication of the Polokwane Declaration on Waste Management. This declaration had led to the banning of single-use plastics, initiating the waste recycling economy in

South Africa. The third stage, starting in 2008 with the promulgation of the NEM:Waste Act (Act 59 of 2008), is known as "The Flood of Regulation", which had encompassed an influx of new policy and regulation within the waste sector. Lastly, "The Drive for EPR" stage began in 2012 with the Integrated Industry Waste Tyre Management Plan (IIWTMP) being published. This stage had encompassed the use of alternative policy instruments to waste management, particularly economic instruments, which include waste-related taxes. This Extended Producer Responsibility (EPR) scheme had, however, been withdrawn in 2017 by the DEA due to concerns and controversy surrounding the approach and had been reopened for comment in 2020 by the Minister of Environment, Forestry and Fisheries of the DEFF[25]. The DEA is still investigating EPR for paper and packaging, waste electrical and electronic equipment (WEEE), and lighting.

The National Pricing Strategy for Waste Management (NPSWM) is a legislative requirement listed under Section 13A of the NEMWA. This pricing strategy highlights waste management charges that are geared toward minimising waste. The NPSWM is an important consideration when investigating the waste-economy relationship and determining economic indicators that affect waste generation. Upstream economic instruments, such as input taxes, product taxes, and EPR fees are earmarked to disincentivise the production of wasteful goods and services, thus decreasing waste generation. Downstream economic instruments, such as volumetric tariffs and disposal tariffs may disincentivise post-consumer waste generation and incentivise the recovery of products. Finally, subsidies may incentivise the recycling and reuse of products, thus also decreasing waste generation.

The Western Cape Government's Department of Environmental Affairs and Development Planning is responsible for the publication of the Integrated Waste Management Plans as required by the NEMWA (59 of 2008) (RSA, 2008). The purpose of the Western Cape's (WC) IWMP is to

[25] During the period of writing this thesis, there had not been updated publications of the results obtained by the DEA for the EPR comments.

provide strategic direction in the province to improve integrated waste management practices (WC, 2017). The 2nd Generation IWMP is the most recent published IWMP which outlines the waste management plans for the years 2017 – 2022.

From a municipal perspective, The CCT's Integrated Waste Management (IWM) By-Law aims to direct the NEMWA into municipal action. The City IWM By-law had first been promulgated in 2009 and, since, had been amended in 2010 and more recently in June 2016 (CCT, 2020d). Moreover, each municipality under the Western Cape Province is responsible for publishing an IWMP. The CCT had published its 3rd Generation IWMP in 2017 which outlines the CCT's waste sector goals, strategies, objectives, and deliverables.

The IWMP and the IWM by-law are considered key documents when investigating socio-economic indicators impacting waste generation. The CCT IWMP not only reports relevant statistics such as waste volumes and quantities, but it also includes existing waste management objectives and strategies that have been employed to ensure waste targets are met. These strategies, which will be discussed in further detail in the sections to follow, include waste minimisation programmes such as the "Think Twice" kerbside recycling collection programme, which accounts for some decrease in waste landfilling rates.

3.1.4.2) Economic Instruments

As explained by the Federal Ministry for Economic Cooperation and Development (Undated: 13), there are 4 user-type charges that can be appointed by service-rendering municipal, provincial or national bodies. These are listed and explained in Table 3.1 below.

Flat-rate tariffs, although appropriately used to obtain stable revenue flows, ignores issues of population income inequalities, and is not successful as an incentive to reduce waste generation

Table 3.1: User-Type Charges

User charge type	*Description*	*Advantages*	*Disadvantages*
Flat-rate tariff	The same tariff is applied to all users (households and commercial users)	It is simple to calculate and provides stable revenues	It ignores indivduals' ability to pay (affordability) It ignores the 'polluter pays priniciple' and fails to create incentives for waste reduction
Variable tariff differentiated by waste quantity produced (PAYT)	Users are charged according to waste container volume, per emptying of their waste containers, or per waste bag purchased in advance (pre-paid)	It creates an incentive to reduce waste production It can be useful for lager commerical and industrial users Pre-paid bag systems are relatively easy to establish and enforce (no collection without payment)	Revenues are less stable Equipment and logistics are needed for measuring waste produced (standardised containers/bags) It can be expensive and complex to administer if the correct use of bag/recepients is to be controlled effectively May encourage illegal dumping - need for enforcement
Variable tariff differentiated according to proxy for income	Different tariff categories/ proportionately rising tariffs linked to property tax bands or water/electricty consumption. Alternatively, tariffs can vary according to size of lot / residential area	Provides the possibility to account for ability to pay and incorporate cross-subsidisation Efficient administration, as registers/collection mechanisms already exist; easy to enforce is intergrated billing is used Can incorporate proxy for waste production	Provides no incentives for waste reduction Information and collaboration by utility company/proper tax registry required, which could result in extra costs Variation by residential area requires income homogeneity for it to be fair
Two-part tariff (flat-rate and variable part)	Combination of options 1 and 2, or 1 and 3	More stable revenues than variable tariffs Accounts for certain fixed system costs	More complicated to calculate, flat-rate part is difficult to include in pre-paid PAYT systems Less transparent to users

Source: Federal Ministry for Economic Cooperation and Development (Undated: 13)

rates. This EI is mostly employed in low- to middle- income earning cities due to ease of calculation (Federal Ministry for Economic Cooperation and Development, undated: 12). Volume- or weight-based variable tariffs, alternatively termed differential-and-variable rates (DVR) are most successful in incentivising a reduction of waste generation. However, these may increase problems of illegal dumping and the stability of revenues. This tariff type is hardly employed in low- to middle- income earning cities due to the high costs of implementation. Where employed, however, a pre-paid system whereby standard waste bags or stickers must be purchased in advance, is used. Variable tariffs based on household earnings, or income, is applied appropriately to suit all income-earning groups, however, it fails to incentivise reductions in waste generation. Moreover, municipalities must assume that all households within a residential area have homogenous income-earnings (Federal Ministry for Economic Cooperation and Development, undated: 12). A combination of the flat-rate tariff and the variable tariff, although appropriate for generating stable revenues and accounting for fixed-system costs, are complicated to calculate and less transparent to economic agents.

There are two types of user charges appointed by the CCT for Solid Waste Management. These are fixed disposal and collection tariffs (flat-rate tariffs) and the variable property taxes (variable taxes differentiated according to residential income). As depicted in Table 3.1, these tariffs do little to provide incentives for waste reduction, but rather are administered prices used as a tool for cost recovery. The plastic-bag levy, introduced in 2004, is the only product tax in South Africa with clearly-defined environmental targets (Nahman & Godfrey, 2010: 523).

An analysis of this plastic-bag levy by Dikgang, Leiman & Visser (2012), shows that the levy only proved successful in the short run. In the long run, however, consumers had begun to steadily increase their consumption of plastic shopping bags. The authors predict that a further increase in carrier-bag consumption will occur over time, despite the price increases. Moreover, the study considers that the steady increase in demand for plastic bags is most likely not diminishing the plastic littering problem, leaving the policy only partially successful. Another notable characteristic of the plastic-bag levy is that the revenues generated from the levy are redirected into general government funds rather than being used for recycling plastic bags or other waste minimising initiatives (Nahman & Godfrey, 2010: 523).

3.1.4.3) Informational Instruments

There are numerous waste minimising initiatives and waste awareness schemes employed by the CCT. These include the 'Think Twice' programme, the Integrated Waste Exchange, or IWEX, and various community programmes. The 'Think Twice' kerbside recycling programme, whereby households are encouraged to dispose of recyclables in clear bags, which are then collected by contracted waste collectors such as *WastePlan* and *Mandala Recycling*, had been initiated in 2007 (CCT, 2017:60). Figure 3.8 graphs the amount of waste diverted through this programme. There has been a fluctuation of waste diversion quantities from the Think Twice programme throughout the study period[26]. According to the CCT (2017: 60), a 2015 "Willingness to Pay" survey conducted in the CCT to determine whether consumers are willing to pay an additional R25/month for collection services in line with the Think Twice, found 64% of respondents declaring they would be willing to pay this fee.

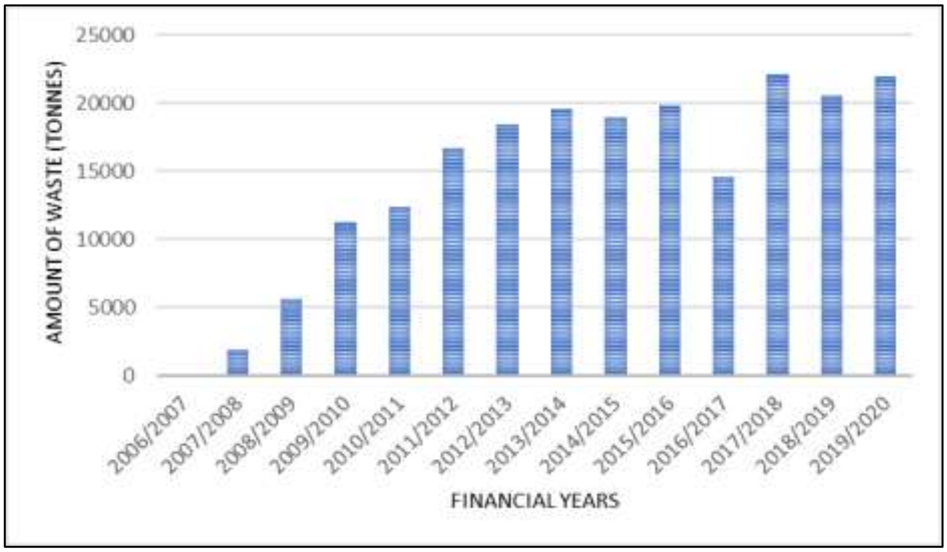

Figure 3.8: Amount of Waste Diverted from the Think Twice Programme Over Time

(Source: Own analysis based on City of Cape Town, 2020b).

IWEXis an example of another waste minimising initiative, which had begun operations in 2010. IWEX is a free online system that allows the public to exchange waste with other businesses (CCT, 2017: 62). Post-2015 and following system upgrades, IWEX had tallied over 1000 registered users. Furthermore, community programmes accounted for on the CCT website include educational exhibitions, the Home Composting Programme, the Housing Consumer Waste Education Programme, the Waste Education and Recycling Programme, waste education for City employees, waste education tours and talks, and the Waste-to-Art Market. Although these education-related

[26] It is noted that during the financial 2016/2017 there is a dip in waste diversion from the Think Twice programme. Upon further investigation, there is no evidence from the literature, nor from the CCT itself, as to what the cause for this dip is.

programmes most likely decrease the amount of total MSW generated, the extent of this decrease is difficult to quantify and cannot be accounted for directly.

3.2) Conclusion

The CCT's waste sector faces an array of challenges, including the lack of appropriate waste classification and a high waste generation rate in conjunction with low recycling and recovery rates. The latter is amplified with the impending issue of diminishing landfill airspace; with an estimated less than 15 years of airspace available between the three operating landfills. Factors that may influence these issues include an increasing population, which can cause growth in the amount of waste generated, a growing economy, which may increase or decrease waste generation rates as per the WKC hypothesis, and tourist flows, which have generally been shown to inflate waste generation rates. Moreover, other socio-economic indicators can be considered, including the share of the elderly population. The CCT has the smallest proportion of elderly persons (60+ years old) in comparison to other age groups but has recorded steady growth in this age-cohort.

There are various policy tools already considered by the CCT's Solid Waste Management Department. The CCT has made advancements concerning their regulatory framework governing the waste sector. The development of waste management legislation and waste by-laws have increased awareness and considerations regarding waste management both from a producer and consumer perspective. The Integrated Waste Management Plan, which acts as a guiding tool for municipalities to ensure waste is managed accordingly, is important by not only providing waste statistics, but also by listing various waste minimising initiatives that have been implemented.

Current waste management economic instruments employed include the fixed collection and disposal tariffs and the variable property tariff. Further instruments include informational instruments which aim at promoting separation at source.

Chapter 4: Empirics and Regression Analysis

The empirical process employed in this study follows the format provided in Chapter 1, which follows Shrestha & Bhatta (2018). Time-series regression analysis is conducted to determine the long- and short-term relationships between per capita MSW and per capita GVA, as well as to investigate the existence of a WKC and to determine the relationship between other socio-economic factors on per capita MSW generation rates. Before model specification can be determined, the stationarity of the variables' series is investigated through various unit root tests. The cointegrating relationships between variables are investigated through various cointegration tests. These tests will determine whether an OLS estimation, an ARDL estimation, an ECM model or all three model specifications can be run.

4.1) Data and methodologies

The data used in the section comprises both of primary and secondary sources. The time-series dataset ranges from 1997 to 2019. Waste data, specifically the values for total MSW and amounts of waste diverted via the 'Think Twice' programme had been obtained from the CCT's Solid Waste Department (2020b). The primary data for waste as provided by the City is available for the years 2007-2019. For the years 1997-2006, statistics reported on data for waste as provided by the City at that time by De Wit, Swilling and Musango (2008) are used. Statistics reported in financial years are converted to calendar years to ensure identical units of measurement are achieved throughout the dataset.[27]

Statistics on the Real Gross Value Added (RGVA), Population, Population Density, Population by Age Group and Unemployment values for the CCT are accessed from the Quantec data portal (2020). Tourism values are gathered from the Statistics South Africa Tourism and Migration archived publications (StatsSA, 2020a). The proxy values used for tourism are the values derived

[27] For example, financial year 2006/2007 is reported as calendar year 2006.

from 'Foreign Arrivals into the Cape Town International Airport'. It is argued by Ercolano *et al*. (2018) and Hage, Sandberg, Söderholm & Berglund (2008), that using foreign travelers as a proxy for tourism flows is suitable, since international travelers may face notable difficulties in understanding recycling rules in host countries. Studies that consider foreign / international tourists / residents as a tourism proxy include Ercolano *et al*. (2018) and Arbulú *et al*. (2015).

Multiple methods are used in this study is to meet all objectives of this study and to ensure the robustness of the findings. Once the descriptive statistics, relevant variable transformations, and unit root[28] and cointegration[29] tests are run and described the methodological process continues as follows: the first model presented is a simple linear model regressing GVA per capita and GVA^2 per capita on MSW per capita. This model is extended to include socio-economic explanatory variables, population density ($POPD$), share of elderly (60+ years) population (OLD_SHARE) , share of unemployed population ($UNEMP$) and tourism flows ($TOUR$). This model expansion is done by including one variable at a time, firstly including the variables considered to be most influential on MSW generation, to variables considered to be the least influential[30]. These results are then analysed in terms of the relationship between MSW generation and economic growth, whether the WKC exists and whether there is evidence of decoupling. Furthermore, the decoupling factor is calculated to cross-check whether the decoupling results from the regression model are robust. Finally, to analyse the effects of policy interventions, a segmented linear regression is used, as proposed by Lagarde (2012). This investigates the effectiveness of the Think Twice Programme. The above-described results act as an informative tool for policy decision-making in the CCT.

For the primary objective of determining the relationship between MSW generation and economic growth, and to test the WKC hypothesis, the method selection process for the time series data is

[28] Unit Root tests determine whether the regression is 'spurious' or not.
[29] Cointegration tests determine whether long-run parameters between variables can be determined in the presence of unit root variables.
[30] This is done by considering the results obtained from the explanatory variables described in the literature review.

adopted from EKC literature. Empirical literature applying these time-series regression techniques, of which this study's methodologies are derived, include Madden *et al.* (2019); Shahbaz, *et al.* (2010); Shuai *et al.* (2017) and Miyata *et al.* (2013). Here the specification of the EKC model using time-series data is defined and the parameters are discussed and regressed.

The specification of the EKC model, in its functional form is as follows (Shuai *et al.*, 2017: 1033):

$$E = f(Y, Y^2, Z) \tag{1}$$

E represents the Environmental Indicator of study, in this case, per capita MSW. Y is the income proxy variable, which is per capita GVA[31]. Z represents other explanatory variables which may impact the rate of per capita MSW. Whilst most EKC studies omit Z, Harbaugh *et al.* (2002:541) observe that, by omitting explanatory variables there is not only potential for omitted variable bias, but it can completely alter the shape of the estimated EKC curve, producing vastly different results compared to studies that do include other explanatory variables. Equation (1) can be log-transformed, which, as indicated by Shahbaz *et al.* (2010); Cameron (1994) and Ehrlich (1975, 1996), provide more appropriate and efficient results relative to simple level-level regression models. Moreover, the log transformation is preferred since coefficients can be directly interpreted as elasticities. The (natural) log-transformed WKC model for this study, which provided the long-run relationships between variables, is given as:

$$\begin{aligned} LMSW \;=\; & \alpha + \beta_1 LGVA + \beta_2 LGVA^2 + \beta_3 LPOPD + \beta_4 LTOUR + \beta_5 OLD\_SHARE \\ & + \beta_6 UNEMP\_SHARE \end{aligned} \tag{2}$$

LPOPD is the population density (number of inhabitants / km^2), which is used as an urbanisation proxy. UNEMP_SHARE is described as the share of the population which is unemployed.

[31] Gross Value Added (GVA) is the value of goods of services produced within a given area, minus all input costs and raw materials used in the production process. The per capita GVA is GVA / total population.

OLD_SHARE is described as the share of the population 60 years or older. TOUR is the number of foreign arrivals into Cape Town International Airport. THINK_TWICE, not listed in equation (2), is the amount of waste diverted via the Think Twice initiative. This variable is later described in the segmented regression model. To determine whether the WKC results estimate an accurate turning point, equation (3) will be used to determine the income at the turning point of model (2), which will then be compared with the mean GVA of the given time period (Madden *et al.*, 2019: 679):

$$\exp\left(-\beta_1/[2\beta_2]\right) \tag{3}$$

The results from equation (2) are then compared with the decoupling factor equation and a graphical representation of MSW and GVA growth to determine whether the decoupling of waste is accurately represented in the regression results. Finally, the segmented linear regression is specified in subsequent sections, and is used to determine the policy effectiveness of the Think Twice programme. To compute and run the above models, various variable transformations and series tests need to be done to determine the nature of the dataset and to determine the appropriateness of selected models.

4.2) Descriptive statistics and data transformations

The raw data variables are described in Table 4.1. Here it should be highlighted that MSW per capita is converted from tonnages to kilograms to ensure comparability with existing literature. GVA is reported in per capita terms. The mean of GVA per capita is R 60,693.93, which will later be compared to the turning point of the estimated WKC, should one exist. The average number of persons/km^2 (population density) in between 1997-2019 is 1,407. Compared to other studies including population density as an explanatory variable, the CCT has a higher population density. Mazzanti *et al*. (2008:58) find an average population density of 244 persons/km^2 in Italian provinces, Mazzanti & Zoboli (2009: 212), find an average population density of 174 persons/km^2 in European countries. Jaligot and Chenal (2018: 262), find an average population density of 617/km^2 for 10 Swiss districts, and Madden *et al*. (2019: 678), find an average population density of 731/km^2 for New South Wales. The average share of the unemployed population is 7.8% and the average share of the elderly population is 8.23%. The average number of foreign arrivals per year between 1997-2019 is 517,292. Finally, the average amount of waste diverted from the Think Twice programme per year is 14,569,664 kg/year.

Table 4.1: Descriptive statistics of the raw data

Variable Acronym	Description	*N*	*Mean (SD)*
MSWPC	Total Municipal Solid Waste generated per annum (Kilograms/ Per capita)	23	566.5858 (115.6028)
GVAPC	Gross Value Added per capita at Current Prices (Rand)	23	60693.93 (24530.14)
POPD	Population Density (Inhabitants/km^2)	23	1407.236 (230.7022)
UNEMP_SHARE	Share of population unemployed (%)	23	7.8047 (2.0356)
OLD_SHARE	Share of population older than 60 years	23	8.2317 (0.8662)
TOUR	Number of foreign arrivals into the Cape Town International Airport	21	517292.9 (483716)
THINK_TWICE	Amount of waste diverted from the Think Twice Kerbside Programme (Kilogram / per annum)	14	14569664 (7358121)

(Source: Own analysis based on various data sources)

As discussed above, log-transformations are preferred. All variables, barring UNEMP_SHARE and OLD_SHARE, are log-transformed. The descriptive statistics for the transformed variables are shown in Table 4.2. All variables need to be tested for stationarity and cointegration prior to running the respective models.

Table 4.2: Descriptive Statistics of log-transformed variables

Variable Acronym	*N*	*Mean* (*SD*)
LMSW	23	6.319018 (0.211116)
LGVA	23	10.92357 (0.451141)
LPOPD	23	7.236608 (0.163282)
UNEMP_SHARE	23	7.804712 (2.035574)
OLD_SHARE	23	8.231671 (0.866225)
LTOUR	21	13.11396 (0.294356)

(Source: Own analysis based on various data sources)

4.3) Unit Root and Cointegration Tests

Unit Root tests are conducted to determine the stationarity of a series. The presence of non-stationary variables within a regression may lead to 'spurious' results, which render the estimated parameters inappropriate for inference. For time-series data, the augmented Dickey-Fuller (ADF) and the Philips-Perron (PP) unit root tests are widely employed to determine stationarity (Shrestha

& Bhatta, 2018 :74). Tables 4.3 and 4.4 present the results of the ADF and PP unit root tests, respectively.

From the ADF and PP unit root tests, all series are of I(1); with stationary at first differences.

Table 4.3:
ADF test results

Variable	Intercept				Trend and Intercept			
	Level		First Difference		Level		First Difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
LMSW	-1.922	0.3162	-3.116	0.0407**	-1.957	0.5894	-3.399	0.0783*
LGVA	-2.223	0.204	-3.436	0.0211**	0.203	0.9963	-4.776	0.0058***
LPOPD	2.136	0.9998	-3.324	0.0266**	-0.548	0.9722	-4.103	0.0207**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]*	-2.923	0.1762	-3.443	0.0724*
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.982	1	-4.342	0.0129***
LTOUR	-0.217	0.9213	-3.551	0.0178***	-3.760	0.0478**	-3.450	0.0744*

, **, and * indicate statistical signifcance at the 10%, 5%, and 1% levels respectively.*

Table 4.4:
PP test results

Variable	Intercept				Trend and Intercept			
	Level		First Difference		Level		First Difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
LMSW	-1.296	0.6122	-3.069	0.0446**	-1.023	0.9195	-3.343	0.0867*
LGVA	-2.153	0.2275	-3.533	0.0172***	0.263	0.9969	-15.70	0.00***
LPOPD	2.136	0.9998	-3.622	0.0143***	-0.548	0.9722	-4.116	0.0202**
UNEMP_SHARE	-1.630	0.4507	-3.485	0.0191***	-1.938	0.6008	-3.437	0.0732*
OLD_SHARE	12.563	1	-0.907	0.7652	2.481	1	-4.345	0.0128***
LTOUR	-0.405	0.8904	-3.609	0.0158***	-1.600	0.7561	-3.520	0.0657*

, **, and * indicate statistical signifcance at the 10%, 5%, and 1% levels respectively.*

LTOUR, shows stationarity at level with a trend and intercept in the ADF test, however, this result is not analogous in the PP test. Given that the statistical significance of the first difference of LTOUR, is greater than when the series is at level, this variable is differenced to obtain integration I(0). This is reinforced by the graphical representations of each level / log variable to the differenced variable, whereby, after applying first differences to the variables, there is reversion to the mean. Appendix A provides the graphical representations of transformed variables from log to log-differenced.

Since all series are integrated of order 1; I(1), using Ordinary Least Squares (OLS) or similar methodologies to derive estimates, may provide spurious results. To determine whether the long-run relationships amongst the variables are spurious or not, Engle and Granger (1987) have developed cointegration tests to analyse the relationships between non-stationary variables. Johansen (1988) and Johansen and Juselius (1990) have since improved the weaknesses of the Engle and Granger (1987) methodologies[32] and developed the Johansen cointegration test models. The Johansen cointegration test can be applied directly should all variables be non-stationary, which, given the ADF and PP test results, applies to this dataset.

A Johansen cointegration test is applied for the following annual series'; LMSW, LGVA, LGVA2, LPOPD, UNEMP_SHARE and OLD_SHARE. Whilst the LTOUR series shows evidence of cointegration with the other series (refer to Appendix B), it does not contain the years 1997 and 1998, therefore, to ensure comparability, it is omitted. The Johansen cointegration test results for the investigated variables are summarised below in Table 4.5. The Null Hypothesis of no cointegration equations is rejected and the alternative, that there is cointegration between investigated variables is accepted.

[32] These weaknesses refer to the Engle and Granger (1987) unit root test showing more than two cointegrating relationships when considering more than two variables.

Whilst some studies do not run the Engle-Granger cointegration test, it is acknowledged that the Johansen cointegration may not always be reliable for small sample sizes. As such, to ensure cogent results, the Engle-Granger two step cointegration procedure is conducted.

Table 4.5
Johansen Cointegration test results

Unrestricted cointegration tank test (Trace)					Unrestricted cointegration tank test (Maximum eigenvalue)				
Hypothesised no. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	Prob.	Hypothesised no. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	Prob.
None *	0.9826	242.0473	95.7537	0	None *	0.9826	85.1184	40.0776	0
At most 1 *	0.9705	156.9289	69.8189	0	At most 1 *	0.9705	73.9873	33.8769	0
At most 2 *	0.8278	82.9416	47.8561	0	At most 2 *	0.8278	36.9381	27.5843	0.0024
At most 3 *	0.7009	46.0036	29.7971	0.0003	At most 3 *	0.7009	25.3454	21.1316	0.012
At most 4 *	0.5981	20.6582	15.4947	0.0076	At most 4 *	0.5981	19.1424	14.2646	0.0078
At most 5	0.0696	1.5158	3.8415	0.2183	At most 5	0.0696	1.5158	3.8415	0.2183

The tau value of | -4.369346| is compared to that of the Engle-Granger critical table with a constant and no trend[33]. The Null Hypothesis of no cointegrating equations is rejected and the alternative is accepted at a 1%, 5% and 10% critical value. From both the Johansen cointegration, and the Engle-Granger test results, the variables are cointegrated.

4.4) Conclusion

As per the model selection process described by Shrestha & Bhatta (2018) in Chapter 1, this study runs the respective tests to determine the stationarity and the cointegration relationships of the variables described. All series are integrated of order 1, as per the Augmented Dickey-Fuller (ADF) and the Philips-Perron (PP) unit root tests. Moreover, these series are found to have

[33] The tau value of the residual ADF when LTOUR is included in the estimation equation is -4.726911, rendering analogues results.

cointegrating relationships, as per the Johansen Cointegration test and the Engle-Granger cointegration test. This implies that both an OLS estimation technique and an ARDL estimation technique can be employed.

Chapter 5: Results and discussion

This chapter provides the relevant model results and estimations to assist in meeting the objectives of (i) determining the relationship between MSW generation and economic growth, (ii) investigating the WKC hypothesis for the CCT and (iii) identifying the main socio-economic and policy drivers of MSW generation. As indicated by the test results provided in Chapter 4, OLS and ARDL models can be run to investigate the relationship between per capita MSW and per capita GVA, as well as to determine the existence of a WKC and the relationship between other explanatory socio-economic variables and per capita MSW generation. This chapter begins by addressing these objectives in Section 5.1. by computing 5 OLS models. To determine the long- and short-run relationships between variables, an ARDL estimation technique is employed, following the same process as the 5-step OLS model format. To determine which model is most appropriate for analysis, diagnostic tests are run. The final chosen model is discussed. Section 5.2. determines the efficacy of the Think Twice programme as a policy variable. This section also controls for periods of economic decline to determine the effects of the 2008/2009 economic crash and the 2018 economic recession in South Africa.

5.1) Investigating the relationship between MSW generation and the economy

This section conducts empirical analysis to answer the first set of objectives; whether economic growth and MSW generation are related, whether the WKC is present for the CCT, whether there is evidence of decoupling, and what socio-economic drivers affect waste generation.

Once cointegration amongst variables have been confirmed, the parameters of the variables in WKC estimation model can be computed. The first estimation technique adopted is the OLS estimation, as described by the model specification (2) in Chapter 4 (Madden *et al.*, 2019; Miyata *et al.*, 2013; Shabaz *et al.*, 2010: and Shuai *et al.*, 2017). It is acknowledged that employing an OLS regression to a small dataset is not preferred. Provided, this study computes an Autoregressive Distributed Lag Model (ARDL), which is more appropriate for smaller and finite datasets and provides long-run unbiased estimates (Nkoro & Uko, 2016: 76).

The OLS model is run by using a 5-step procedure, with the first model regressing GVA and GVA^2 on LMSW. Model 2 includes the variable LPOPD, which is the most adopted variable in EKC and WKC literature. Model 3 includes the variable LTOUR. Whilst this variable does reduce the model by two years, it has been identified as an important driver of MSW generation in waste management literature. Model 4 includes the variable OLD_SHARE, which has been found to show ambiguous results in the literature. Lastly, Model 5 includes UNEMP_SHARE, which is mostly found to have a negative effect on MSW generation in the literature. For all models, a one-period lag of LMSW is included under the expectation that past solid waste generation rates influence waste management decision-making, and therefore, would be a driver of waste generation rates in the future.

The OLS model output is presented in Table 5.1. An optimal lag structure, using the Akaike Information Criteria (AIC), most appropriate for smaller datasets, is used when computing the OLS estimation. In Models 1-4, per capita LGVA is shown to have a positive relationship with per capita LMSW and, given the negative coefficients of LGVA^2, this effect is occurring a decreasing rate. This implies evidence of a WKC, albeit statistically insignificant. This effect is reversed in Model 5, with the inclusion of UNEMP_SHARE and is, similarly, statistically insignificant. LPOPD has a positive statistically significant effect on LMSW in Model 4, however this is only statistically significant at a 10% level of significance. LTOUR has a negative statistically significant effect on LMSW in Model 3, at a 5% level of significance. Ercolano *et al.* (2018) finds a similar result. When diagnostically tested, however, this model (Model 4) shows evidence of heteroscedasticity, using the Breusch-Pagan-Godfrey Heteroskedasticity Test, rendering the Standard Error incorrect. Finally, per capita MSW generation in the previous period, has a positive statistically significant effect on future per capita MSW generation rates for all models.

Table 5.1:
OLS estimation output

Dependent Variable: LMSW										
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	β Estimate (SE)	T-value	β Estimate (SE)	T-value	β Estimate (SE)	T-value	β Estimate (SE)	T-value	β Estimate (SE)	T-value
C	-33.03706 (27.21018)	-1.214	5.598591 (77.66641)	0.072	-101.8398 (108.1042)	-0.942	-141.3118 (106.3657)	-1.329	103.4521 (134.239)	0.771
LMSW(-1)	0.717261*** (0.20947)	3.424	0.663882*** (0.236095)	2.812	1.042711*** (0.291585)	3.576	1.187786*** (0.293788)	4.043	0.957386*** (0.26786)	3.574
LGVA	6.552879 (5.127385)	1.278	0.970404 (11.71391)	0.083	16.6569 (16.33933)	1.019	10.68818 (16.07699)	0.665	-25.58891 (20.07779)	-1.274
LGVA2	-0.307638 (0.23604)	-1.303	-0.02555 (0.581791)	-0.044	-0.807753 (0.807606)	-1.000	-0.650122 (0.778347)	-0.835	1.131217 (0.979423)	1.155
LPOPD			-1.52402 (2.861122)	-0.533	3.395065 (3.954509)	0.859	15.43777* (8.604991)	1.794	7.349795 (8.049021)	0.913
LTOUR					-0.646123** (0.31443)	-2.055	-0.073514 (0.474763)	-0.155	-0.299508 (0.416084)	-0.720
OLD_SHARE							-1.182311 (0.758987)	-1.558	-1.10116 (0.649843)	-1.695
UNEMP_SHARE									0.116331 (0.046924)	2.479
Observations:	23		23		21		21		21	
Adjusted R^2	0.5148		0.4947		0.5734		0.6104		0.71518	
P-value	0.0010		0.0030		0.0022		0.0023		0.00065	
Durbin-Watson	1.3541		1.3636		1.9883		2.1466		2.42864	
Turning Point	R43,088		R182,016,489		R30,324		R3,517		R81,675	

, **, and * indicate statistical significance at the 10%, 5%, and 1% levels, respectively.*

Under the ARDL specification, the dependent variable is a function of its lagged values and the current and lagged values of other explanatory variables in the model. The ARDL method has often been applied in EKC research (Alrajhi & Alabdulrazag, 2016; Islam *et al.*, 2013; Köhler & de Wit, 2019 and Yang, 2019). A 5-step modelling procedure for the ARDL model is run, following the same process as the OLS estimations. The ARDL estimates for all 5 models are reported in Appendix C. Various diagnostic tests on each model are run to test which model is best-fitted for hypothesis testing. The diagnostic test results for Model's 1-5 are reported in Table 5.2. To test for serial correlation, the Breusch-Godfrey Serial Correlation Lagrange Multiplier Test is employed. The results show that only Model 2, with an F-statistic of 0.3738 can Reject the Null Hypothesis of serial correlation. The Breusch-Pagan-Godfrey Heteroskedasticity Test is run to ensure that the error terms are homoscedastic and independent of the explanatory variables. For all models, the F-statistic is above the 5% critical value and no heteroskedasticity is determined. Finally, to investigate whether the error terms are normally distributed, the Jarque-Bera normality test is employed. Whilst the F-statistic for all models are above the 5% critical value, at the 10% critical value, Model 4 has residuals that are not normally distributed. Thus, Model 2, the ARDL (1,1,1,1) Model, produces the best diagnostic test results to perform hypothesis testing.

The OLS Model 2 estimation is shown to have the similar diagnostic test results as the ARDL Model 2, allowing for comparisons to be conducted between both models. The OLS Model 2 at log-log transformation and the OLS Model 2 at levels is reported in Appendix D. Only the lag of LMSW is shown to have a positive statistically significant relationship with LMSW in both OLS models. The log-transformed estimation of the OLS Model 2 shows that the income elasticity of 0.97, is comparable to international studies which typically find that waste generation has a positive income elasticity, but that it is lower than 1 (Beede & Bloom, 1995). These results, however, are statistically insignificant, implying that there is insufficient evidence in the sample to conclude that a non-zero correlation exists between all variables.

Table 5.2:
Diagnostic Test Results

Test	Model	P-value	Result
Serial Correlation LM Test: *Breusch-Godfrey*			
	Model 1	0.0291	Serial Autocorrelation
	Model 2	0.3738	No Serial Autocorrelation
	Model 3	0.0055	Serial Autocorrelation
	Model 4	0.0001	Serial Autocorrelation
	Model 5	0.0001	Serial Autocorrelation
Heteroskedasticity Test: *Breusch-Pagan-Godfrey*			
	Model 1	0.0849	No heteroskedacity
	Model 2	0.1428	No heteroskedacity
	Model 3	0.5418	No heteroskedacity
	Model 4	0.9047	No heteroskedacity
	Model 5	0.807	No heteroskedacity
Normality Test: *Jarque-Bera*			
	Model 1	0.825	Normal Distribution
	Model 2	0.763	Normal Distribution
	Model 3	0.82	Normal Distribution
	Model 4	0.075	Normal Distribution
	Model 5	0.38	Normal Distribution

More importantly, economists and policy makers are concerned with long-term relationships between variables. The ARDL Least Squares estimates are reparamitised into the Conditional Error Correction Model (ECM), to provide the short-run dynamics and long run relationship of the variables. In the long run, from the LGVA and LGVA2 parameters, the CCT conforms to the WKC and LPOPD has a positive relationship with LMSW. These estimates, which are presented in Appendix E, however, exhibit statistical insignificance and, therefore, cannot be confirmed. Whilst the Engle-Granger and Johansen cointegration tests do suggest evidence for long-run cointegrating relationships, Kohler (2013: 1045) notes that there are several econometric advantages of employing the ARDL bounds test over traditional cointegration tests. These advantages are highlighted in Chapter 1. The results from the ARDL bounds test indicate that there exists a long-run relationship, but only at 10% level of significance. Only the ARDL ECM short-run estimates are analysed, all of which, show statistical significance, rendering them appropriate for analysis (Table 5.1).

Before the estimates are analysed, several points are made. Firstly, the Johansen and the Engle-Granger cointegration tests show evidence of cointegration between variables – this implies that, over time, the variables move towards equilibrium and disequilibrium in the same manner, but it does not confirm that there is long-run causation relationships between variables. Secondly, the dataset is relatively small ($n<30$) for a time-series dataset, this implies that strong causal interpretations cannot be made, but general observations of the relationships between variables can be analysed[34].

From these estimates, in the short run, LGVA is shown to have a negative statistically significant relationship with LMSW generation. This relationship is occurring at an increasing rate, as shown

[34] This study omits Granger causality tests on the models due to the small dataset. Rather, it is acknowledged that only general relationships can be deduced with the given sample size. It is suggested that future research conduct a panel regression (for the CCT region, or other cities in South Africa) to investigate similar research objectives with a larger dataset.

by the squared GVA coefficient, which is also statistically significant. This implies that, rather than observing an inverted U-shaped relationship, the CCT's waste generation and economic growth exhibit a positive parabolic (U-shaped) trend and there is no evidence of a Waste Kuznets Curve. This result, whilst unique, has been found by Raymond (2004), who invested the WKC for 142 countries. The turning point of the estimated U-shaped curve is found at R47,086.83 per capita, and, given that the average annual income for the time-period under investigation is R60,693.93 per capita, the CCT is situated on the inclining segment of the U-curve. This suggests there is relative decoupling of waste from economic growth. The estimates of the long-run estimates present a turning point of R19,762 per capita, which is lower than the average R60,693.93, and shows evidence of a WKC and absolute decoupling. However, provided that these estimates are statistically insignificant, these results cannot be accepted[35]. To determine the long-run status of decoupling, the Decoupling Factor equation is used. To determine the annual fluctuations of waste decoupling, indexed values of per capita GVA and per capita MSW are plotted, as per the explanation presented in Chapter 1.

[35] Should a longer time-series dataset be acquired, an additional polynomial variable, of cubic form, can be included in the estimation to determine whether a N-shaped curve for MSW generation and economic growth can be identified for the CCT.

Table 5.3:
ARDL ECM regression output

Short Run Estimates			
Dependent Variable: D(LMSW)			
Variable	β Estimate (SE)	T-value	P-value
D(LGVA)	-52.6524** (20.43400)	-2.576707	0.0219
D(LGVA2)	2.44673** (0.954702)	2.562821	0.0225
D(LPOPD)	-15.4537*** (4.133416)	-3.738731	0.0022
CointEq(-1)	-0.53099*** (0.144117)	-3.684420	0.0025
Adjusted R^2	0.374		
AIC	-1.172851		

, **, and * indicate statistical significance at the 10%, 5%, and 1% levels, respectively.*

The results of the short-run estimates are cross-checked by calculating the Decoupling Factor (D_f)[36] and by analysing the per capita GVA and per capita MSW indices. The D_f for the entire period (1997-2019) is 0.713, implying that long-run decoupling of waste is relative. To determine short-run fluctuations of waste decoupling, indexed (growth) values (using 1997 = 100) of MSW per capita and GVA per capita are plotted and reported in Figure 5.1. To reiterate Chapter 1's explanation, absolute decoupling exists when the growth of MSW per capita is zero or negative, and relative decoupling exists when the growth of MSW per capita is positive, but below per capita GVA values (Inglezakis *et al.*, 2012: 2362-2363). Figure 5.1 indicates that between 1997 and 1999, where per capita $MSW_{1997=100}$ is above per capita $GVA_{1997=100}$, there is no decoupling of waste. Relative decoupling of waste took place between 2000-2006 and 2008-2017. The CCT experiences

[36] To reiterate, if 0 < D_f > 1, relative decoupling exists.

absolute decoupling of waste between 2006-2008 and 2017-2019. Evidently, during the study period of 1997-2019, the CCT has mostly been experiencing relative decoupling of waste, with short fluctuations of absolute decoupling of waste. In Section 5.2. it is empirically tested whether these short periods of absolute decoupling of waste can be brought about by waste policy initiatives, such as the Think Twice recycling campaign, and by investments being directed towards waste facilities, such as the commissioning of additional drop-off facilities. More realistically, financial, and economic downturns, which effect consumer purchasing power may explain why these periods of absolute decoupling occur briefly (Khajevand, 2016). Ruiz-Peñalver, Rodríguez and Camacho (2019), (Rodriguez, Ruiz-Peñalver & Camacho-Ballesta, 2016) and Khajevand (2016) conclude that the overall reduction in waste generation is explained by a downturn in the economy. From an empirical standpoint, the speed of these adjustments of these short-run fluctuations towards long-run equilibrium is given by the Error Correction Term (ECT), which is presented in Table 5.1's ARDL ECM short-run estimation output. The speed of adjustment brought about by external shocks, such as the global financial crises, is -0.5. This suggests, that even in times of economic contractions, the CCT cannot rely on the economy to reduce per capita MSW generation. In times of economic downturn, whilst the CCT does experience reductions in per capita MSW generation rates, this is brought about by a reduction in consumption and is not sustainable. Declining MSW generation rates are, therefore, signals of economic stress.

Finally, whilst most socio-economic variables are shown to be insignificant using the OLS and ARDL model, population density, as an urbanisation proxy, is shown to have a negative statistically significant relationship with LMSW generation in the ARDL ECM model. This result, which is ambiguous in the literature, is analogous with Jaligot & Chenal (2018), Ercolano *et al.* (2018) and Madden *et al.* (2019). This effect can be attributed to these areas having a higher proportion of high-density residential development, where rates of per-capita generation are typically lower due to, for example, reduced green waste generated (Madden *et al.*, 2019: 681). Jaligot & Chenal (2018) and Ercolano *et al.* (2018) argue that decreases in land availability implies greater scarcity of land resources, which spurs directed efforts towards waste minimisation strategies to preserve land scarcity. Lastly, and as previously mentioned, the ECT of -0.5, which shows that all variables are cointegrated (as indicated by the negative sign), estimates the speed of adjustment to long-run equilibrium should an external shock occur.

In summary, the short-run relationships between per capita MSW and GVA exhibit a U-shaped

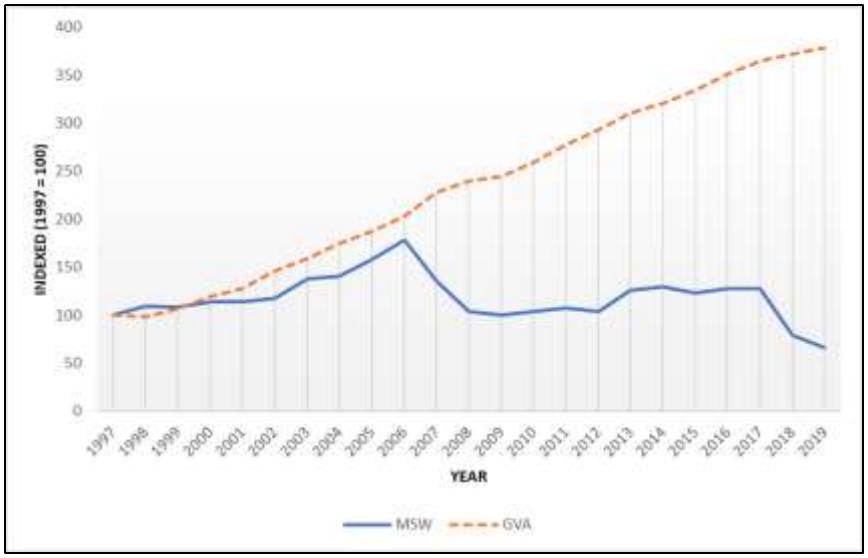

Figure 5.1: Absolute and relative decoupling analysis for the CCT

(Source: Own analysis)

curve. In the long run, the estimates show evidence of the WKC, however the statistical insignificance of these estimates render the analysis ineffectual. The implications of these results suggest that, whilst economic growth generation may have a negative relationship with MSW in the short run, the CCT cannot fully rely on economic growth alone to reduce waste generation in the long run. This is further expressed by calculating the U-shaped curve's turning point and graphical representations of per capita $MSW_{1997=100}$ and per capita $GVA_{1997=100}$. These indicate that the CCT is mostly experiencing relative decoupling of waste from economic growth, with short periods of absolute decoupling of waste. The short periods of absolute decoupling can not be attributed solely to the implementation of the recycling programme, but more appropriately, to periods of economic downturn, such as the 2007/2008 global financial crises. Whilst relative decoupling of waste is found for most countries and cities in WKC literature, it can be argued that the goal of prolonged absolute decoupling of waste can be achieved by the CCT through the employment of appropriate additional Economic Instruments and policy tools. Furthermore, other possible drivers of per capita MSW generation reduction need to be accounted for when considering these policy suggestions, such as the rate of urbanisation, or more directly; population density.

5.2) Investigating waste policy effectiveness

This section begins by investigating the efficacy of the Think Twice recycling programme using a segmented linear regression. The segmented linear regression is often conducted in health and medical studies to inform the effectiveness of health interventions (Lagarde, 2012 and Wagner, Soumerai, Zhang & Ross-Degnan, 2002). This method of analysis has expanded to other domains of research. Stinson and Lubov (1982) compute a segmented linear regression to determine how population changes effect government expenditures, specifically, expenditures related to police services. More pertinent, Park and Lah (2015) consider the efficacy of a volume-based waste fee on recycling rates in South Korea. They find that, although the implementation of this unit-pricing system had immediate effects by boosting the recycling rate, this effect was temporary rather than constant.

To determine the impact of the Think Twice recycling programme on per capita MSW generation, a segmented linear regression is specified. The specification is computed as (Lagarde, 2010: 79):

$$Y_t = \beta_0 + \beta_1{}^{*}time + \beta_2{}^{*}intervention + \beta_3{}^{*}postslope + \varepsilon_t \tag{4}$$

Y_t is the outcome variable at time t. This variable is MSW generated per capita. Time is a continuous variable, ranging from the beginning of the study period (1997) to the end of the study period (2019). β_0, the intercept, is the baseline level of the outcome before the intervention. β_1 estimates the structural trend of utilisation, alternatively, it can be interpreted as the year-on-year change in per capita MSW generation before the intervention. β_2, estimates the immediate effect of the intervention; the Think Twice programme. β_3 represents the change in the trend after the intervention. The assumptions of the segmented linear regression, listed in Chapter 1, are met. Firstly, the graphical representation of per capita MSW (Figure 5.1) confirms linearity of the pre-intervention trend. Secondly, there are no notable waste interventions that had been implemented in the financial year 2006/2007 other than the Think Twice campaign.

Three models are estimated using the specification equation (4). Models 1, 2 and 3 are reported in Table 5.4. The first model does not control for autocorrelation and has a Durbin Watson statistic of 0.8399, suggesting the presence of serial correlation. Model 2 is run using the Prais–Winsten estimator that corrects for data auto-correlation (Lagarde, 2012: 80). Model 2's Durbin Watson statistic of 1.482, however, provides evidence that there is still auto-correlation present in the estimation. Unlike the Lagarde (2010) and Park and Lah (2015) studies, this study proceeds to control for second-order auto-correlation. An OLS regression is computed using 2 lagged variables of the dependent variable (MSW per capita, alternatively termed 'outcome') and is presented as Model 3. The Breusch-Godfrey Serial Correlation LM Test is conducted on Model 3 and confirms that there is no evidence of autocorrelation in the model. All models have statistically significant estimates either at a 1% or 5% level of significance.

The estimates in Model 3, presented in Table 5.4, indicate that, at the beginning of the period of observation (1997), on average 248.31 kg of MSW had been generated per person per annum in the CCT. Inter annual changes in the amount of waste generated per person before and after the intervention is shown to be statistically significant, as can be observed from the secular trend $\beta 1$ and the change in trend $\beta 3$. Prior to the implementation of the Think Twice initiative, there is an increasing change of the amount of MSW generation on an annual basis, estimated with a 35kg increase per capita annually. Immediately after the implementation of the Think Twice initiative, there is evidence of a significant immediate effect of the amount of solid waste generation, whereby solid waste generation is shown to decrease by 163.9 kg per capita. The subsequent trend post-intervention shows that per capita waste generation decreases annually by 39kg.

Table 5.4:
Regression output for the Think Twice programme

Model 1 *(no correction for autocorrelation)*			
Variables	β Estimate (SE)	T-value	P-value
β0	408.9482*** (55.7228)	7.34	0.000
Secular trend β1	37.35887*** (8.980542)	4.16	0.001
Change in level β2	-196.0036*** (67.83591)	-2.89	0.009
Change in trend β3	-45.46523*** (10.82629)	-4.2	0.000
Model 2 *(correcting for first-order correlation)*			
Variables	β Estimate (SE)	T-value	P-value
β0	410.772*** (90.64515)	4.53	0.000
Secular trend β1	39.23557*** (13.14051)	2.99	0.008
Change in level β2	-178.6816** (74.87226)	-2.39	0.028
Change in trend b3	-55.46049*** (18.69449)	-2.97	0.008
Model 3 *(correcting for second-order correlation)*			
Variables	β Estimate (SE)	T-value	P-value
outcome_L1	0.7125593*** (0.1931839)	3.69	0.002
outcome_L2	-0.4595474** (0.2011652)	-2.28	0.037
β0	248.3189** (103.3544)	2.4	0.03
Secular trend β1	34.79341*** (11.52982)	3.02	0.009
Change in level β2	-163.9043*** (58.02297)	-2.82	0.013
Change in trend β3	-39.62451*** (13.5269)	-2.93	0.01

, **, and * indicate statistical significance at the 10%, 5%, and 1% levels, respectively.*

Figure 5.2 provides a graphical trend representation of the raw data with the three fitted models. It can be observed that, before the Think Twice programme, per capita MSW generation experiences steady annual increases. Once the Think Twice programme had been initiated in the 2006/2007 financial year, there is an immediate drop in per capita MSW generation rates. This drop, however, begins to level off in 2008, with slight fluctuations, which may lead one to believe that the effect of the Think Twice is temporal, as experienced in South Korea with the waste-fee intervention (Park & Lah, 2015). On the 1st January 1995, the South Korean Ministry of Environment announced that the volume-based waste system would be extended from pilot areas to a nationwide implementation. Park and Lah (2015) investigate the effects of this waste intervention on the recycling rate in South Korea and conclude that, although the initial increase of the recycling rate post-intervention increases by 6.8%, in the long run, the recycling rate returns to the original, pre-intervention trend of an increase by 1.9% annually. In Figure 5.2, from 2017 onwards an additional reduction in per capita MSW generation is depicted, which may be attributed to the completion of two new drop-off sites in Kensington and Induland and the release of the 3rd Generation Integrated Waste Management Plan (CCT, 2017). Before jumping to such conclusions, these drops could also be better explained by the decline in economic activity from the 2008/2009 economic crash and the 2018 economic recession. This is investigated in Model 4.

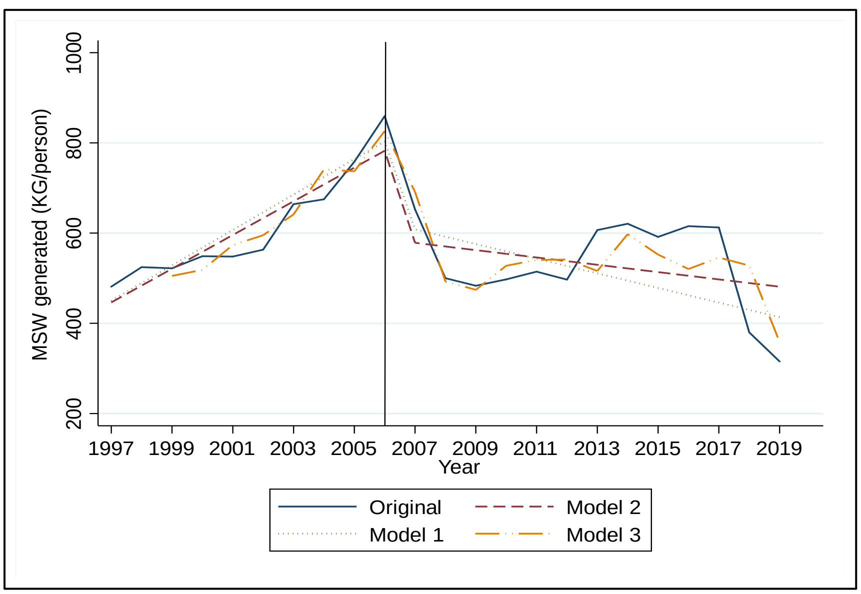

Figure 5.2: Per capita MSW Generation and the fitted results
(Source: Own analysis using STATA15 software)

Lagarde (2012: 81-82) notes that policy interventions may be implemented amidst broader economic changes, which may affect the sector of study (e.g. economic recessions, economic booms). In the period of study (1997-2019), there had been two periods of economic decline. Economic recessions, typically defined as two consecutive periods of economic decline, had occurred in 2008/2009 and in 2018 in South Africa (StatsSA, 2020b). Periods of reduced economic activity typically decrease industrial activities of producers and lower purchasing power of consumers, resulting in a decrease in the overall amount of solid waste generated in the economy (Gangolells, Casals, Forcada, & Macarulla, 2014: 99-100). To control for this effect, a dummy variable of South African recession periods is included in the model for the years 2008, 2009 and 2019. The model estimates are presented in Table 5.5.

In Model 4, at the beginning of the observation period, the average amount of per capita MSW generated per annum is 183.98 kg. Inter annual changes in the amount of waste generated per person before and after the intervention is shown to be statistically significant, as can be observed from the secular trend β1 and the change in trend β3. Prior to the implementation of the Think Twice initiative, there is an increasing change of the amount of MSW generation on an annual basis, estimated with a 24.5kg increase per capita annually. Immediately after the implementation of the Think Twice initiative, there is evidence of a significant immediate effect of the amount of solid waste generation, whereby solid waste generation is shown to decrease by 125.72 kg per capita. The trend post-intervention shows that per capita waste generation decreases annually by 29.83kg. Most notably, all these above-mentioned values are lower than that of Model 3, mostly due to the decrease in explanatory power from including the ‘Recession’ variable. The recession variable estimates indicate that, during periods of economic decline (2008/2009 and 2018 specifically), the amount of MSW generated decreases by 118.11 kg/capita on average. This statistical evidence indicates that it is not only the Think Twice programme (or the waste infrastructural developments in 2017) that has resulted in a long-run reduction of per capita MSW generation in the CCT, but rather, economic recessions contribute towards reducing the amounts of per capita MSW generation.

Table 5.5:
Regression output for Think Twice and recessions

Model 4 *(correcting for first-order correlation, controlling for economic shocks)*			
Variables	β Estimate (SE)	T-value	P-value
outcome_L1	.5071179*** (.15407047)	3.29	0.005
β0	183.9821** (79.55534)	-2.97	0.034
Secular trend β1	24.57455** (9.023538)	2.72	0.015
Change in level β2	-125.7237** (53.71509)	-2.34	0.033
Change in trend β3	-29.83742** (10.94914)	-2.73	0.015
Recession	-118.115*** (39.82664)	-2.97	0.009

, **, and * indicate statistical significance at the 10%, 5%, and 1% levels, respectively*

There are notable arguments to be made contradicting unfounded claims regarding the effectiveness of the Think Twice intervention. The first argument corresponds to the scale or measurements used. The amount of waste diverted from the Think Twice initiative is measured on a volumetric scale. This implies that the rate of the success of the intervention is based on how many kilograms or tons of waste is diverted. However, it can be argued that household materials suitable for recycling (i.e.: glass bottles and jars, cardboard, tins/cans, and plastics), tend to weigh more than materials not suitable for recycling (i.e.: metallic plastic film, light bulbs, and most polystyrene). This can skew results in favour of the success of recycling initiatives (Everett & Peirce, 1992: 359). When considering the statistics, it can be shown the Think Twice programme has diverted a small amount of waste from the MSW stream. Between 2006/2007 and 2018/2019, an average of 0.72% of generated MSW had been diverted through the Think Twice programme. Figure 5.3 presents the percentages of MSW diverted each year from the Think Twice programme. The maximum amount of MSW diverted from this waste intervention is a mere 1.55%.

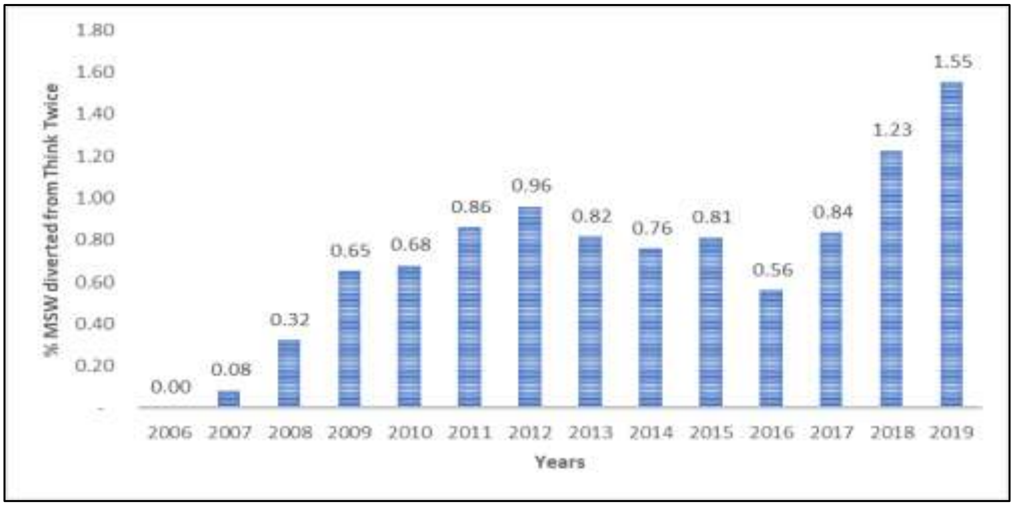

Figure 5.3: Percentage of MSW diverted from the Think Twice programme (2006-2019)

(Source: Own analysis using CCT (2020b) data sources)

Secondly, it can be argued that, even if recycling initiatives are successful in diverting waste, the marginal costs of these programmes need to be less than the marginal benefits for the municipality and to society, in order to have a socially optimal solution to MSW management. The diversion of waste through recycling programmes can increase short-term municipal costs if the disposal costs are less than that of the recycling costs (Everett & Peirce, 1992: 358). Long-term municipal costs may increase if the costs of disposal facility operations (such as extending landfill airspace, increasing operations to new landfills and transportation costs of waste) are increasing in the long run. Folz (1999) compares the municipal costs associated with landfilling and incineration and costs associated with recycling in the US. The municipal estimated costs of recycling schemes had been found to be much lower than that of the costs of collection and landfilling. The study does not calculate external costs associated with recycling schemes, but the author argues that these costs would be notably lower for recycling initiatives in comparison to landfilling. The external costs and benefits can be accounted for through methods such as Cost-Benefit analysis, Full-Cost Accounting and LCA’s.

What the statistical tests have shown is that the Think Twice initiative has reduced per capita MSW, however, this programme has only had limited and temporary success so far. When accounting for economic recessions, the success of the Think Twice programme is brought into perspective.

There are other forms of economic policy intervention that are needed to reduce the rates of MSW generation more sustainably. As previously highlighted, the two existing waste user-charges implemented by the CCT (the fixed disposal and collection tariffs and the variable property taxes), do little to incentivise the reduction of MSW generation. Typically, economic instruments are used as a source of revenue and not to alter consumer and producer behaviour, and even less so as vehicles of sustainable waste management (Panayotou, 1994: 2).

5.3) Conclusion

The empirical findings of this study which pertain to the first objective of this study; the relationship between MSW generation and economic growth and evidence of the WKC, are manifold. From the long-run estimates presented in the OLS and ARDL model, no inferences of the waste-economy relationship and the WKC can be drawn, as provided by the statistical insignificance of the estimated parameters. The short-run estimates provided in the ARDL ECM model, however, indicate that the CCT's economy (per capita GVA) is negatively related to (per capita) MSW generation. This relationship occurs at an increasing rate, providing evidence of a U-shaped, parabolic relationship between MSW and the economy. By calculating the turning point of this parabolic curve, the CCT is currently positioned on the increasing segmented of the estimated U-shaped curve, implying there is relative decoupling of waste. This finding is reinforced through the decoupling factor calculations and the graphical representation of the MSW and GVA indices, which indicate that the CCT has mostly exhibited relative decoupling of waste between 1997 and 2019, with short fluctuations of absolute decoupling.

When investigating the effect of socio-economic drivers of MSW generation in the CCT, once again, no long-run estimates can be used for hypothesis testing given the statistical insignificance of variables and the diagnostic tests of the OLS Model 4 and 5. The short-run estimates of the ARDL ECM model provides statistically significant evidence of the relationship between population density and per capita MSW generation. The short-run relationship between the degree of urbanisation (population density) and per capita MSW generation is found to be negative.

Finally, the efficacy of current waste policies implemented by the CCT are analysed. The policy variable under investigation is the Think Twice programme. The segmented linear regression used to analyse this policy indicates that the success of the Think Twice programme is not perpetual, in that there is an observed level reduction in MSW generation at the time of the implementation, however, this drastic level decrease is not sustained in the long run. Furthermore, the analysis controls for exogenous economic shocks. It is found that periods of economic recessions further reduce the explanatory power of the Think Twice initiative in the regression results. Therefore, reductions in MSW generation quantities, that are achieved in the period 2008/2009 and in 2018, can better explain per capita MSW generation reductions, as opposed to only attributing per capita MSW generation reductions to the Think Twice initiative.

Chapter 6: Policy suggestions for waste management

Provided that the CCT has not yet implemented incentivising structures which minimise MSW generation reduction, there is a need to reform policy design to better achieve goals of absolute decoupling of waste and a greener economy for the waste sector. This chapter considers the statistical results obtained in Chapter 4 and 5 to help guide waste policy design. This chapter begins by reiterating the main findings of the empirical analysis, specifically in terms of the study objectives. In Section 6.1., the first objective of determining the waste-economy relationship and the existence of a WKC, is analysed, and policy suggestions are made regarding the reliance on economic growth to reduce MSW generation. Section 6.2. considers which socio-economic variables will be impactful when introduced into waste policies, as per the statistical findings of Chapter 5. Section 6.3. considers the findings of the Think Twice programme and current waste policies in the CCT to determine whether amendments are required to achieve absolute decoupling of waste.

6.1) Reliance on economic growth

The empirical evidence in Chapter 5 suggests that the CCT should not rely only on economic growth to achieve desired results of MSW generation reductions in the longer run. From the short-run estimates, economic growth is shown to have an inverse relationship with MSW waste generation, however, this relationship is occurring at an increasing rate, implying that economic growth in the CCT will result in higher rates of per capita MSW generation in the short run.

Evidence from the decoupling factor and the plotted indices of MSW and GVA indicate that the CCT has experienced long-run relative decoupling of waste, with short-run fluctuations of absolute decoupling. These periods of absolute decoupling predominantly occur during years of economic decline, implying that, even if the CCT did rely on the economy to reduce MSW generation, absolute decoupling would not be achieved sustainably.

A green economy of achieving long-term economic growth without exposing future generations to risks of environmental scarcities, cannot be achieved if there is only reliance on economic growth to reduce MSW generation rates. Rather, it is proposed that specific economic policy interventions be designed and implemented to target the goal of MSW reduction. These policy interventions, consisting of complementary instruments (regulatory, economic, and informational), must account for the impacts brought on MSW generation rates during periods of economic growth and economic decline, whereby there is a loosening of policy instruments (such as waste taxes) during periods of economic decline. It is, again, advised that these policy interventions consist of coherent and complementary policy packages that include EI's and CAC's, as well as 'softer' instruments, as discussed in Chapter 2. Various authors (Choe & Fraser, 1999; Han *et al*., 2016; Lakhan, 2015; Sidique, Josni & Lupi, 2010 and Tojo, 2008) provide empirical evidence on the effectiveness of policy packages in combating the reduction of MSW generation and improving source separation. These studies all find that a well-developed policy package produces greater success in achieving waste management objectives, as opposed to stand-alone instruments.

6.2) Inclusion of socio-economic drivers in waste management

This study considers several socio-economic drivers of MSW generation, including population density, tourism flows, the age structure, and the unemployment rate. For these investigated variables, only hypothesis testing of the short-run population density (urbanisation) relationship with MSW generation can be conducted given the validity of the models and the statistical significance of the variables.

The short-run relationship between the degree of urbanisation and per capita MSW generation is negative, which indicates that an increase in land scarcity, prompted by increases in population densities, has resulted in the promotion of waste minimising strategies to preserve land and resources (Ercolano *et al.*, 2018; Jaligot & Chenal, 2018; and Madden *et al.*, 2019). Provided that the CCT has begun taking a more dedicated approach to waste minimisation through the employment of the IWMP, the IWMP by-laws and other instruments and regulations, this argument is feasible. This is also in line with Wilson *et al.*'s (2012) study of global waste management strategies, whereby it is found that low- and middle-income cities are directing investments towards improving controlled waste disposal and waste recovery facilities.

Since long-run relationships between population density and MSW generation cannot be determined, advising policy targets using population density is not advisable from this thesis, especially considering that policy instruments are often implemented to obtain long-run objectives. Moreover, there is uncertainty in the statistical result found between population density and MSW generation, since this relationship could be attributed to the disproportionate amounts of waste generated in construction, manufacturing, and park management[37] (GreenCape, 2020: 15). Provided that this relationship is only found in the short run, this study suggests that per capita MSW generation and population density should be investigated in the long run, by employing other models such as geographically and temporally weighted regression model (GTWR), which requires a panel dataset.

6.3) Efficacy of current waste management policies and options to improve design

Since the CCT has not employed any EI's which incentivise MSW generation reductions, this study investigates the effect of the Think Twice programme, a waste diversion programme, and how it has impacted the amounts of per capita MSW generated in the CCT. The segmented linear regression results indicate that the success of the Think Twice programme is transient.

Current waste EI's employed by the CCT are waste charges that generate revenue, used to finance administrative costs (collection charges based on property value and fixed disposal tariffs[38]). Waste taxes on landfilling and incineration have been argued to have minimal impacts on the amount of MSW generated (Oosterhuis *et al.*, 2009: iv). This is largely on account of households not being able to 'internalise' the incentive of the waste tax due to the lack of the DVR charging

[37] These streams are often handled by the private sector.
[38] See CCT (2017: 44-45) for details of waste collection and disposal tariffs for the CCT.

for waste collection. Current waste policy strategies implemented by the CCT are mainly aimed at diverting post-consumer waste; IWEX, Think Twice, composting programmes and deposit-refund schemes.

Since the CCT cannot rely on economic growth to reduce MSW generation rates, it is suggested that policy design be adjusted to include policies that target not only MSW *diversion*, but MSW *generation*. Policies targeted at MSW generation include variable tariffs based on volume or quantity of waste produced; although, it is emphasised that it is difficult to determine the effects of these variable waste taxes on illegal dumping (Oosterhuis *et al*., 2009: 27). Moreover, taxes on raw materials and products are alternative forms of EI's that can be implemented to reduce the amount of waste produced. Unlike collection charges, which are rates on waste at the end of the waste chain (downstream instruments), taxes on raw materials are applied at the beginning of the waste chain (upstream instruments) to financially incentivise producers to avoid using virgin materials and to substitute with production materials that are, and can be, reused and recycled (Oosterhuis *et al.*, 2009: 42). Although there have been considerations of implementing EPR schemes, which target producer waste generation, caution must be drawn when considering these schemes. There are notable financial implications for South African producer responsibility organisations (PRO's) that would discourage them from supporting EPR systems (Le Roux, 2020). Ultimately, the EPR schemes are calculated to reduce PRO revenues dramatically (an estimated 72% drop in revenues for PETCO[39] using 2019 figures). Le Roux (2020) argues that these reductions in revenue will most likely result in opposition and lobbying against the EPR system.

From a sectoral approach, waste *diversion* policies should be targeting the waste-producing sectors which generate higher benefits in comparison to the costs of recirculation, thus effectively using waste as a resource. Here it is important to understand the economic efficiency of waste in that these resources must be allocated efficiently towards the sectors which produce the highest value.

[39] PETCO is a PET recycling company in South Africa.

Policies aiming to reduce waste *generation*, should be directed to waste producing sectors which produce higher external and internal costs of waste recovery relative to the external and internal benefits of waste recovery. The three largest revenue-generating markets for recyclables in the CCT; the plastic sector and the organic waste sector and the e-waste sector[40], should be accounted for in these *diversion* policies, in that, if the benefits obtained from these recycling markets outweigh the costs, policy design should allow these markets to create waste for recirculation. To determine the possible costs and benefits of the recyclable markets for each sector, which will guide policy-makers to determine which sector should appoint waste diversion, waste generation or both waste policy-types, it is suggested that economic analysis using CBA, MFA and FCA be conducted in future research.

6.4) Conclusion

This chapter discusses policy options for waste management as guided by the empirical results conducted in Chapter 5. It is emphasised that the CCT should not be fully reliant on economic growth to reduce MSW generation but should rather opt for specific policies consisting of complementary economic, regulatory, and informational instruments. Although the short-run inverse relationship between population density and per capita MSW generation has been determined, it is not suggested that this relationship be leveraged in policy design, provided that the short-run estimates cannot fully support long-run policy objectives and that this relationship may be the effect of disproportion in the amount of municipal waste collected by certain waste sectors. It is suggested, however, that this relationship be investigated using alternative methodologies to obtain long-run results, which would better inform policy design. Provided that the CCT cannot exclusively rely on economic growth to reduce the amount of MSW generated, this study recommends that the CCT adjust policy design to include targets of reducing MSW *generation* rates. These policy targets must be thoroughly investigated in future research to ensure

[40] See GreenCape (2019: x).

issues, such as illegal dumping, will not be aggravated, and that these policies provide maximum marginal benefits at the lowest marginal costs when targeting the respective waste-producing sectors. Methods, such as Cost-Benefit analysis, Full Cost accounting and Material Flow Analysis, as briefly described in Chapter 2, can be used to determine the appropriateness of these policy options for the CCT, especially in determining the costs and benefits of the various markets for recyclables and waste-producing sectors.

Chapter 7: Summary conclusions and recommendations for future research

7.1) Summary conclusions

The purpose of this study is to investigate the relationship between MSW generation and economic growth for the CCT. Furthermore, the extension of this objective includes an investigation of the WKC hypothesis for the CCT and determining the impacts of various socio-economic drivers and waste policy interventions in the CCT. This study begins by providing a broad overview of the study in Chapter 1, including the research problem of landfill scarcity in the CCT, the various study hypotheses and an outline of the research methodologies. There are several research hypotheses described in this chapter. The first is that MSW generation is positively correlated to economic growth (as measured by change in GVA) in both the short and long run. The second is that a WKC for the CCT exists, but that only relative decoupling is observable in the long run, with temporary absolute decoupling taking place during economic recessions. The socio-economic driver, population density, is hypothesised to have a positive relationship with MSW generation. Finally, the Think Twice programme is hypothesised to only have an immediate impact of reducing MSW generation.

Chapter 2's literature review begins by highlighting and defining relevant waste concepts. This enables a broad understanding of the waste economy and the different economic approaches of investigating waste management options. Waste management theories and economic policies are discussed to provide insights of the available policy options for the waste sector. Empirical evidence investigating policy packages finds that policy mixes are preferred over stand-alone policy implementation. These results are used in Chapter 6 as part of the policy suggestion. To analyse waste management in practice, studies investigating global waste management is reviewed. It is deduced that, in developing cities, there has been a concerted efforted of redirecting municipal investments towards waste facilities, the informal sector is a large contributor to waste collection and diversion, and inclusivity and financial stability is often poor for these cities. Chapter 2 also reviews the empirical evidence of literature investigating the waste-economy relationship, the WKC hypothesis and the various socio-economic and policy drivers of MSW.

The empirical evidence suggests that, for most studies, there is relative decoupling of waste, non-conforming WKC relationships and ambiguous relationships between population density and MSW generation. Empirical studies deduce that volume-based weight fees fare well in developed cities, however, caution is drawn when appointing these variable charges on cities with high rates of illegal dumping of waste.

Chapter 3 introduces the waste economy for the CCT. This chapter introduces the variables which are later empirically investigated in subsequent chapters. Here GVA, MSW, population trends, tourism flows, age structure, unemployment rates, and policy design for the waste sector is discussed. The overall state of the waste economy is presented, especially highlighting issues of diminishing landfill airspace in the CCT.

Chapter 4 provides the description of the data and the data sources for the study period (1997-2019), as well as the various methods used in the study. Statistical tests, relevant for time series datasets are run, presented, and discussed. This chapter concludes that the appropriate models that can be run, given the results from the various unit root and cointegration tests, are OLS models and ARDL models.

Chapter 5 presents the regression outputs for the OLS model, the ARDL (ECM) model and the segmented linear regression model. The conclusion drawn from this chapter is that no long-run relationship between per capita GVA and per capita MSW can be confirmed, implying that the stated hypothesis of a long-run relationship between these two variables, is not accepted. In the short run, there is evidence of a parabolic relationship between per capita MSW and per capita GVA, implying that the CCT is non-WKC conforming. The CCT has experienced long-run relative decoupling of waste with short fluctuations of absolute decoupling of waste for the given period. Here, the hypothesis of an existing WKC for the CCT is rejected, however the hypothesis that only relative decoupling is observable in the long run, with temporary absolute decoupling taking place during economic recessions is accepted. The degree of urbanisation has a short-run negative statistically significant relationship with per capita MSW generation. This implies that in the short run, increases in urbanisation are correlated with a decrease in MSW generation. The long-run relationship between population density and MSW generation remains unanswered, meaning that this study cannot accept or deny the stated hypothesis that population density increases MSW generation. When investigating the Think Twice programme, it is inferred that this waste-minimising intervention had been successful in the short run, but that periods of economic recession reduce the amount of waste generated in the CCT (with 48% of the reduction of MSW generation between 2008/2009 being explained by the economic recession).

Chapter 6 considers the results presented in Chapter 5 when providing waste management policy options for the CCT. It is concluded that the CCT should not depend solely on economic growth to decrease the rate of MSW generation but should rather implement a policy package consisting of complementary instruments. Short-run estimates obtained to determine the relationship between per capita MSW generation and population density cannot fully advise long-run policy objectives. Finally, policy packages must be realigned to target MSW generation, as opposed to only targeting MSW diversion. To effectively use waste as a resource, policies targeting waste diversion must be appointed to waste-producing sectors which achieve higher benefits of recirculating waste compared to the costs of recirculating waste. Policies targeting waste generation must be appointed to waste-producing sectors that produce few benefits of recycling waste and high costs of recycling waste.

7.2) Research limitations and suggestions for future research

The research conducted in this study assists in investigating the relationship between economic growth and MSW generation in the CCT. However, there are several research limitations noted in this study. The empirical findings obtained in this study are based off a relatively small sample ($n<30$), and, although general relationships between investigated variables have been found, strong causal long-run relationships cannot be identified. Provided that it is unlikely to obtain a larger time-series dataset for this type of investigation, this study suggests that a panel dataset, compiled of data for the broader CCT region, or other South African cities, be obtained. Fixed effects, Random effects and GTWR models can be used to determine similar objectives as outlined by this study, with possible greater statistical significance.

This study had investigated several hypotheses regarding the relationship between MSW generation, economic growth and socio-economic variables. Some of these hypothesis had failed to be statistically determined, therefore, it is suggested that the following relationships be investigated in future research; the long-run (causal) relationship between MSW generation and economic growth in the CCT and the long-run (causal) relationship between population density, tourism flows, unemployment share and the share of the elderly population with MSW generation.

It is further suggested that the policy suggestions that are geared around waste generation and diversion targets should be investigated using Full-Cost Pricing (Accounting) strategies and Cost-Benefit analysis. These approaches should not overlook the possible externalities incurred by the various suggestions, to obtain a socially optimum solution and longer-term sustainable solution. To reiterate, these techniques can be used to determine the (full) costs and benefits of implementing EI's that target MSW generation, which can then inform policy-makers as to whether or not these EI's will provide net municipal and societal benefits if implemented for the CCT.

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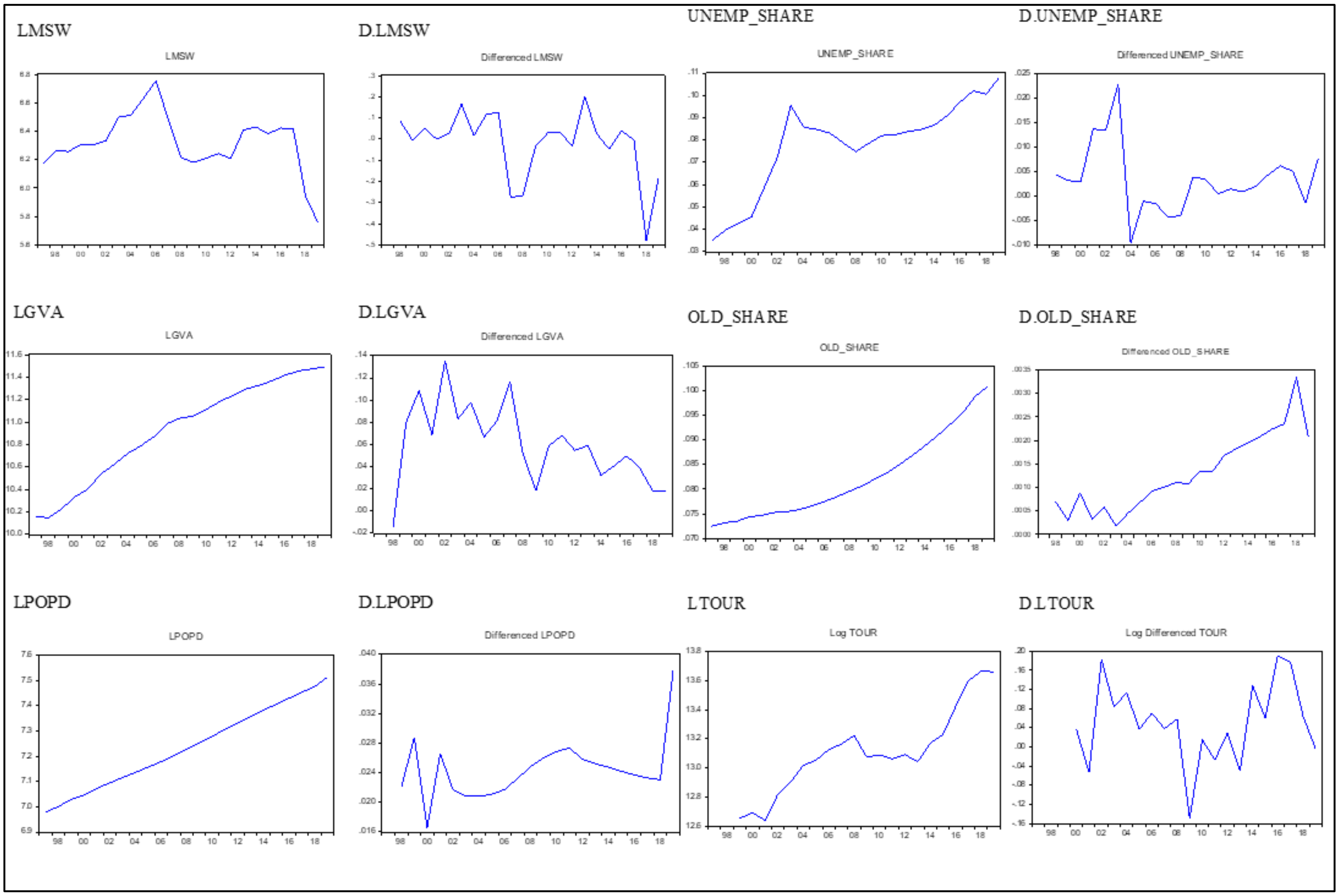
Appendices

Appendix A:

Graphical representation of the logged variable series and the log of the first differenced variable series



Appendix B:

Johansen Cointegration test results for series: LMSW, LGVA, LGVA2, LPOPD and LTOUR

Unrestricted cointegration tank test (Trace)					Unrestricted cointegration tank test (Maximum eigenvalue)				
Hypothesised No. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	Prob.	Hypothesised no. of CE(s)	Eigenvalue	Trace statistics	0.05 Critical value	Prob.
None *	0.950065	130.1684	69.81889	0	None *	0.950065	56.94364	33.87687	0
At most 1 *	0.806334	73.22476	47.85613	0	At most 1 *	0.806334	31.19081	27.58434	0.0164
At most 2 *	0.725124	42.03396	29.79707	0.0012	At most 2 *	0.725124	24.53726	21.13162	0.0159
At most 3 *	0.534492	17.4967	15.49471	0.0247	At most 3 *	0.534492	14.52791	14.2646	0.0454
At most 4	0.144656	2.968786	3.841466	0.0849	At most 4	0.144656	2.968786	3.841466	0.0849

Appendix C:

ARDL Model output(s)

Dependent Variable: LMSW		
ARDL (2,0,0) Model 1		
Variable	β Estimate (SE)	T-value
LMSW(-1)	0.984212*** (0.122404)	8.041
LMSW(-2)	-0.595447*** (0.152761)	-3.898
LGVA	10.22652* (5.158475)	1.982
LGVA2	-0.472978* (0.238454)	-1.984
C	-51.32478 (26.93255)	-1.906

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*

Dependent Variable: LMSW		
ARDL (1,1,1,1) Model 2		
Variable	β Estimate (SE)	T-value
LMSW(-1)	0.469013** (0.224664)	2.087617
LGVA	-52.65244 (30.32687)	-1.736165
LGVA(-1)	71.29387** (33.9301)	2.101198
LGVA2	2.44673 (1.457355)	1.678883
LGVA2(-1)	-3.39054** (1.60156)	-2.117023
LPOPD	-15.45373 (9.58508)	-1.612269
LPOPD(-1)	19.75355 (12.65896)	1.560439
C	-118.2391 (115.0086)	-1.028089

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*

Dependent Variable: LMSW		
ARDL (1, 2, 2, 0, 2) Model 3		
Variable	β Estimate (SE)	T-value
LMSW(-1)	0.539927 (0.306421)	1.762043
LGVA	-107.9696 (57.93034)	-1.863783
LGVA(-1)	70.49917* (35.30073)	1.997102
LGVA(-2)	79.66904 (69.25635)	1.15035
LGVA2	4.765919 (2.614264)	1.823044
LGVA2(-1)	-3.3404* (1.642121)	-2.034199
LGVA2(-2)	-3.568584 (3.213275)	-1.110575
LPOPD	9.231912 (6.485663)	1.423434
LTOUR	0.818173 (0.524939)	1.558605
LTOUR(-1)	-0.384927 (0.418748)	-0.919232
LTOUR(-2)	-1.238779** (0.383753)	-3.228062
C	-258.0569 (165.2884)	-1.561252

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels, respectively*

Dependent Variable: LMSW		
ARDL(2, 1, 2, 2, 2, 2) Model 4		
Variable	β Estimate (SE)	T-value
LMSW(-1)	-1.245888 (0.573972)	-2.170642
LMSW(-2)	0.495487 (0.221671)	2.235232
LGVA	345.0577* (92.56454)	3.727753
LGVA(-1)	-364.7677** (91.92775)	-3.967982
LGVA2	-15.79439* (4.170824)	-3.786874
LGVA2(-1)	16.25602** (4.139052)	3.927476
LGVA2(-2)	-0.12503 (0.078702)	-1.588653
LPOPD	-67.96165* (17.70173)	-3.839265
LPOPD(-1)	-11.00755 (59.18398)	-0.185989
LPOPD(-2)	161.0508* (42.65923)	3.775286
LTOUR	2.001741 (1.133463)	1.76604
LTOUR(-1)	0.667355 (0.27591)	2.418745
LTOUR(-2)	0.616535 (1.071657)	0.57531
OLD_SHARE	-5.125499 (2.287871)	-2.240292
OLD_SHARE(-1)	5.636073** (1.027496)	5.485252
OLD_SHARE(-2)	-10.21446** (2.440691)	-4.185069
C	-366.7016** (53.47717)	-6.857163

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*

Dependent Variable: LMSW		
ARDL (2, 0, 1, 1, 0, 0, 0) Model 5		
Variable	β Estimate (SE)	T-value
LMSW(-1)	0.762638*** (0.239524)	3.183975
LMSW(-2)	0.416311 (0.330994)	1.25776
LGVA	-14.49215 (19.74763)	-0.733868
LGVA2	0.493461 (1.045417)	0.472023
LGVA2(-1)	-0.105345 (0.050874)	-2.070725
LPOPD	1.638686 (9.351792)	0.175227
LPOPD(-1)	27.86576*** (8.5254)	3.268557
LTOUR	0.355838 (0.67779)	0.524998
OLD_SHARE	-2.734699** (1.180645)	-2.316276
UNEMP_SHARE	0.070667 (0.049346)	1.432059
C	-84.94778 (196.4078)	-0.432507

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*

	Model 1	Model 2	Model 3	Model 4	Model 5
Adjusted R^2	0.618374	0.566691	0.7211	0.982125	0.797008
P-value	0.000495	0.005501	0.018783	0.015779	0.000954
AIC	-0.962817	-0.809215	-1.116881	-4.590768	-1.49267
Durbin-Watson	2.106518	1.894389	2.238746	3.022495	2.336334

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*

Appendix D:

OLS Model 2 at log and level

	Dependent Variable: LMSW			Dependent Variable: MSW			
	OLS Log-transformed			OLS Levels			
Variable	β Estimate (SE)	T-Value	P-value	Variable	β Estimate (SE)	T-Value	P-value
C	5.598591 (77.66641)	0.072	0.9434	C	290.7594 (200.7429)	1.448417	0.1657
LMSW(-1)	0.663882*** (0.236095)	2.812	0.012	MSW(-1)	0.512679** (0.224364)	2.285033	0.0354
LGVA	0.970404 (11.71391)	0.083	0.9349	GVA	0.005185 (0.005367)	0.966003	0.3476
LGVA2	-0.02555 (0.581791)	-0.044	0.9655	GVA2	-4.00E-08 (4.27E-08)	-0.93609	0.3623
LPOPD	-1.52402 (2.861122)	-0.533	0.6012	D(POPD)	-4.693657 (3.698286)	-1.26914	0.2215
Observations	23			Observations	23		
Adjusted R^2	0.494782			Adjusted R^2	0.495481		
P-value	0.003016			P-value	0.002983		
AIC	-0.73424			AIC	11.87108		
Durbin-Watson	1.363683			Durbin-Watson	1.71631		
	Turning Point: R 176, 882, 821				Turning Point: NA		

*All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively*

Appendix E:

ARDL (1,1,1,1) Model 2 long-run estimate results

Dependent Variable: LMSW			
Long Run Coefficients			
Variable	β estimate (SE)	T-value	P-value
LGVA	35.10715 (33.64889)	1.043337	0.3145
LGVA2	-1.77746 (1.688876)	-1.05245	0.3104
LPOPD	8.097783 (8.324883)	0.97272	0.3472
C	-222.678 (224.3556)	-0.99252	0.3378
	Turning Point:	R19,762	

All models were estimated using Newey-West standard errors to account for the presence of heteroscedasticity and autocorrelation.
, **, and * indicate statistical significance at the 10%, 5%, and 1% levels respectively*