David Almasi
Central European University

Is the European Strategy for Plastics in a Circular Economy feasible?

Estimating the economic, environmental, and social benefits of a circular economy transition policy in the European Union

By

David Almasi

Submitted to the Department of Economics and Business, Central European University.

In partial fulfilment of the requirements for the degree of Master of Arts in Economics.

Supervisors: Anke Schaffartzik, Soomin Lee

Vienna, Austria

2022

CEU eTD Collection

David Almasi
Central European University

Abstract

This research investigates the feasibility of the European Strategy for Plastics in a Circular Economy (SPCE), which addresses the circular economy transition of plastic waste trade management within the framework of the European Green New Deal and its Circular Economy Action Plan (CEAP). With a combination of material flow analysis (MFA) and vector autoregressive models (VAR) and cost-benefit analysis, the aim of this research is to pinpoint the possible directions of waste production, waste exports, and recycling capacities in the EU until 2030, the benchmark date for the SPCE policy goals using three scenarios. Furthermore, the aim of the study is to determine the possible consequences of SPCE to the economy, the environment and to human health. Results show a significant increase in recycling capacities and a stark decrease in exports to non-EU countries if the policy is successful, in line with the goals of SPCE. Regarding the consequences of SPCE, the study finds robust profitability from increasing recycling capacities and a substantial decrease in CO2 emissions, moderately depending on whether the policy is successful. An estimated amount of 14.1 million tonnes of CO2 emissions could be saved if the SPCE is implemented, which means a yearly 14 000 drop in preventable mortality by 2030. Hence, the research provides a transdisciplinary assessment on an important strategy for circular economy transition.

CEU eTD Collection

Acknowledgements

The author would like to thank Anke Schaffartzik, Soomin Lee, Dóra Csernus and Zsolt Becsey for all the help.

CEU eTD Collection

Contents

CEU eTD Collection

List of tables

CEU eTD Collection

List of Figures

CEU eTD Collection

List of abbreviations

Name	Abbreviation
European Commission	EC
European Union	EU
European Environmental Agency	EEA
Circular Economy Action Plan	CEAP
A European Strategy for Plastic in a Circular Economy	SPCE
United Nations Conference on Trade and Development database	Unctadstat
European Union's Statistics database	Eurostat
Auroregressive (number of lags)	AR(q)
Moving average (number of lags)	MA(p)
Vector Autoregression (number of lags)	VAR(p)

CEU eTD Collection

Introduction

Waste trade is a billion-dollar business, with the World Trade Organisation estimating its net worth to be 3 billion dollars – more than the net worth of agricultural product trade, for example, which only accounts for 1.8 billion dollars (WTO, 2020). The EU is among the largest waste exporter globally, with an especially large share in plastic waste trade. Almost 17 million tonnes of plastic waste are generated in the EU in 2018, 16.75% of which is outsourced for recycling abroad (Eurostat, n.d., a; European Commission, 2018; European Parliament, 2018a). According to the European Parliament, reasons for outsourcing include the lack of capacity, financial or technological resources (European Parliament, 2018a). To mitigate the current dependency on outsourcing and to steer the European economy towards sustainability, the new Strategy for Plastics in a Circular Economy (SPCE), part of the European Green New Deal's attempts to increase domestic plastic packaging recycling rates up to 55% from the current 40.6%.[1] (European Commission, 2018). This is expected to boost the overall plastic recycling rates as well. At the same time, the 2018 Waste Shipment Regulation, in conjunction with SPCE, prohibits the export of plastic waste for disposal to non-EU countries, further incentivising the development of local plastic recycling capacities in the EU (Regulation (EC) No 1013/2006).

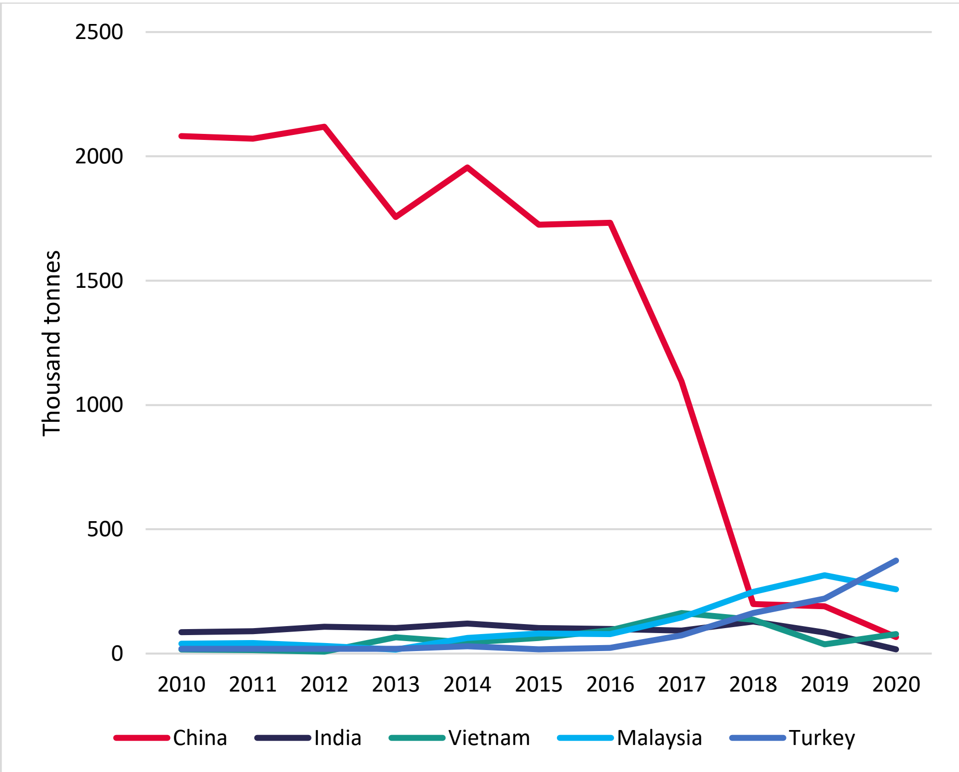
CEU eTD Collection

SPCE is especially timely as political, and economic tensions regarding international waste management are growing and possibilities for global capacities to recycling are narrowing. Waste is often shipped to developing countries, where it is either recycled, landfilled, or incinerated. However, the ecologically unequal exchange which has characterised these transactions resulted in ever-increasing risks to the environment and to human health in

[1] 40.6% in 2019, latest data (Eurostat, n.d., a)

these countries (Okaru, 1992; Schindler & Demaria, 2020). Consequently, more and more countries realise that the economic benefits from participating in the waste trade as an importer might be less than the social and environmental hazards the waste flows cause (Sembiring, 2019). China, the country with the largest recycling capacity has banned all waste imports after 2021, and the president of the Philippines, Roberto Duterte threatened Canada with war dared they ship more, potentially toxic waste to them (Sembiring, 2019; Smiley, 2019; Wang et al., 2019).

Figure 1: Imported plastic waste volumes to the top five outsourcing countries from the EU, 2010-2020.[2] Source: Unctadstat.



China's role was so substantial in waste relations that after the anti-waste import policy was announced, trade relations broke down even though the regime only commenced officially in 2021 (Figure 1). Furthermore, as of the latest available data, it is not obvious whether there

[2] Top five countries in 2016. Values for Hong Kong and China were summed up.

CEU eTD Collection

is a major substitution effect, replacing China with other outsourcing destinations (Figure 1). Albeit Turkey and Malaysia's volumes have increased since the announcement of the Chinese waste import ban in 2017, Malaysia followed suit with banning plastic waste imports as well, except some exceptions from the United States (Recycling International, 2018; Reuters, 2021) Therefore, there are indeed narrowing opportunities for plastic waste exports, which poses a demand for building local waste management capacities even in countries and regions which were exporters in the past waste management relations. It is especially true for the European Union, from where a substantial amount of waste streams towards East Asia, where many anti-waste import insurgencies are present (Figure 2).

Figure 2: Plastic waste trade destinations from the European Union in 2019. Source: own calculation based on Unctadstat.

The European Union tackles the waste problem as a part of its Circular Economy Action Plan (CEAP), which is the economic segment of the European Green New Deal, first introduced in 2018 as a complete policy package aiming to re-orient the EU economy towards

CEU eTD Collection

sustainability. In this research, the European Strategy for Plastics in a Circular Economy (SPCE), part of the wider Circular Economy Action Plan dealing with plastic waste management is inspected. SPCE affects the EU waste management structure in three ways. Firstly, along with the 2018 Waste Shipment Regulation, SPCE bans the export of hazardous plastic waste to non-EU countries. Secondly, the abovementioned policies heavily regulate the export of non-hazardous plastic waste. Finally, SPCE incentivises both private and public players to increase the recycling of plastic packaging to reach the aimed rate of 55% by 2030 by taking pledges for developing more recycling capacities. The paper focuses on plastic waste because it is one of the best-documented waste type (Geyer et al., 2017). Since even a relatively small amount of plastic waste is considered as directly toxic,[3] it tends to be better-documented than other waste types, providing more credibility to the data and hence the results (Schindler & Demaria, 2020).

This research applies a transdisciplinary approach, as a twofold evaluation is carried out. Firstly, a vector autoregressive (VAR) model is employed to forecast the direction of plastic waste production, plastic waste exports within EU and to foreign countries, as well as the recycling capacities. With this, scenario analysis is conducted – the practice of using three realistic scenarios for predicting possible outcomes of the policy shock to recycling rates. Secondly, the evaluation of results is conducted with a cost-benefit analysis regarding the expected profitability of the policy. Finally, externalities to the environment and to human health, notably CO2 and other emissions, as well as preventable human mortality are estimated using the different scenarios for a comparative analysis.

It is found that whereas SPCE will not affect plastic waste generation and within-EU trade, with both of them showing steadily increasing patterns in the next years. This is plausible

[3] Not considering microplastics for this demonstration, as the effects of them to human and non-human health are yet to be fully explored. See: Prata et al. (2020).

CEU eTD Collection

as SPCE only considers increasing recycling capacities and restricting plastic waste exports to non-EU countries as policy goals. These two impact areas, however, exhibit different outcomes depending on the scenarios. If the policy is successful, approximately 1.5 million tons more waste is being recycled than if not.

As for economic outcomes, a traditional cost-benefit analysis is conducted about the economic returns on developing the predicted increase of recycling capacities in the EU. Ecological benefits are measured in the estimated drop in CO2 emissions due to a decrease in plastic incineration. Finally, both EU and non-EU countries benefit from building recycling capacities though several channels. Within EU, the reduction in air pollution due to increased recycling and less incineration leads to a decrease in preventable mortality via reducing the incidence of cancer and respiratory diseases, currently the first and second leading cause of preventable mortality in the EU (Eurostat n.d., b). At the same time, decreasing waste exports to developing countries may result in the loosening of the current unequal structural relationship between the global North and the South (Schindler & Demaria, 2020). This latter results in that these countries may receive more autonomy to decide their own waste management policies, but on the other hand, they might lose an important source of revenue (Sembiring, 2019).

Results indicate that implementing SPCE would lead to a substantial increase in recycling capacities and a decrease in exports to foreign countries, while waste production and within-EU plastic waste trade is unchanged. Economic cost-benefit analysis shows that building recycling capacities will be profitable until 2030. If the policy is successful, plastic recycling within the EU is expected to be less profitable in the short-, but more profitable in the long-run. Furthermore, the current pace of building recycling capacities needs to be accelerated to keep up with the increased demand for plastic recycling. The success of the policy means a 5.5 million yearly decrease in CO2 emissions by 2030, which translates to a yearly reduction of 14 000 in preventable mortality.

CEU eTD Collection

This research has the potential to inform both economic and environmental policymakers about the possible implications of SPCE from a transdisciplinary perspective. The research starts with introducing the policy and identifies the gap in contemporary waste management literature which provides the motivation of the paper. The structure follows with describing the data and the empirical strategy. Finally, the discussion of the results take place with the conclusion, summarising the main take-away messages.

CEU eTD Collection

II. Literature review

II. a. The European Strategy for Plastics in a Circular Economy (SPCE)

SPCE is a part of the European Union's New Circular Economy Action Plan for a Cleaner and More Competitive Europe, or Circular Economy Action Plan (CEAP). CEAP is a strategy to ensure a climate-neutral transition by introducing a framework for circular economy. Circular economy is a regenerative economic model where the extraction of natural resources and the generation of waste is minimised (Giampietro, 2019). It recognises that since the economy follows the entropic laws of nature in that resources are scarce and limited, in order to ensure the long-term sustainability of society, energy loss from economic processes have to be minimal. Practically, this means that waste generation has to be reduced, and the value from waste that does generate needs to be returned. Whereas CEAP consists of several measures towards sustainability, this research concerns itself with only a part of it, namely the European Strategy for Plastics in a Circular Economy.

Plastic waste is the largest waste stream produced in the EU, totalling almost 17 million tonnes each year (European Commission 2018; Eurostat, n. d., a). At the same time, recycling rates have been stagnating for the last years around 30%, whereas incineration rates remained high, around 39% with ever-increasing plastic waste generation (European Commission, 2018). The loss of value from plastic waste is estimated to be 70-105 million Euros a year, placing a large burden on the economy – this value could be preserved by careful circular economy planning (European Commission, 2018). Finally, plastic puts a burden on the ecology as well, with over 150 million tonnes of plastic are estimated to be in the oceans and plastic incineration leads to a substantial contribution to air pollution through CO_2, polystyrene and other halogens (Verma et al., 2016). Ecological pollution has an effect on human health as well – exposure to plastic incineration smoke has been proven to contribute to respiratory diseases and lung cancer,

CEU eTD Collection

whereas microplastics entering nature from careless waste management potentially also have severe consequences to human health (Barboza et al., 2018; Chu et al., 2021).

SPCE minimises plastic waste upon several premises (European Commission, 2018), such as improving plastic packaging for easier recycling, for a ban on oxo-degradable and single-use plastics, as well as regulations towards more rigorous landfill standards. However, this research considers three major directives which has the potential to substantially alter European plastic waste management structure in the medium term. Firstly, SPCE issues a 55% recycling benchmark on plastic packaging waste, which was 39.9% of total plastic waste produced in the EU. The benchmark aims to be achieved by individual pledges of both private and public entities to take up fore recycling, as well as use more recycled plastics. The success of this target depends on whether EU can develop substantial recycling capacities. This is because secondly, SPCE bans all export of hazardous plastic waste to non-EU countries. This may further increase the demand for building recycling capacities. Thirdly, the export of non-hazardous waste to non-EU countries is severely regulated, resulting in the same effects as the previous policy (Table 1).

Table 1: Expected changes of SPCE on different measurements of EU waste management structure. Source: European Commission (2018).

Likely effect on:					
Within-EU waste trade	Export to non-EU countries	Waste generation	Recycling rates	Incineration rates	Landfill dumping
↓	↓	?	↓	↓	↓
↑	↓	?	↑	?	?
↑	↓	?	↑	?	?

CEU eTD Collection

II. b. Motivation of the research and outlook to current topics in waste management literature

The motivation for conducting this research stems from two main concerns. The First concern is that as waste is a special commodity with various social and environmental externalities, hence, a more transdisciplinary and holistic approach is needed *beyond* the traditional economic cost-benefit analysis to effectively measure the economic, social, and environmental outcomes of waste trade and in this case, circular economy planning. The second concernis that to date, there has been relatively scarce documentation of forecasting material flows in face of an external shock in the literature.

Waste is not an ordinary economic good. As Schindler and Demaria (2020) argues, differently to other goods, one may have disutility upon owning waste. The generally global North-South dominated waste trade is especially problematic. Numerous studies have linked the increase in global waste trade to the introduction of the free-market oriented neoliberal regime from the eighties, described in, for example, Mujezinovic (2020) and Blumm (1992). This regime removes the social and ecological externalities from market calculations and only considers monetary valuation, hence commodifying nature and society (Lohmann, 2012). At the same time, waste management evokes such external factors to society that a neoclassical, closed-economy approach cannot sufficiently capture the social and environmental aspects of waste trade and deposition. This is widely illustrated in the literature. Okaru (1992) suggests that albeit some developing countries may benefit from waste trade economically, the social and environmental externalities of waste being deposited in the country may outweigh its economic benefits. At the same time, this does not mean that one needs to give up characterising waste trade flows – there are innovative solutions. For instance, the research of Demaria (2010) explores shipbreaking as an ecological distribution conflict and finds that the unequal distribution of benefits and burdens of having waste between more and less powerful countries

CEU eTD Collection

results in that while some earn large profits from waste trade, the poor will bear the environmental and social externalities. Given that the European Union is the second largest player in global plastic waste trade, understanding its management patterns, similarly to the abovementioned studies, need to be conducted in a transdisciplinary framework, in which other measures besides monetary valuation have a role as well.

Indeed, countries seem to realise that the environment is as important as the economy. The research of Sembiring (2019) provides several anecdotal examples of this. China, the by-then largest importer of plastic waste, made plans to ban most plastic waste imports in 2017. Albeit the policy officially started from 2021, its effects can still be seen after the announcement of the plan in 2017 (Figure 1). Malaysia has followed suit by first shipping back its waste to the origin countries given their local waste management capacities are saturated and has also banned most plastic waste imports in 2018. The practice of popular plastic waste outsourcing destinations restricting waste imports is problematic for the developed world as well – as Sembiring (2019) notes, the increasing refusal of waste imports increases the need to orient towards local waste management solutions, which may include the development of recycling capacities.

Ecological economic approaches are increasingly playing a key role in overcoming the abovementioned difficulties of characterising waste trade in recent years. These transdisciplinary approaches recognise that economy is but smaller part of a larger, socio-cultural metabolism, which is in turn embedded into an even wider ecological metabolism, following the laws of nature (Krausmann, 2017). Waste, in this framework, is a commodity which jeopardises this metabolism through its social and environmental externalities (Álvarez & Coolsaet, 2020). Examples of this approach for waste management include the abovementioned studies of Mujezinovic (2020) and Demaria (2010). Furthermore, the study of Schindler and Demaria (2020) places conflicts over the global waste trade into a wider socio-

CEU eTD Collection

metabolic approach, arguing that as waste is increasingly viewed as a value given it is an important trade good, new techniques and approaches are needed for waste management studies to not only capture the strictly speaking economic benefits. Nevertheless, strongly quantitative studies trying to link these ideas are missing from economic literature.

The flow of goods in the economy has traditionally been understood using material flow analysis (MFA), a technique to analyse the transformation, transportation, and storage of raw or processed materials in an economy (Brunner and Rechberger, 2004). Waste management is no exception, as the generation, flow and transformation of waste can be mapped using MFA. However, a substantial problem concerning waste management studies using material flow analysis is that waste is often rather poorly documented, since a substantial amount of waste trade is conducted in black markets (Calderoni et al., 2014; Schindler & Demaria, 2020). However, there are exceptions, such as plastic waste, which is usually well-documented due to that apart from the abovementioned risk of microplastics, plastic waste tends to be not directly hazardous to human health. Hence, plastic waste is relatively well-studied in material flow analysis. For example, the study of Geyer, Jambeck, and Law (2017) drafts all aspects of plastic waste production, lifespan and fate using MFA, and finds that the production of waste is expected to rise by 25% by 2050, and that if the current evolution of plastic waste management continues, recycling rates will likely not increase in the future.

The problem is that MFA is a descriptive technique, so apart from a few special situations, it is inadequate for predicting future flows. However, there are some examples. Song et al. (2017) develops an advanced generalised methods model for forecasting demolition waste evolution in China. Althaf, Babbitt, and Chen (2019) forecast electric waste streams for circular economy planning. They note, however, that while material flow analysis may be appropriate for forecasting in certain situations, by design, MFA is a backward-looking methodology. Indeed, material flow analyses generally assume that the evolution of waste trade follows the

CEU eTD Collection

general, natural equilibrium of the economy. Hence, this research cannot fully incorporate material flow analysis as the Circular Economy Action Plan evokes a substantial recycling demand shock, potentially influencing production and trade as well through the joint movements of waste generation, trade and end of product life-management (Andersen et al., 2007).

The closest to the subject of this research may be the study of Kanaoka (2018), who forecasted the potential value of circular economy transition in Florida using an ARIMA-based time series forecasting method supplemented with cost-benefit analysis of the potential economic returns from developing recycling capacities. Similarly, the United Kingdom's Department for Environment, Food & Rural Affairs (2013) estimated waste flows and waste management capacities by 2020 using a SARIMA approach. This research follows the tradition of using autoregressive models for forecast as they allow for a flexible scenario analysis, in this case based on the possible shock to recycling that the SPCE would pose on the waste management structure. In essence, the existence of an external policy shock artificially increasing recycling rates and hence capacities are best demonstrated with time-series modelling. Hence, albeit this research builds on some basic premises of material flow analysis, it is novel in the sense that it uses different specifications of time series forecasting, depending on the shock scenario, to account for multiple possible futures within the waste management structure.

This research attempts to fill the gap of limited literature on material flow forecasting in face of an external policy shock while introducing a holistic approach for evaluating some effects of the circular economy transition.

CEU eTD Collection

III. Material and Method

III. a. Data

The data can be placed into two main groups: one is the data used for forecasting waste trade flows, and the other group of data is for the cost-benefit analysis of the forecasted values.

Four variables are especially interesting for time series forecast in this case: plastic waste trade volumes within- and outside EU, plastic waste production within the EU, and plastic recycling rates (Andersen et al., 2007). Firstly, trade volumes were acquired from the UN Trade and Development dataset (Unctadstat), a comprehensive trade data framework for all major goods in the economy, consisting of the trade volumes, the importer and exporter countries. Data is available between 1995 and 2020, however, data is scarce at best for the first five years (DeLuca, 2017). Trade volumes were aggregated for the EU countries every year.[4] Plastic recycling rates for within-EU recycling are from Eurostat (n. d., c), consisting of a time series of plastic packaging recycling rates from 2005 to 2019. Thirdly, total plastic waste production was also downloaded from Eurostat (n. d., a): the bi-yearly values from 2004 to 2018 were promptly converted to yearly observations using linear last-match approximation. The timespan of the series consisting of the for variables is from 2004 to 2018 (Appendix A, Table 1.).

After conducting the forecast of the abovementioned variables describing the EU waste structure until 2030, the benchmark date for re-assessing the success of SPCE, results are interpreted using an economic cost-benefit analysis. A number of variables are used for assessing the policy's effect on the environment and to society, such has landfill tipping fees,

CEU eTD Collection

[4] The list of considered EU countries is the following: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. Albeit Romania and Bulgaria only joined the European Union in 2007 and Croatia in 2013, calculations were made assuming if they joined in 2004. This is because of data availability issues on Eurostat – time series are often incomplete for individual countries, but are not "EU27" series, which is an aggregation of the abovementioned 27 countries.

preventable mortality measures and emission statistics. The full list of these variables with the source are in Appendix A, Table 2.

III. b. Forecast

This research identifies four main factors which jointly contribute to the evolution of global waste-management structure: waste generation, within-EU trade, waste exports to non-EU countries and recycling rates (Andersen et al., 2007). Problems with scarce data on recycling capacity is mitigated by introducing three possible scenarios of recycling rate evolution, making sensitivity analysis possible. The inaccuracy stemming from the shortness of time series is mitigated by differencing, when appropriate, and introducing Holt-Winters exponential smoothing with linear trends. Finally, a vector autoregressive model is used to forecast the evolution of plastic waste management structure in the EU until 2030, following Kanaoka (2018) and the UK Department for Environment, Food & Rural Affairs using an autoregressive method of forecasting. At the same time, a multivariate vector autoregression model is employed instead of the often-used ARIMA approach, since the goal is to map the continuous evolution of multiple time series subject to the same policy shock posed by SPCE. Hence a multivariate time series approach is needed.

Estimating the recycling rates is problematic as Eurostat (n. d., c) only publishes the recycling rates for plastic packaging rates, and not for all plastic recycling rates. Under the SPCE policy regime, the current plastic packaging recycling rates are to be increased up to 55% until 2030. This policy goal has the potential to increase the rates of the overall plastic recycling rate, since plastic packaging alone gives 39.9% of the total plastic waste (European Parliament, 2018b). It is also known that in 2018, the EU recycled 30% of its overall plastic (European Commission 2018). These pieces of information allow to build a reasonable estimation of

CEU eTD Collection

recycling rates. To provide a framework for scenario analysis three reasonable scenario on the evolution of plastic waste was built. The scenarios are seen below at Table 2. For all the values prior to 2018, it was assumed that the overall plastic recycling rate follows the trend of plastic packaging recycling rate prior to 2018.

Table 2: Three scenarios of recycling rates depending on the strength of the policy shock.

Scenario 1: Major increase	The major increase scenario is given by a linear projection in which the 55% plastic packaging recycling by 2030 policy goal is fully met.
Scenario 2: Moderate increase	The moderate increase scenario is given by a linear increase with half the gradient of scenario 1.
Scenario 3: No increase	In this case, recycling rates do not increase after 2018. This is plausible since plastic packaging recycling rates have substantially slowed increasing and are roughly stagnating since 2016 (Appendix B, Figure 1.).

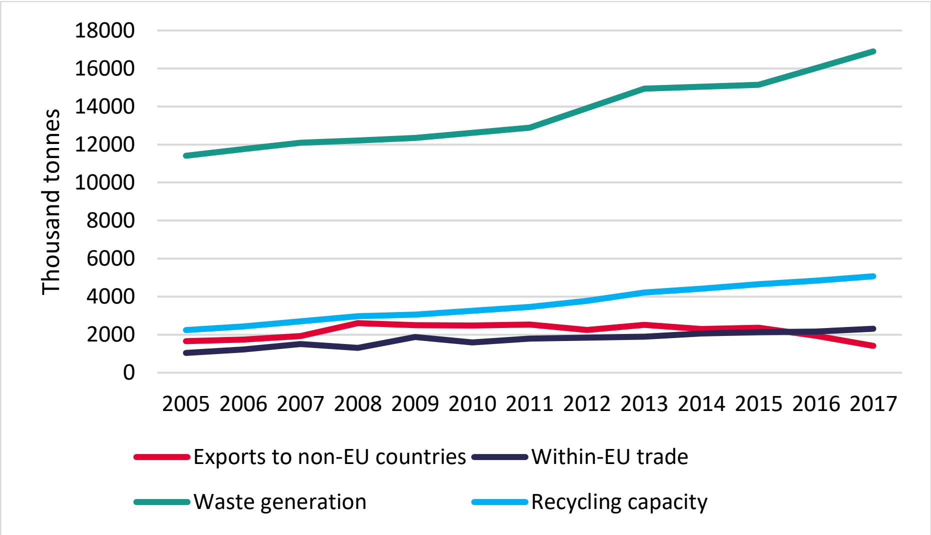
The results of the forecasted recycling rates are converted to recycling capacities for interpreting the results. This allows for controlling the evolution of recycling capacities as a function of waste production. In addition, recycling capacities allow for a better visualisation. Recycling capacities of EU countries for domestic waste management were estimated using a simple extended material flow analysis framework introduced at Althaf, Babbitt, and Chen (2019):

(1) $$C_t = \sum(I \times Y)_t \times P_t$$

CEU eTD Collection

Where C is recycling capacity in year *t*, *P* is the probability of recycling at time *t*, and $(I+Y)_t$ are the sum of local output and imports of waste in the EU at time *t*. The evolution of the four selected variables until 2018 can be seen below at Figure 3.

Figure 3: Evolution of the EU waste management structure, 2005-2018.



Since the full time series only consist of a few observations, it is important to introduce exponential smoothing. This technique is an adaptive forecast which adjusts itself based on previous forecast errors, resulting in a tighter forecast error and hence a more accurate presentation (Bowerman & O'Connell, 1993; Hyndman et al., 2002). A Holt-Winters exponential smoothing assuming linear trend was introduced on the time series recycling rates, waste production, trade within the EU and outside exports.

The baseline model being used to predict the evolution of plastic waste trade is an VAR(3) model. Structural VAR (SVAR) cannot be applied in this case because it assumes that the structural shocks influencing the variables are uncorrelated. However, here, the same SPCE policy shock affects all variables. Ideal lag selection was determined by the Box-Jenkins method for multivariate time series for finding the best-fitting lag (Appendix A, Table 3.). The VAR(3) model employed in the research can be represented the following way:

CEU eTD Collection

(2)
$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \\ y_{3,t} \\ y_{4,t} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} + \begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & a_{1,4} \\ a_{2,1} & a_{2,2} & a_{2,3} & a_{2,4} \\ a_{3,1} & a_{3,2} & a_{3,3} & a_{3,4} \\ a_{4,1} & a_{4,2} & a_{3,4} & a_{4,4} \end{bmatrix} \times \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{3,t-1} \\ y_{4,t-1} \end{bmatrix} + \begin{bmatrix} b_{1,1} & b_{1,2} & b_{1,3} & b_{1,4} \\ b_{2,1} & b_{2,2} & b_{2,3} & b_{2,4} \\ b_{3,1} & b_{3,2} & b_{3,3} & b_{3,4} \\ b_{4,1} & b_{4,2} & b_{3,4} & b_{4,4} \end{bmatrix} \times$$

$$\begin{bmatrix} y_{1,t-2} \\ y_{2,t-2} \\ y_{3,t-2} \\ y_{4,t-2} \end{bmatrix} + \begin{bmatrix} d_{1,1} & d_{1,2} & d_{1,3} & d_{1,4} \\ d_{2,1} & d_{2,2} & d_{2,3} & d_{2,4} \\ d_{3,1} & d_{3,2} & d_{3,3} & d_{3,4} \\ d_{4,1} & d_{4,2} & d_{3,4} & d_{4,4} \end{bmatrix} \times \begin{bmatrix} y_{1,t-3} \\ y_{2,t-3} \\ y_{3,t-3} \\ y_{4,t-3} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$$

This matrix notation means that four regressions are run for each four outcome variables: waste exports to foreign countries, within-EU trade, waste generation and recycling rates. The respective outcome variable is regressed on a constant, their own three-period lag, and the three-period lag of the other three variables, and an error term. Error terms are assumed to be white noises. Three VAR(3) models were run for the three scenario of the possible direction of the policy shock. Variables were first differenced to achieve stationarity. Serial correlation of the error terms was avoided by using yearly values to cancel out potential short-term correlations, and a relatively large number of lags (3) was used to mitigate potential long-term autocorrelations (Appendix A, Table 3.). Residual autocorrelation of the models tells that the VAR(3) model sufficiently captures autocorrelation for the selected variables (Appendix A, Table 3, a-c.). Furthermore, checking the VAR stability conditions tells that all AR polynomial roots are less than one and lie within the unit circle, making the estimated VAR equation stable (Appendix B, Tables 5. a-c.).

CEU eTD Collection

III. c. Cost-Benefit Analysis and forecast evaluation

Simply having the forecasted values do not talk much about the effects of the policy on the economy, environment, and society. Hence, in order to determine whether the policy is indeed feasible, a cost-benefit analysis is conducted to realise the economic profitability of introducing the SPCE policy regime. In addition, externalities regarding the environment and society are also measured. Environmental benefits are measured by the possible reduction in CO_2 emissions if the policy is successful using the recycling capacity results of the forecasts.

Finally, reductions in CO_2 emissions are translated to decreases in preventable mortality, hence contributing to social outcomes.

Economic outcomes were measured by a simple economic cost-benefit framework – whether and when the installation of additional recycling capacities predicted by the model would be profitable. Maintaining a recycling facility include both direct (variable) and indirect (fixed) costs, the sum of which gives the total cost. Direct costs constitute of the operations and maintenance of the facility (O&M), which typically include labour, maintenance, transportation and raw material costs (Jamasb & Nepal, 2010). Indirect costs enter as the original installation cost of the facility, or simply saying, the investment cost. It is assumed that the additional recycling capacities are built overnight on the 1st of January the respective year. The cost functions of recycling facilities are taken from the research based on the inspection of European waste management facilities from Tsilemou & Panagiotakopoulos (2006) and (Jamasb & Nepal, 2010), for a typical European recycling plant processing 2.5-20 thousand tonnes of recyclable plastics every year. It is assumed that the new recycling capacities are built overnight on the 1st of January in each respective year and start processing from day 1.

(3) $$C_y = 33{,}332 \times (x1)^{0.473}$$

(4) $$C_{O\&M} = 4{,}681 \times (x2)^{-0.481}$$

$$where\ x2 = 0.8x1$$[5]

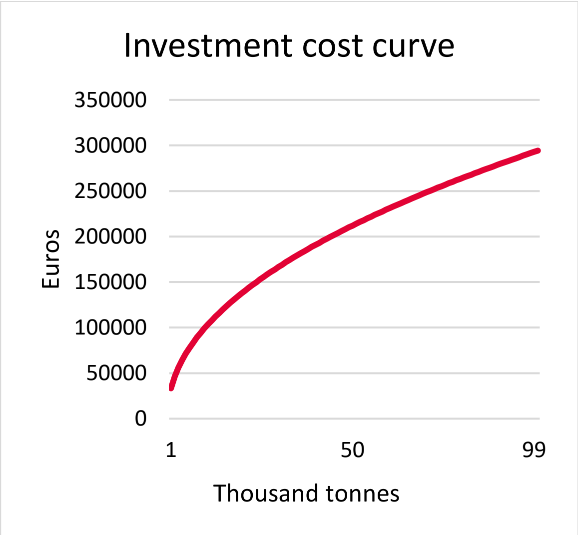
The following graph sketch the investment, O&M and total cost functions of recycling facilities. For the latter, following Tsilemou & Panagiotakopoulos (2006), annualised costs

[5] Assuming that recycling capacities are built according to the demand for recycling posed by the recycling capacity increase that year, and they process waste with 80% efficiency.

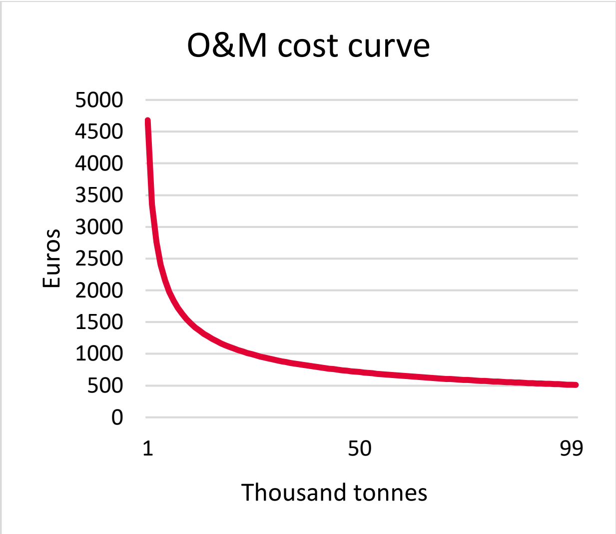
CEU eTD Collection

were obtained considering a 8% total discount rate was with 20 years facility life, meaning a discount factor of 0.102. Transport costs were excluded as in the case of within-EU recycling, due to the relatively small distances, transport costs are negligible compared to O&M and investment costs (Kellenberg, 2015). Furthermore, it is assumed that the plastic recycling facilities operate with a 80% efficiency (Faraca & Astrup, 2019). Adding up the two cost curves for direct and indirect costs gives the total cost curve.

Figures 4. a-b. Investment and O&M cost curves.



(a)



(b)

Total economic revenues are given by the difference between private benefits and opportunity cost. Upon the assumption of price-taking, revenue sources scale up with the processed waste. Hence, the private benefits are the market price of all recycled material leaving the factory. Recycled plastic prices were predicted using Holt-Winters multiplicative exponential smoothing to avoid inference due to seasonal fluctuations. Opportunity cost is represented by the landfill tipping fees and landfill taxes, since the higher they are, the more incentive there is for recycling (Reschovsky & Stone, 1994).[6] Hence, the avoided costs from landfilling enter as a benefit, along with the total estimated market price of recycled material.

(5) *Total cost = investment cost + O&M costs*

(6) *Total revenue = private revenue – (–opportunity cost)*

To estimate the environmental benefits of the recycling capacities, a projection of landfilling and incineration capacities were conducted based on the forecasted values of recycling. Primarily, it is plastic incineration that omits polystyrene, halogens and carbon dioxide, all of them being harmful to human health and contribute to climate change (Verma et al., 2016). This paper only considers CO2 emissions, as with the current plastic incineration technology, the other groups of polluting materials give less than 10% of total emissions coming from incineration (Lee et al., 2018). The expected rise in recycling leads to a decrease in both incineration and landfill dumping, which in turn means less CO2 emissions. A recent study on European recycling capacities estimates that for each tonne of waste incinerated, 2599 kilograms of CO2 gets to the air (Gradus et al., 2017), which is used as a baseline estimate for calculation.

Outcomes to human health were evaluated in terms of reduction in preventable mortality. Respiratory diseases are the second largest cause of preventable death in the EU, largely due to the excess air pollution stemming from waste management, most notably, incineration (Eurostat, n.d., b). Hence, the expected drop in preventable mortality may be estimated building on the results of the environmental cost-benefit analysis. Less preventable mortality may increase labour force participation and productivity, an aspect also covered in the analysis (Hansen & Selte, 2000). Using the findings of Bressler (2021), it is assumed that

CEU eTD Collection

[6] The underlying assumption is that the alternatives are either recycling or landfilling/incineration.

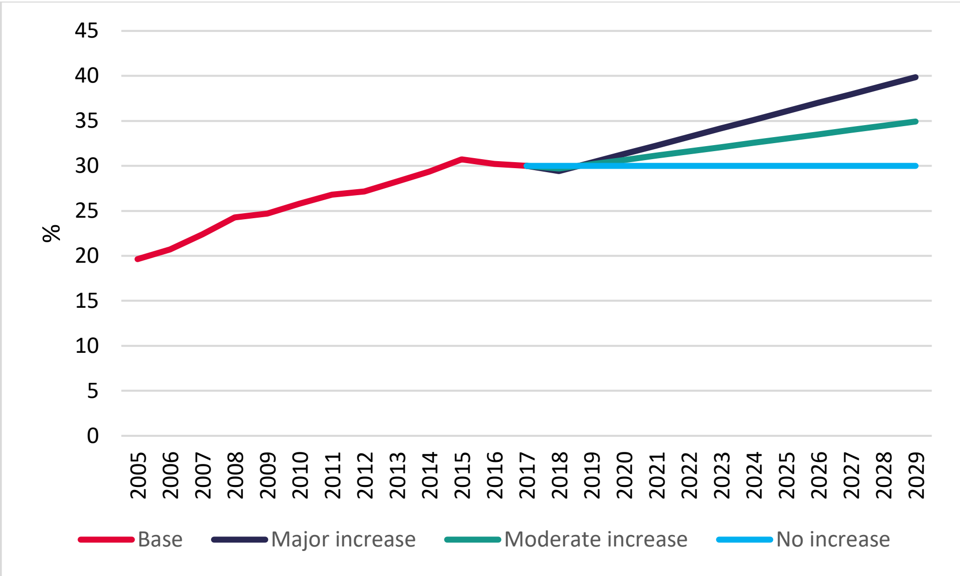
crudely a 4434 kilograms of additional CO_2 emissions contribute to an additional preventable death.

CEU eTD Collection

IV. Results

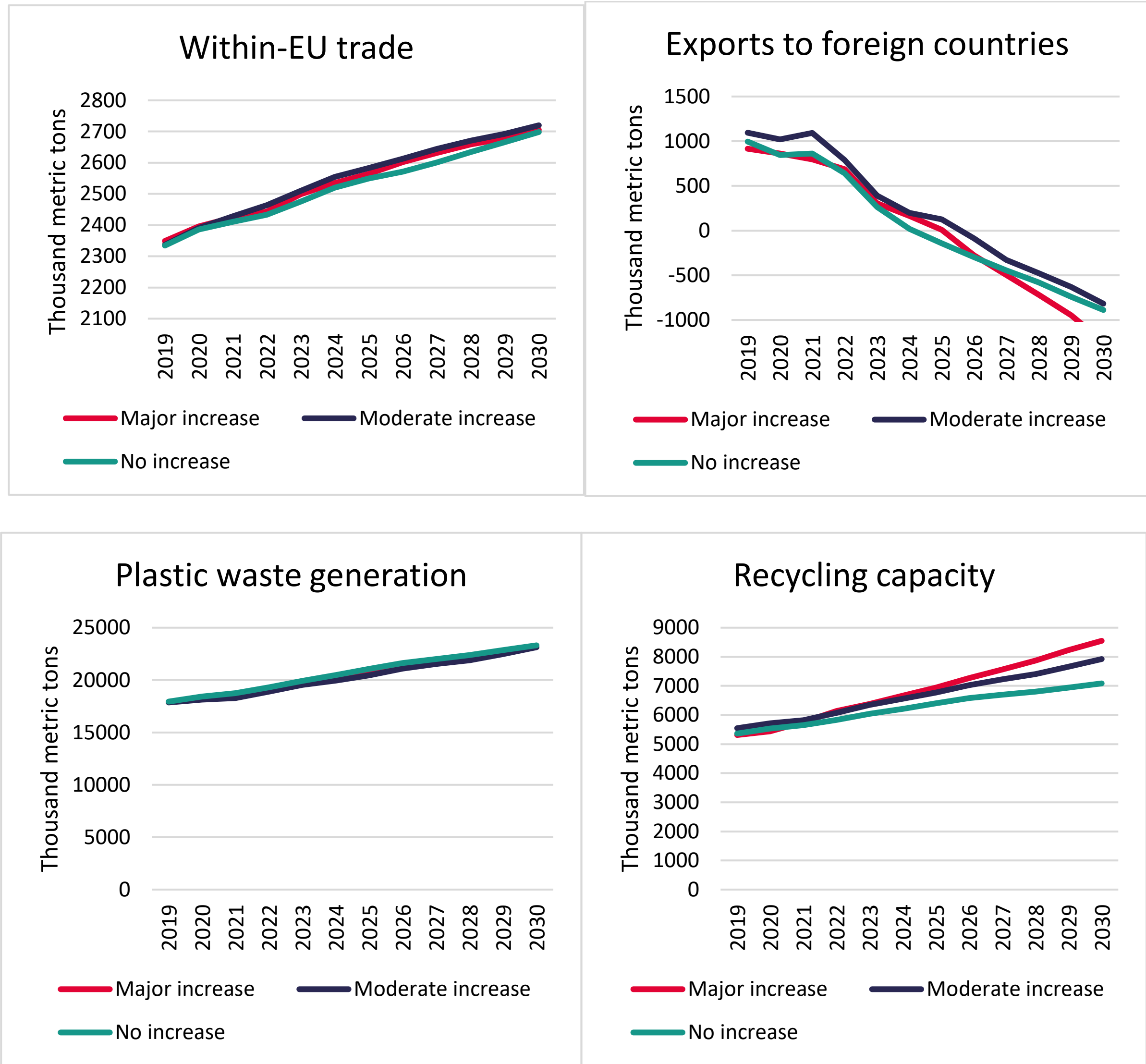
IV. a. Forecast results

Figure 5.: The predicted evolution of the three different recycling rate scenarios.



First, recycling capacities were predicted according to the three scenarios described in chapter III. a. The forecasted values of plastic waste production, within-EU trade, exports to foreign countries and recycling rates bore similar results in all but two sense. Only exports to foreign countries and recycling capacities are substantially different from each other in the three scenarios. Nevertheless, results are in line with the suggestive directions of the policy. Cost-benefit analysis implies that plastic recycling is expected to be profitable for the future, however, to meet the policy goals, a substantial effort in building recycling capacities is needed.

Figures 6., a-d. Forecasted waste structure scenarios for each of the main variables.[7]



Plastic waste production is not substantially different in the three scenarios. This is not surprising, as SPCE does not regulate plastic waste production directly (European Commission, 2018). Albeit SPCE does ban certain kinds of plastics, the reality is that the vast majority of plastic is imported to the EU, therefore the source of plastic waste generation is outside the EU's control (Geyer et al., 2017). Therefore, in the absence of regulations restricting plastic waste generation, the results of the forecast are reasonable. Similarly, within-EU trade accounts

[7] A complete set of series from 2005 to 2030 for demonstration of the "major increase" scenario can be seen in Appendix B, Figure 4.

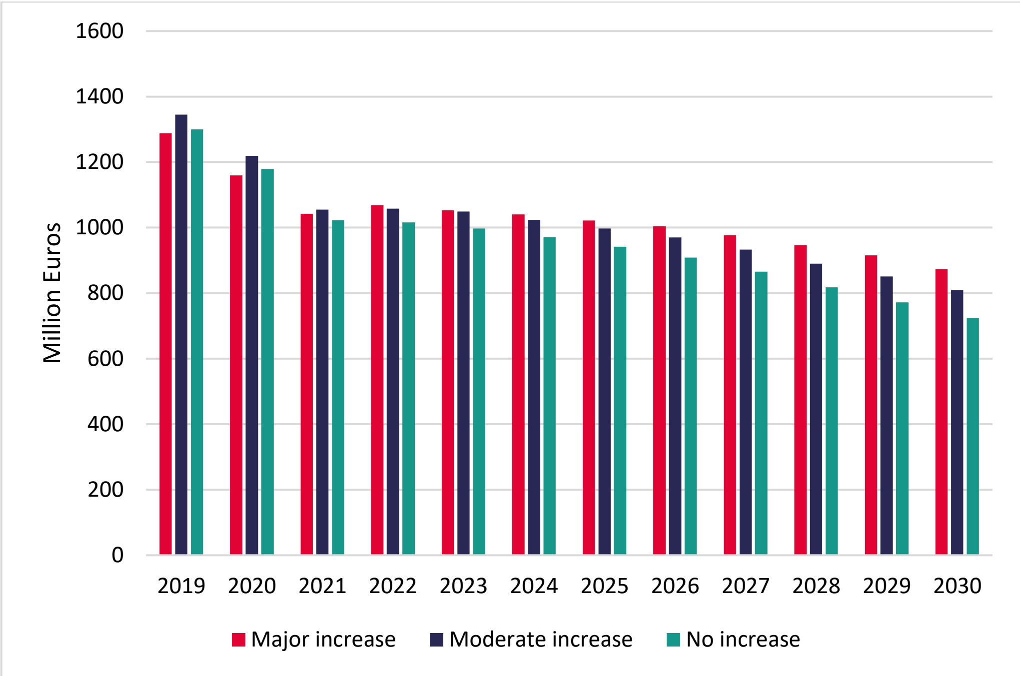
a moderate expected increase. This is likely due to the increased building of recycled capacities, the locations of which is probably not going to be uniform within the EU (Haas et al., 2015), resulting some overall increase in within-EU trade.

On the contrary, exports to foreign countries will likely result in a substantial decrease in the following years. The negative values persist for all three scenarios, hence it shows that the EU's trade balance may be negative by 2030 in terms of plastic waste trade (Figure 6. b.). Albeit this does not seem very plausible, it is definitive that exports to non-EU countries would almost cease by 2030, even in the absence of SPCE. SPCE does restrict exports of plastic waste to non-EU countries, but it is unlikely that non-EU countries would start importing waste to the EU given the past trends. However, there are some explanations to this result. Some non-EU countries, like the UK, or Switzerland may directly benefit from the development of EU recycling capacities by importing waste within the EU, it is unlikely that they would participate in such magnitude as they have high domestic recycling rates and hence already existing capacities to do so (Figure 12., Eurostat, n.d., c). The most likely scenario is that EU's role as a connecting hub in plastic waste trade flows between the waste producers in the Americas and the import receivers in Middle Eastern outsourcing destinations, most notably Turkey will increase. Indeed, Turkey has somewhat increased its plastic waste imports, especially after China's plastic waste ban (Figure 2). At the same time, there is little evidence of this happening based on the plastic waste imports of other main exporters of waste into the EU (Figure 12). Finally, plastic recycling capacities are substantially different in all three scenarios, with a moderate scenario implying roughly one million increase in capacity relative to the no increase scenario, whereas the major increase scenario provides 1,5 million tonnes more recycling capacities compared to the no increase scenario (Figure 4, d.). Hence, the results indicate that if successful, SPCE could increase EU recycling capacities by 20.6% compared to the no increase scenario by 2030 (Figure 6. d.).

CEU eTD Collection

IV. b. Cost-benefit analysis and forecast evaluation

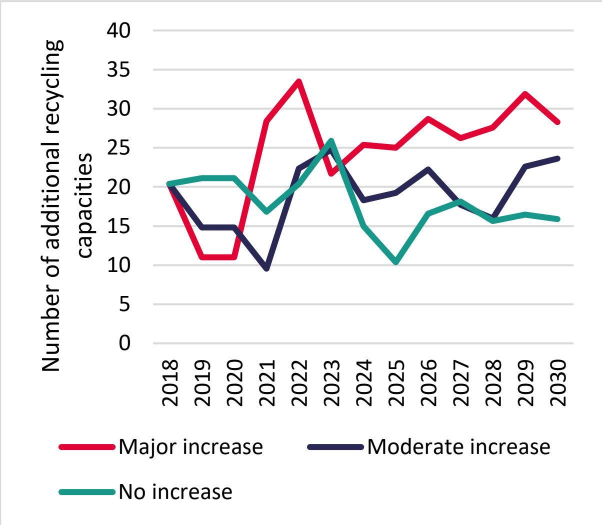
Figure 7. Cost-benefit balance of the three scenarios, 2019-2030.



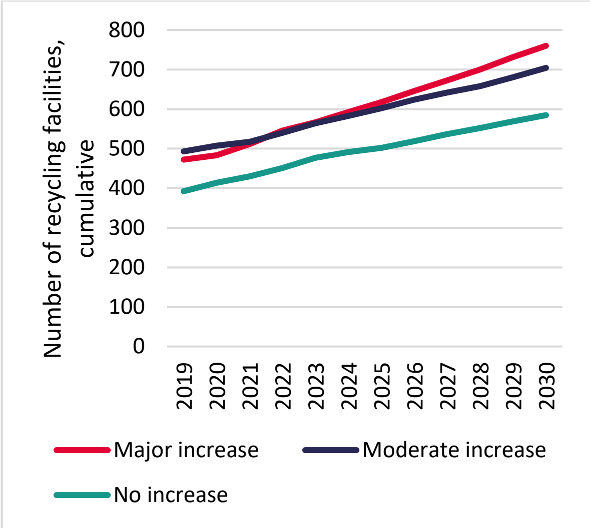
The results of the economic cost-benefit analysis (Figure 7) indicate that regardless whether the SPCE regime is introduced, recycling rates are going to be profitable on both the long and short run. However, in 2019-2020, estimates predict that investing in the policy will result in a lower profit margin, which is promptly mitigated in the later years. The magnitude of profits is a reasonable estimate on scale, as the global recycled plastic market was around 43 billion Euros (46.09 billion USD) in 2021 (Grand View Research, 2022), and the European Union is the second largest producer of plastic waste after China (Research and Markets, 2019). Decreases in profitability for the farther future are possibly due to the expected decrease in the price of recycled plastic, which means an elastic demand. Demand for recycled material will also possibly grow in the future, indicated by the larger profitability of the „major increase" scenario.

CEU eTD Collection

Figures 8. a-b: Number of recycling capacities needed for each scenario. Cumulative and annual increase, 2019-2030.[8]



(a)

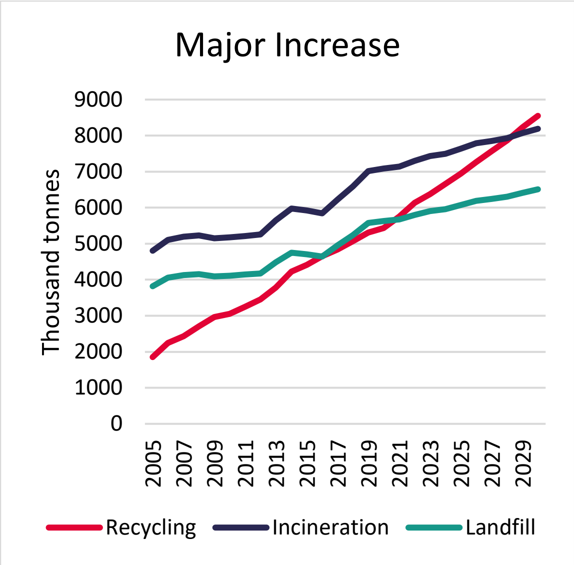


(b)

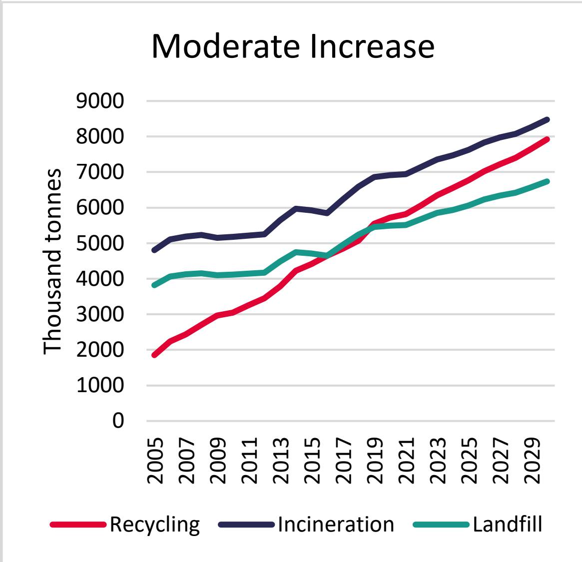
Figure 8 shows the required number of recycling capacities needed to be built in each year in the three scenarios. Notably, implementing the policy would mean an additional 150 recycling facilities being built in the EU by 2030, which means a strong commitment, given that only 73 such recycling capacities were built in the past 8 years (ENF Recycling Directory, n.d.).

[8] Assuming an average recycling facility capacity of 11.25 thousand tonnes per year.

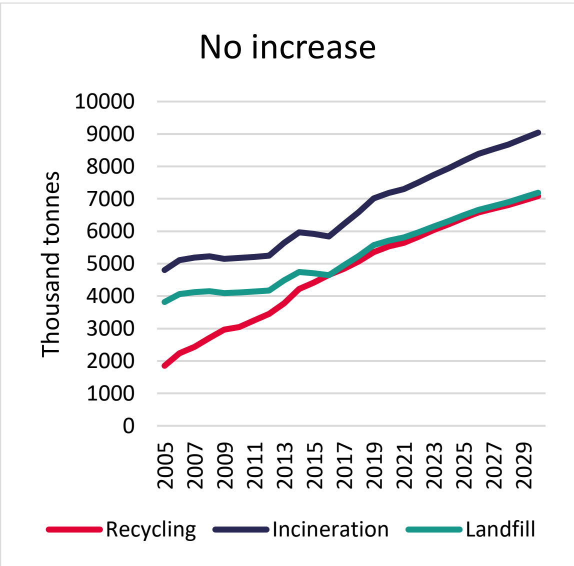
Figures 9, a-c. Landfilling, and incineration rates as a subject to recycling rates based on the three scenarios.



(a)



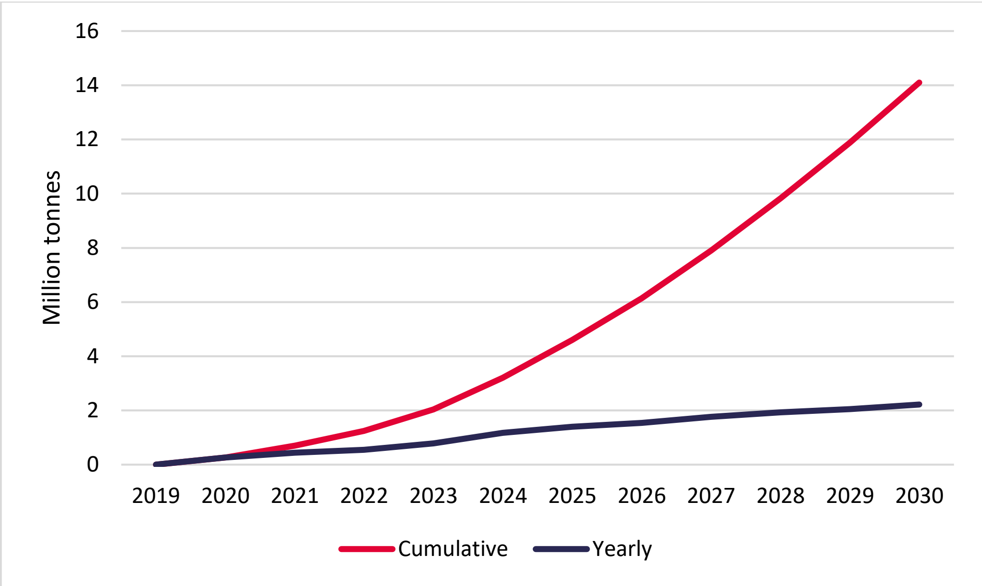
(b)



(c)

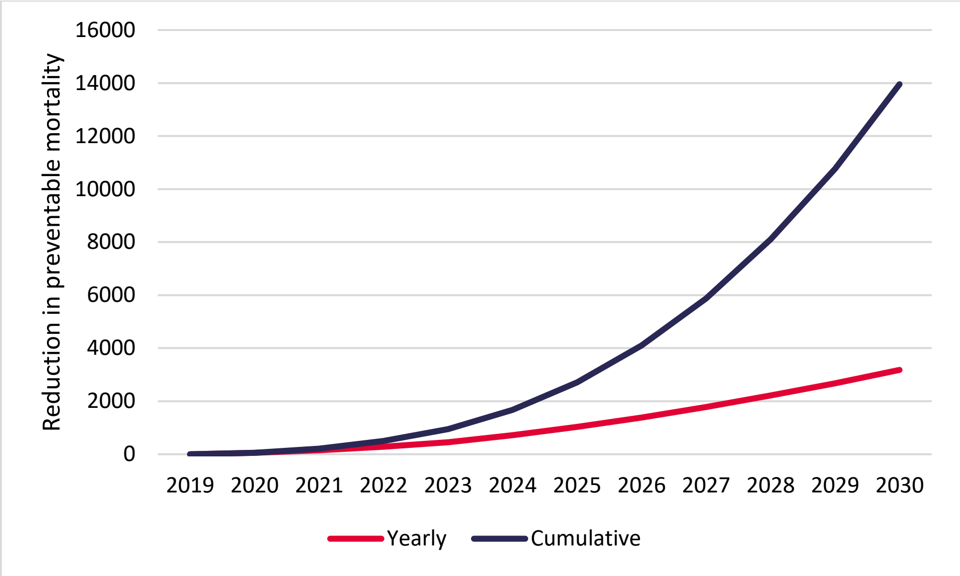
Incineration and landfilling rates were projected as a function of the evolution of recycling rates. Differences to outcomes regarding waste disposal are substantially different – for instance, if the policy is successful, almost 5.5 million tonnes of plastic waste would be recycled instead of incineration by 2030 (Appendix B, Figure 3.). This would mean an expected yearly 14.1 million tonnes reduction in CO2 emissions by 2030 only from reorienting incineration towards recycling (Figure 10.).

Figure 10: Reductions in CO2 emissions due to SPCE (Difference between the major increase and no increase scenarios).



As for the human health consequences, approximately 4434 metric tons of CO2 leads to one excess death (Bressler, 2021). Using this value as the baseline calculation, it is revealed that the reduction in carbon emissions lead to a significant drop in preventable mortality (Figure 11). According to the estimation, by implementing the policy, almost 14 000 lives can be saved by 2030.

Figure 11: Reductions in Preventable mortality due to SPCE (Difference between the major increase and no increase scenarios).



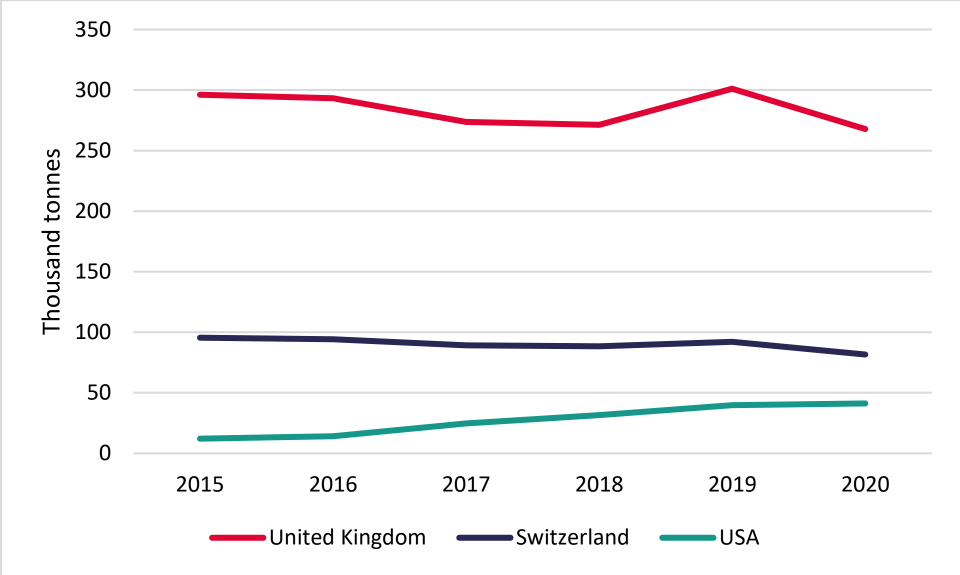
V. Discussion of the results

Results need to be understood and evaluated in the context of the current reality of waste trade. In the following, the contribution of the results to the current knowledge about waste management is examined by returning to the questions posed posed in chapter I and II of this paper.

As for forecast results, negative values of exports to non-EU countries need to be interpreted with caution. Albeit there is a notion that the EU is becoming a connecting hub between the Americas and the Middle East, the extent of it is not obvious from the data available (Figure 12). In fact, imports to EU from the Americas have decreased substantially in the past years, making these results less believeable. Nevertheless, results do indicate the breakdown of trade exports to non-EU countries, which means that the current global North-South dominated plastic waste flow direction will falter a bit, given the European Union is the second-largest exporter of plastic waste trade. This means that on one hand, countries might lose an important source of revenue, but on the other hand, might gain more from freeing their waste management capacities to deal with domestic waste, which improves environmental and social channels through reducing emissions and decreasing preventable mortality (among many other benefits) (Schindler & Demaria, 2020). Hence, the results of this paper regarding the future of waste exports show the same general pattern that the study of Sembiring (2019) predicts. However, since the magnitude of the research predicts a stark decrease which is not supported in literature, results of exports need to be interpreted with caution.

CEU eTD Collection

Figure 12. Plastic waste imports to the EU from some major waste exporter non-EU countries, 2015-2020. Source: own calculation based on Unctadstat.



The 20.3% recycling capacitiy increase predicted by the forecast if the policy is successful requires a lot of direct intervention. It is unclear how SPCE would like to achieve the 55% plastic packaging recycling goal, since the policy only incentivises private and public players to commit to more recycling, but has not announced any legal changes for incentivising building recycling capacities (European Commission 2018). Another issue is that building recycling facilities has substantial investment costs at first (Figure 4. A.), which might deter opening them upon a strong preference against risk. The European Commission is investing 100 million Euros to:

"drive investment towards resource-efficient and circular solutions, such as prevention and design options, diversification of feedstock and innovative recycling technologies such as molecular and chemical recycling, as well as the improvement of mechanical recycling; highlights the innovative potential of start-ups in this regard"(European Commission, 2018).

The concern is that a hundred million Euros might not be enough to incentivise the whole recycling sector, as it is simply too small on scale. Hence, the optimistic scenario of a major success of SPCE need to be taken with caution as well since political will for incentivising building the needed recycling capacities for achieving the benchmark plastic recycling goal of SPCE is limited.

Even if SPCE is moderately successful, further decreases in the environmental and social externalities are expected. If the policy fails, however, the increasing recycling capacities are driven by waste production alone, which means that environmental and social externalities will not change substantially compared to the status quo (Figure 6. d.). At the same time, even a moderate success would mean an additional 836 thousand tonnes recycling capacity increase by 2030, which still is substantially more than than if SPCE is not successful at all.

CEU eTD Collection

VI. Conclusion

The research forecasted and evaluated the effects of the European Strategy for Plastics in a Circular Economy (SPCE). Based on the results, SPCE seems to be feasible with limited external validity.

Regarding economic benefits, implementing SPCE means less outsourcing, which is beneficial to the receiving countries on the environmental and social level though less pollution from waste management through local logistics, dumping and incineration. It also means that while the import destinations might lose some of their revenue coming from participating in the waste trade, as the contemporary literature like Schindler & Demaria (2020) point out, lower imports also free local recycling capacities for managing locally produced waste.

Recycling capacities are estimated to increase by 20.6% by 2030 if the SPCE is successfully introduced. This means that the negative externalities of plastic waste management, especially plastic incineration are also reduced; implementing the policy is estimated to involve a yearly 14.1 million tonne reduction in CO2 emissions, which translates into a 14 000 drop in preventable mortality by 2030. Results are robust at scale.

Results indicate that if implemented, SPCE is may be feasible from various points of view – it contributes to reducing harmful emissions while also being profitable. However, results are weak on external validitiy – on the large scale, emission reductions due to the policy constitute only 0.17% of all CO2 emissions and 1.3% of total preventable mortality in the EU (Eurostat, n. d., b; latest data from 2017). Furthermore, there is no clear political will to adequately subsidise building the additionally required recycling capacities to reach the benchmark recycling rates. However, the realities of the current EU waste management practices limit the results, but also open up further research opportunities for assessing other specific economic policies within the Circular Economy Action Plan (CEAP) to assess its

CEU eTD Collection

overall impact on circular economy transition. Another further direction could be to explore what implications SPCE has on the exports of plastic waste importer countries. Nevertheless, the research provides some important insights for evaluating the feasibility of one of today's most ambitious circular economy transition policy.

CEU eTD Collection

VII. Bibliography:

VII. a. Data

Eurostat. (no date, a). *Generation of waste by waste category, hazardousness and NACE Rev. 2 activity*. [Data set]. Eurostat. https://ec.europa.eu/eurostat/databrowser/view/env_wasgen/default/table?lang=en
Eurostat. (no date, b). *Preventable and treatable mortality statistics*. [Data set]. Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Preventable_and_treatable_mortality_statistics
Eurostat. (no date, c). *Recycling rates of packaging waste for monitoring compliance with policy targets, by type of packaging*. [Data set]. Eurostat. https://ec.europa.eu/eurostat/databrowser/view/ENV_WASPACR__custom_2615144/default/table?lang=en
Unctadstat. (no date). *Plastics trade*. [Data set]. United Nations Conference on Trade and Development. https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx

VII. b. Literature

Althaf, S., Babbitt, C. W., & Chen, R. (2019). Forecasting electronic waste flows for effective circular economy planning. *Resources, Conservation and Recycling*, *151*, 104362. https://doi.org/10.1016/j.resconrec.2019.05.038
Álvarez, L., & Coolsaet, B. (2020). Decolonizing Environmental Justice Studies: A Latin American Perspective. *Capitalism Nature Socialism*, *31*(2), 50–69. https://doi.org/10.1080/10455752.2018.1558272
Andersen, F. M., Larsen, H., Skovgaard, M., Moll, S., & Isoard, S. (2007). A European model for waste and material flows. *Resources, Conservation and Recycling*, *49*(4), 421–435. https://doi.org/10.1016/j.resconrec.2006.05.011
Barboza, L. G. A., Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A.-K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin*, *133*, 336–348. https://doi.org/10.1016/j.marpolbul.2018.05.047
Blumm, M. C. (1992). Fallacies of Free Market Environmentalism, The. *Harvard Journal of Law & Public Policy*, *15*, 371.
Bowerman, B. L., & O'Connell, R. T. (1993). *Forecasting and Time Series: An Applied Approach*. Duxbury Press.
Bressler, R. D. (2021). The mortality cost of carbon. *Nature Communications*, *12*(1), 4467. https://doi.org/10.1038/s41467-021-24487-w
Calderoni, F., Favarin, S., Garofalo, L., & Sarno, F. (2014). Counterfeiting, illegal firearms, gambling and waste management: An exploratory estimation of four criminal markets. *Global Crime*, *15*(1–2), 108–137. https://doi.org/10.1080/17440572.2014.883499

CEU eTD Collection

Chu, J., Liu, H., & Salvo, A. (2021). Air pollution as a determinant of food delivery and related plastic waste. *Nature Human Behaviour*, *5*(2), 212–220. https://doi.org/10.1038/s41562-020-00961-1

DeLuca, L. (2017). *United Nations: Online data repositories and resources | DeLuca | College & Research Libraries News*. https://doi.org/10.5860/crln.78.1.9607

Demaria, F. (2010). Shipbreaking at Alang–Sosiya (India): An ecological distribution conflict. *Ecological Economics*, *70*(2), 250–260. https://doi.org/10.1016/j.ecolecon.2010.09.006

ENF Recycling Directory. (n.d.). *Plastic Material Recovery Facilities In Other Europe.* Retrieved May 30, 2022, from https://www.enfrecycling.com/directory/plastic-mrf/Other-Europe

European Commission *(2018) A European Strategy for Plastics in a circular economy. Thursday, 13 September 2018*. Retrieved May 16, 2022, from https://www.europarl.europa.eu/doceo/document/TA-8-2018-0352_EN.html

Faraca, G., & Astrup, T. (2019). Plastic waste from recycling centres: Characterisation and evaluation of plastic recyclability. *Waste Management*, *95*, 388–398. https://doi.org/10.1016/j.wasman.2019.06.038

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Giampietro, M. (2019). On the Circular Bioeconomy and Decoupling: Implications for Sustainable Growth. *Ecological Economics*, *162*, 143–156. https://doi.org/10.1016/j.ecolecon.2019.05.001

Gradus, R. H. J. M., Nillesen, P. H. L., Dijkgraaf, E., & van Koppen, R. J. (2017). A Cost-effectiveness Analysis for Incineration or Recycling of Dutch Household Plastic Waste. *Ecological Economics*, *135*, 22–28. https://doi.org/10.1016/j.ecolecon.2016.12.021

Grand View Research (n.d.). *Recycled Plastic Market Size & Share Report, 2030*. Retrieved May 28, 2022, from https://www.grandviewresearch.com/industry-analysis/recycled-plastics-market

Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How Circular is the Global Economy?: An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005. *Journal of Industrial Ecology*, *19*(5), 765–777. https://doi.org/10.1111/jiec.12244

Hansen, A. C., & Selte, H. K. (2000). Air Pollution and Sick-leaves. *Environmental and Resource Economics*, *16*(1), 31–50. https://doi.org/10.1023/A:1008318004154

European Parliament (2018a) *Plastic waste and recycling in the EU: facts and figures.* European Parliament. https://www.europarl.europa.eu/news/en/headlines/society/20181212STO21610/plastic-waste-and-recycling-in-the-eu-facts-and-figures

European Parliament. (2018b). *How to reduce plastic waste: EU strategy explained.* European Parliament. https://www.europarl.europa.eu/news/en/headlines/society/20180830STO11347/how-to-reduce-plastic-waste-eu-strategy-explained

Hyndman, R. J., Koehler, A. B., Snyder, R. D., & Grose, S. (2002). A state space framework for automatic forecasting using exponential smoothing methods. *International Journal of Forecasting*, *18*(3), 439–454. https://doi.org/10.1016/S0169-2070(01)00110-8

CEU eTD Collection

Jamasb, T., & Nepal, R. (2010). Issues and options in waste management: A social cost–benefit analysis of waste-to-energy in the UK. *Resources, Conservation and Recycling*, *54*(12), 1341–1352. https://doi.org/10.1016/j.resconrec.2010.05.004

Kellenberg, D. (2015). The Economics of the International Trade of Waste. *Annual Review of Resource Economics*, *7*(1), 109–125. https://doi.org/10.1146/annurev-resource-100913-012639

Krausmann, F. (2017). Social Metabolism. In *Routledge Handbook of Ecological Economics*. Routledge.

Lee, H., Yi, S.-M., Holsen, T. M., Seo, Y.-S., & Choi, E. (2018). Estimation of CO2 emissions from waste incinerators: Comparison of three methods. *Waste Management (New York, N.Y.)*, *73*, 247–255. https://doi.org/10.1016/j.wasman.2017.11.055

Lohmann, L. (2012). *Financialization, commodification and carbon: The contradictions of neoliberal climate policy* (Vol. 48).

Mujezinovic, D. (2020). *The global industrial metabolism of e-waste trade: A Marxian ecological economics approach*. 9542713 B, 370 pages. https://doi.org/10.17635/LANCASTER/THESIS/1137

Okaru, V. O. (1992). The Basel Convention: Controlling the Movement of Hazardous Wastes to Developing Countries. *Fordham Environmental Law Report*, *4*, 137.

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of The Total Environment*, *702*, 134455. https://doi.org/10.1016/j.scitotenv.2019.134455

Recycling International. (2018, October 29). *Malaysia bans import of plastic waste*. Recycling International. https://recyclinginternational.com/plastics/malaysia-to-ban-import-of-all-plastic-scrap-within-three-years/17628/

Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste, 190 OJ L (2006). http://data.europa.eu/eli/reg/2006/1013/oj/eng

Reschovsky, J. D., & Stone, S. E. (1994). Market incentives to encourage household waste recycling: Paying for what you throw away. *Journal of Policy Analysis and Management*, *13*(1), 120–139. https://doi.org/10.2307/3325093

Research & Markets. (2019). *Europe's Recycled Plastics Market 2019-2024: Market Projected to Reach a Volume of 12.8 Million Tons by 2024*. GlobeNewswire News Room. https://www.globenewswire.com/news-release/2019/09/13/1915436/28124/en/Europe-s-Recycled-Plastics-Market-2019-2024-Market-Projected-to-Reach-a-Volume-of-12-8-Million-Tons-by-2024.html

Reuters. (2021, March 31). Malaysia permits import of US plastic waste after it passes new UN treaty test. *New York Post*. https://nypost.com/2021/03/31/malaysia-permits-import-of-u-s-plastic-waste-shipment/

Schindler, S., & Demaria, F. (2020). "Garbage is Gold": Waste-based Commodity Frontiers, Modes of Valorization and Ecological Distribution Conflicts. *Capitalism Nature Socialism*, *31*(4), 52–59. https://doi.org/10.1080/10455752.2019.1694553

Sembiring, M. (2019). *Global Waste Trade Chaos: Rising Environmentalism or Cost-Benefit Analysis?* S. Rajaratnam School of International Studies. https://www.jstor.org/stable/resrep26804

CEU eTD Collection

Smiley, B. (2019, May 10). Duterte Threatens War With Canada Over Waste Dispute. *The Organization for World Peace*. https://theowp.org/duterte-threatens-war-with-canada-over-waste-dispute/

Song, Y., Wang, Y., Liu, F., & Zhang, Y. (2017). Development of a hybrid model to predict construction and demolition waste: China as a case study. *Waste Management*, *59*, 350–361. https://doi.org/10.1016/j.wasman.2016.10.009

Tsilemou, K., & Panagiotakopoulos, D. (2006). Approximate cost functions for solid waste treatment facilities. *Waste Management & Research*, *24*(4), 310–322. https://doi.org/10.1177/0734242X06066343

Verma, R., Vinoda, K. S., Papireddy, M., & Gowda, A. N. S. (2016). Toxic Pollutants from Plastic Waste- A Review. *Procedia Environmental Sciences*, *35*, 701–708. https://doi.org/10.1016/j.proenv.2016.07.069

Wang, W., Themelis, N. J., Sun, K., Bourtsalas, A. C., Huang, Q., Zhang, Y., & Wu, Z. (2019). Current influence of China’s ban on plastic waste imports. *Waste Disposal & Sustainable Energy*, *1*(1), 67–78. https://doi.org/10.1007/s42768-019-00005-z

CEU eTD Collection

VIII. Appendix:

VIII. a. Appendix A: Tables

Table 1. Variables used for the VAR forecast.

Name of the variable	Name	Time series span	Effective time series span	Source
Plastic waste trade volumes within EU countries	within_eu	1995-2020	2005-2018	Unctadstat
Plastic waste trade exports from EU to outside countries	outside_eu	1995-2020	2005-2019	Unctadstat
Within-EU recycling rates	env_waspacr	2005-2019	2005-2020	Eurostat
Within-EU plastic waste production	env_wasgen	2004-2018	2005-2021	Eurostat

Table 2. Variables used for the cost-benefit analysis.

Name of the variable	Name	Time series span	Effective time series span	Source
Preventable Mortality	prev_mort	2011-2019	2011-2019	Eurostat
CO2/tonne of incinerated plastics	CO2/Ton	Constant	Constant	Gradus et al., 2017
Landfilling rates	landfill	2010-2018	2010-2018	EC, 2018
Incineration rates	incineration	2010-2018	2010-2018	EC, 2018

Table 3. Lag structure of the three VAR models using multivariate Box-Jenkins method for minimising AIC.

Lag	*Major increase*	*Moderate increase*	*No increase*
0	44.04354	43.01418	43.60488
1	39.19818	36.58877	35.47494
2	39.08031	36.10832	33.71606
3	34.33398*	30.00844*	27.38841*

CEU eTD Collection

Tables 4, a-c. Autocorrelation tests for the respective lags for the three SPCE policy shock scenario.

Null hypothesis: No serial correlation at lag h.

a. Major increase scenario

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	224.3775	16	0.0000	5166374.	(16, 6.7)	0.0000
2	52.39268	16	0.0000	18.63888	(16, 6.7)	0.0004
3	38.45551	16	0.0013	6.494310	(16, 6.7)	0.0102
4	21.42236	16	0.1628	1.581704	(16, 6.7)	0.2817

b. Moderate increase scenario

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	68.09340	16	0.0000	13.00138	(16, 22.0)	0.0000
2	25.85320	16	0.0561	1.977993	(16, 22.0)	0.0687
3	42.54812	16	0.0003	4.586200	(16, 22.0)	0.0006
4	52.21701	16	0.0000	6.943533	(16, 22.0)	0.0000

c. No increase scenario

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	68.18773	16	0.0000	59.71041	(16, 6.7)	0.0000
2	49.70022	16	0.0000	15.24871	(16, 6.7)	0.0008
3	26.40582	16	0.0486	2.457022	(16, 6.7)	0.1206
4	21.86998	16	0.1474	1.648010	(16, 6.7)	0.2626

CEU eTD Collection

VIII. b. Appendix B: Figures

Figure 1: Plastic packaging recycling rate evolution before the introduction of SPCE. Source: Eurostat.

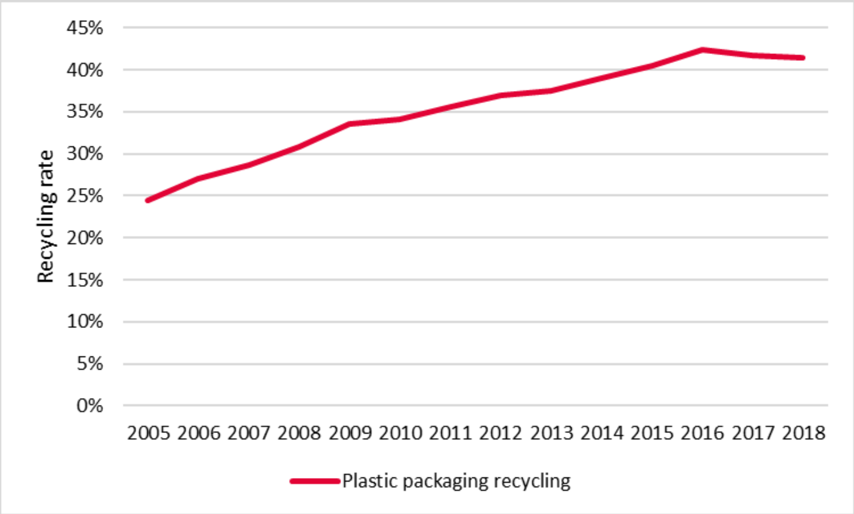
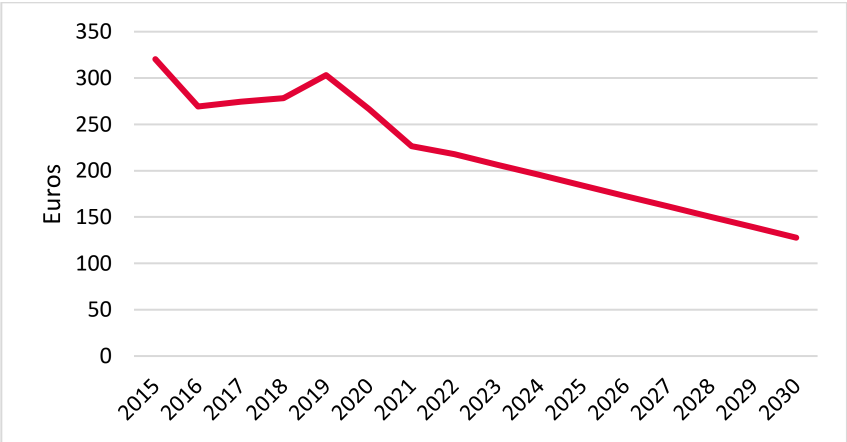


Figure 2: Price projection on the expected price of recycled plastic material, 2005-2030.



CEU eTD Collection

Figure 3: Reductions in incinerated plastic waste due to SPCE (Difference between the major increase and no increase scenarios).

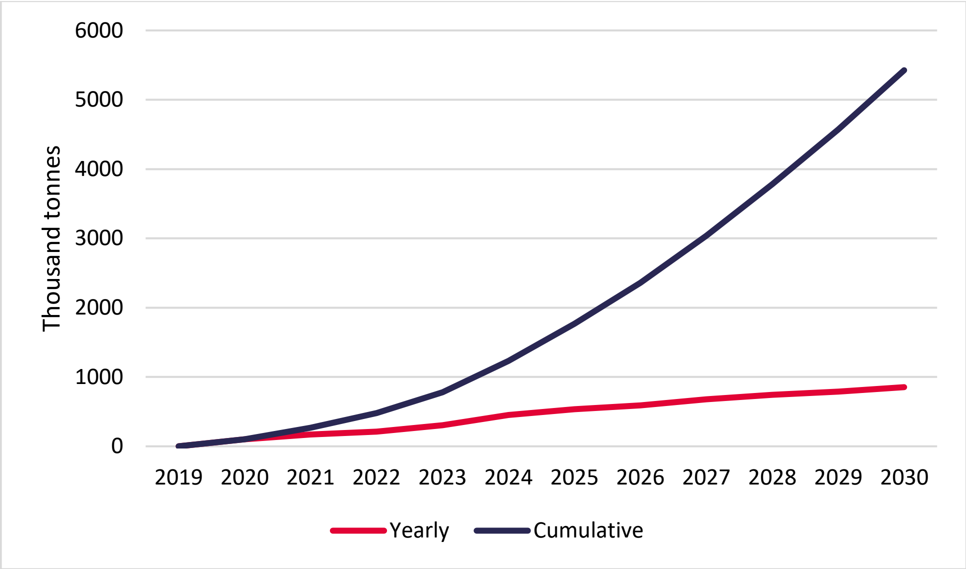
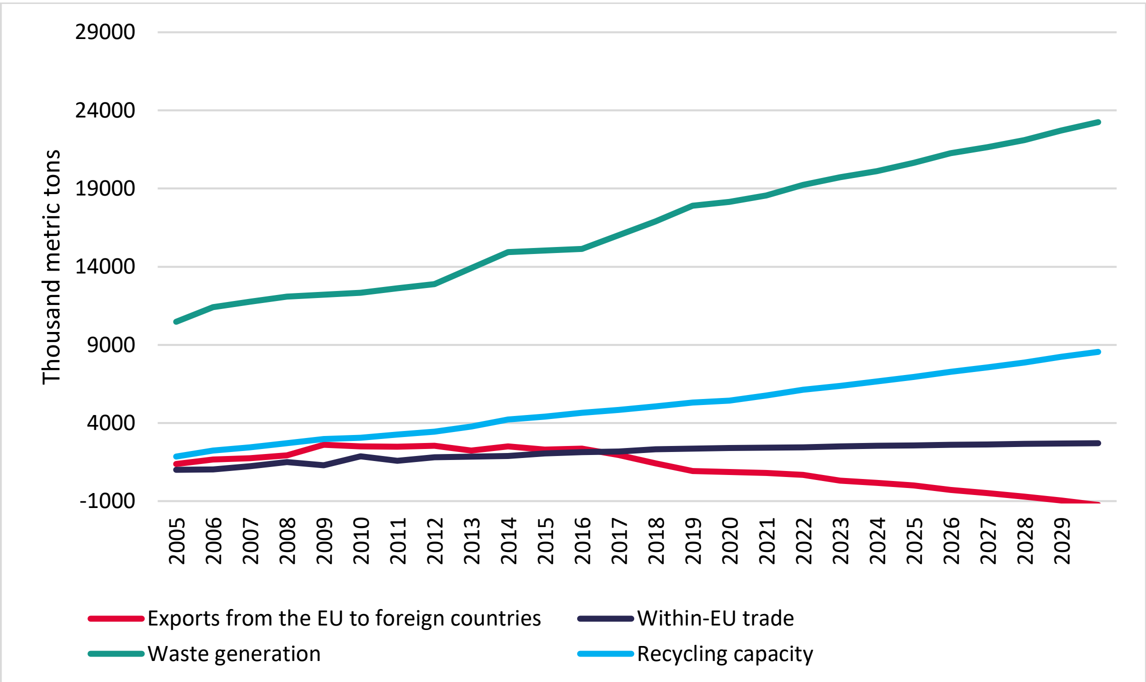
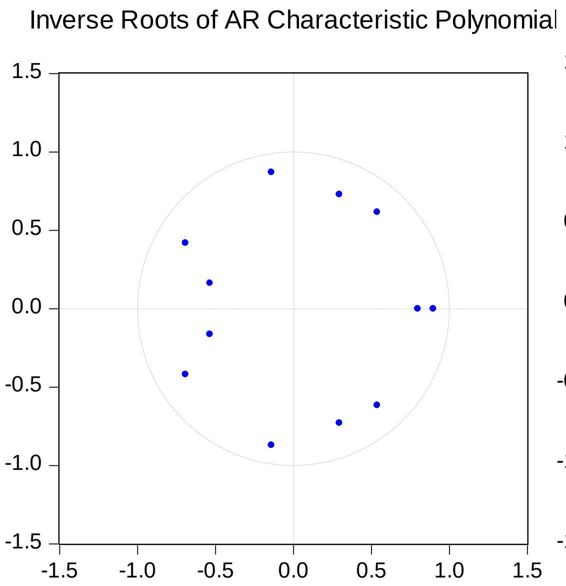


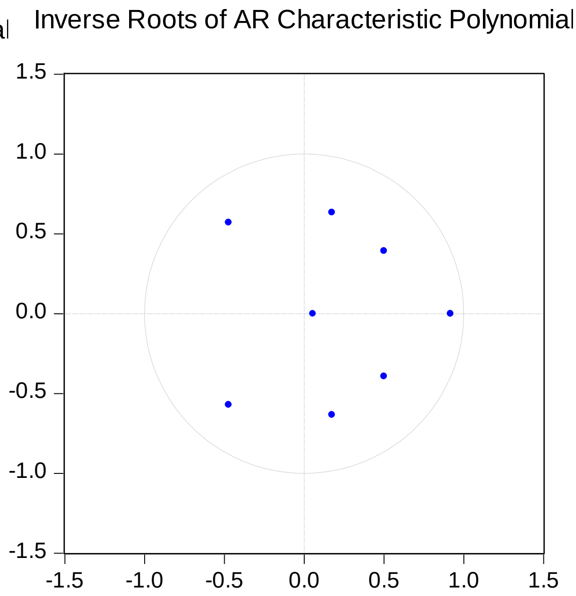
Figure 4. VAR forecast for the major increase scenario. Forecast starts from 2019.



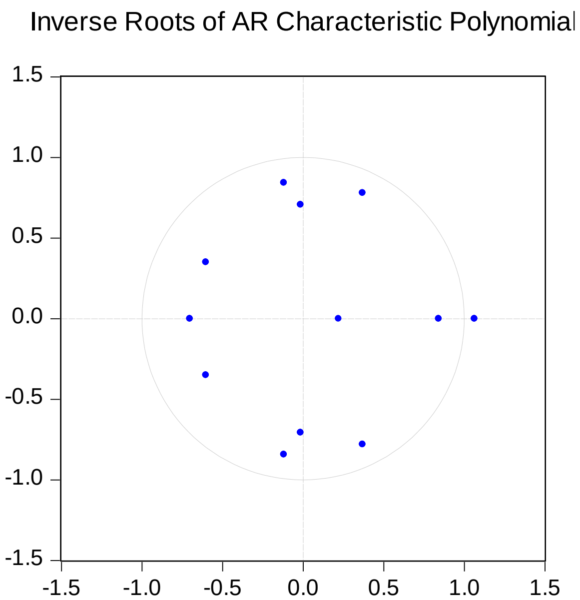
Figures 5, a-c. AR unit root graphs for the major increase scenario (a), moderate increase (b) and the no increase (c) scenarios.



(a)



(b)



(c)

CEU eTD Collection