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Taxing Away the Takeout Trash? Evidence from a local Packaging Tax in Germany

Stefan Moderau

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Taxing away the takeout trash?
Evidence from a local packaging tax in Germany*

Stefan Moderau[a]

[a]University of Tübingen, Nauklerstraße 47, 72074 Tübingen, Germany, stefan.moderau@uni-tuebingen.de

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Abstract

To decrease the amount of packaging waste in the public space and compensate for the disposal costs, the German city of Tübingen has introduced a tax in the amount of €0.50 on disposable takeout beverage and food containers in January 2022. No tax is levied if reusable cups or plates are used by the restaurants and snack bars subject to the tax. This is a unique policy experiment as no other city in Germany has implemented a takeout packaging tax during the period of this study. Using the synthetic control method, I identify appropriate control groups for Tübingen to compare the public waste quantity and the spread of reusable food containers. There is no significant reduction in the weight of the waste in public litter bins in Tübingen. This might be due to the fact that packaging subject to the tax is relatively light in weight compared to other items in the bins such as illegaly disposed household waste. On the other hand, the number of restaurants in Tübingen that offer reusable food and beverage containers increases sharply in the months before the intervention.

Keywords: Packaging tax, environmental taxes, reusable packaging, waste management, policy evaluation

JEL classification: H23, R11

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1 The experiment

The debate on how to tackle environmental problems in recent years has drawn attention to market-based policy instruments such as environmental taxes. While the aim of most taxes is to generate revenue without creating market distortions, environmental taxes are designed to correct market failures. They aim at internalizing negative environmental externalities through price adjustments that accurately reflect the environmental costs of a product or service (Hanson and Sandalow, 2006, p. 3). This concept goes back to Pigou (1920) and such taxes are therefore generally referred to as 'Pigouvian taxes'. Environmental problems connected to waste are the emissions caused by the production process and the pollution of water, air, and soil caused by improper waste disposal (Cabernard, Pfister, Oberschelp, and Hellweg, 2022; Umweltbundesamt, 2019).

The subject of this study are the steering effects of a tax on disposable takeaway food and beverage packaging (hereinafter referred to as packaging tax). This packaging tax came into force in the German city of Tübingen in January 2022. There have been packaging taxes in Germany in around 50 cities in the 1990s which were all abolished after a court ruling in 1998 (Städte- und Gemeindebund Nordrhein-Westfalen, 1998). However, in contrast to the current packaging tax in Tübingen, those taxes aimed at the packaging of food consumed at the restaurant itself and not the takeaway orders. In a legal essay on one of those abolished packaging taxes, Hedderich (1996) states that 95% of the restaurants affected declared in their tax return that they were no longer using single-use packaging. To the best of my knowledge, there is no other study that assesses the effects of a packaging tax that is intended to change the behavior of the final consumers. A related field of research found that the introduction of levies on plastic shopping bags significantly reduced their sales numbers (Dikgang, Leiman, and Visser, 2012; Martinho, Balaia, and Pires, 2017; Poortinga, Whitmarsh, and Suffolk, 2013).

The city where the treatment occurs, Tübingen, is a medium-sized town in the south of Germany with a population of around 90,000, including around 28,000 students at the University of Tübingen. Around 400 businesses such as snack bars, bakeries, and restaurants are subject to the tax. Importantly, no tax is levied if reusable cups or plates are used. Since the tax aims at the waste generated by takeaway meals and drinks, the consumption in a restaurant itself remains untaxed. Also, supermarkets are not subject to the tax as their products are usually consumed at home. The tax is fixed at €0.50 per disposable container such as a cup or a plate. Disposable cutlery is taxed at €0.20. To limit the impact on meals with several packagings, the maximum tax per order is limited to €1.50. If a business passes the packaging tax along to the consumers, i.e. increases its prices, the tax base of the value added tax (VAT) also increases.

The introduction of a packaging tax in Tübingen was first discussed publicly in May 2018 (see Figure 1). In January 2020, the local council of Tübingen passed a statute which would have put the tax into force in January 2021. However, to avoid additional burden for restaurant owners during the Covid-19 pandemic, the local council decided in July 2020 to postpone the introduction of the tax by one year to January 2022. At the end of March 2022, three months after the introduction of the tax, the Administrative Court of Baden-Württemberg declared the packaging tax statute invalid. However, the tax remains into force for now as the city of Tübingen appeals against the decision. The German Federal Administrative Court is expected to return a verdict in the coming year 2023.

Two goals were stated in the draft resolution for the packaging tax statute: First, the generation of tax revenues to make up for the costs of the city to empty the public litter bins and the subsequent disposal. Second, to reduce the amount of waste in the public space. The waste from the public litter bins is collected by city employees and a contractor and stored in a press container on the city's building yard. The container is driven to a waste disposal company once or twice a week. The city pays the disposal company a fixed amount per ton of waste delivered. According to the city administration, the yearly costs for the public litter bins amounted to a bit more than one million euros in 2018: 106 thousand euros

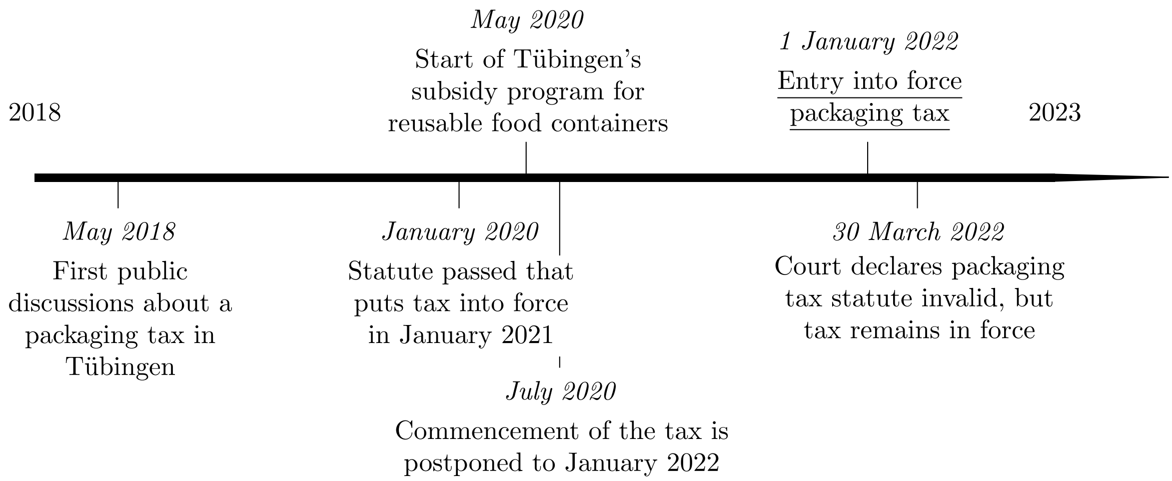

Figure 1: Events connected to the packaging tax in Tübingen.

paid to the disposal company and 918 thousand euros in labor costs. The administration estimates that in summer, around 80% of the public waste consists of packaging from takeout meals and drinks. No estimate is given for the other seasons (Universitätsstadt Tübingen, 2020). It can not yet be answered how much of these costs can be covered by the packaging tax revenue. The first tax collection by the city is planned for the beginning of the year 2023, after the businesses have filed their tax returns. My hypothesis for the waste quantity is:

H1: The introduction of the packaging tax in Tübingen will lead to a decrease of waste in the public space as measured by the amount of waste in public street litter bins.

The goal of the packaging tax is not to avoid the sale of takeout meals and drinks overall. Instead, the city of Tübingen wants the replacement of single-use packaging of takeout orders by reusable plates and cups. There are several young companies that have implemented systems of reusable cups and plates. These are either deposit-based or use a smartphone application to register the loan of a cup or plate. My hypothesis for the development of reusable food containers is:

H2: The packaging tax will lead to an increase in the number of restaurants and snack bars that offer reusable cups and plates for takeout orders.

A simple pre-post comparison of Tübingen to evaluate the effects of the packaging tax disregards other factors of influence such as the EU-wide ban on some single-use plastic items (Article 5 Single-Use Plastic Directive (EU) 2019/904). Since Tübingen is the only German city that implemented a packaging tax during the period of this study, I am able to set up control groups that consist of other German cities. I employ the synthetic control method (SCM) to identify sets of control cities for the waste quantity and the participation in reusable food container systems. The procedure to build the synthetic control is data-driven and uses both observations of the variable of interest and observations of fundamental characteristics of the cities. These are, among others, population density, mean age, and net commuters.

After one year of the packaging tax being in force, I find no evidence that supports H1. There is no decrease in the amount of waste in public litter bins in Tübingen. This is true for the comparison to previous years but also for the comparison to the synthetic control. The results do not rule out the possibility that less disposable takeout food containers were used. To measure the waste quantity, I observe the weight of the waste in public litter bins. Disposable plates and cups are usually light in weight and therefore the signal of a possible reduction might be too weak to see in the data. This is in line with prior analyses of the components of waste in public litter bins in German cities. The *INFA* institute reports that 33.7% in terms of volume but only 9.1% in terms of weight of public litter bin waste comes from single-use plastic packaging such as takeout food containers, takeaway cups, and carrier bags (Institut für Abfall, Abwasser und Infrastruktur-Management GmbH, 2020).

In addition, packaging for takeout food only makes up a small share of all packaging used in Germany. In a study for the Federal Environmental Agency of Germany, the weightwise share of paper cups in all paper and cardboard packaging is stated as 0.3%. Single-use plastic cups have a share of 0.6% of the weight of all plastic packaging (Umweltbundesamt, 2019). This suggests that a packaging tax can only be influential on the overall waste if it applies to more items than just takeaway cups and plates at snack bars. Since 99% of the overall packaging are not subject to the packaging tax, the possible impact is very limited. The considerable attention for takeaway packaging despite the limited overall relevance for the waste quantity is explained by two aspects: First, disposable cups and plates, if not adequately disposed of, spoil the cityscape. Second, the disposal of the takeaway packaging falls under the responsibility of the cities' cleaning departments, which are publicly funded (Umweltbundesamt, 2019).

To facilitate the introduction of reusable food container systems by takeout restaurants, Tübingen offers financial support. The program started already in May 2020 and reimburses up to 100% of the fees of return-refill systems to restaurants for up to one year. These system fees usually lie between €300 and €500 per year. In addition, up to €1000 but not more than 50% of the costs of a dishwasher for reusable containers are reimbursed by the city. A few other cities such as Freiburg im Breisgau and Marburg have also adopted support programs and reimburse system fees. Contrary to Tübingen, some of the other cities restricted the application period to a few months or set a maximum nubmer of supported restaurants.

To test H2, I observe both the number of takeout restaurants offering reusable cups and the number of takeout restaurants offering reusable plates. In both cases, there is a sharp increase in the count of partner restaurants in Tübingen in the last months of 2021, just before the packaging tax entered into force. The subsidy program for restaurants offering reusable food containers in Tübingen was also still in place during the time of that steep increase. But since the sharp increase occurs just before the introduction of the tax, H2 can be confirmed: The imminent packaging tax lead to a rise in the number of reusable container restaurants. This does not preclude that a similar increase of reusable container restaurants cannot be achieved solely through a subsidy program. Marburg, a city with similar demographics as Tübingen, has also achieved a steep growth of return-refill restaurants while having a subsidy program in place.

2 Literature

The packaging tax in Tübingen is the first tax applied on takeout food packaging in Germany, but there have been other packaging taxes before. In 1992, the city of Kassel introduced a local tax on single-use packaging for meals and drinks in the amount of 0.40 DM per cup and 0.50 DM per plate. Contrary to the tax in Tübingen, the packaging tax in Kassel was only applied on the consumption at the restaurant itself. Before the introduction of the tax, the city administration of Kassel identified 1200 businesses that were using single-use packaging. After a lead time of half a year between the publication of the packaging tax statute and its commencement, 95% of these businesses stated in their tax return that they were no longer using single-use packaging (Hedderich, 1996). In the following years, close to 50 German cities and municipalities imposed a tax on single-use packaging in Germany (Städte- und Gemeindebund Nordrhein-Westfalen, 1998). The Federal Constitution Court declared the packaging tax statute of Kassel invalid in 1998 because it infringed the federal waste law and all packaging taxes were abolished swiftly.

Prior economic research has used the introduction of environmental taxes and levies to investigate their steering effects. One subject under study which is close to food packaging are plastic shopping bags. Convery, McDonnell, and Ferreira (2007) find a significant change in consumer behavior after Ireland introduced a €0.15 levy on plastic shopping bags in 2002: Based on interviews with retail chain executives, they estimate that the number of plastic bags entering the consumption stream reduced by 94%. A similar levy on plastic bags as in Ireland was introduced in South Africa in 2003. Dikgang, Leiman, and Visser (2012) report a 44% reduction in the number of bags per purchase value of 1000 South African Rands. However, a large part of this reduction persisted only in the short term. Martinho, Balaia, and Pires (2017) surveyed customers near grocery stores and supermarkets in Portugal before and after the the introduction of a €0.10 tax on lightweight plastic bags in 2015. The average number of plastic bags per respondent per shopping trip reduced from 2.25 before the tax to 0.59 after the introduction. In return, the average number of reusable plastic bags increased from 0.31 to 0.50 per respondent per shopping trip. The introduction of a charge of five pence for each single-use carrier bag in Wales in 2011 was examined by Poortinga, Whitmarsh, and Suffolk (2013). Contrary to the other studies concerned with carrier bags presented above, the authors also set up a control group to account for general trends in the use of carrier bags. They conducted telephone surveys two weeks before and six months after the commencement of the Welsh single-use carrier bag charge both in Wales and England. The share of respondents bringing their own bag to the supermarket increased from 62% to 82% in Wales and from 61% to 73% in England. Thus, respondents stated to have increased their own bag use in both countries but the increase was greater in Wales. Nielsen, Holmberg, and Stripple (2019) provide an overview of 160 public policies on plastic carrier bags around the world which includes both bans (56%) and pricing mechanisms (32%).

Davis and Kilian (2011) look into historical changes of gasoline taxes from 1989 to 2008 in the U.S. on the state level and estimate their effect on gasoline consumption. By focusing on gasoline tax changes instead of the price of gasoline, the authors address the endogeneity of the gasoline price with respect to the demand. Also because of a violation of the exogeneity assumption, ad valorem taxes are excluded and only taxes that levy a fixed dollar amount per gallon of gasoline remain in the data. The authors' estimate for the change in gasoline consumption for a 10-cent gasoline tax increase is -1.43%.

Besides the environmental area, there are other taxes which are at least partly designed to achieve a steering effect. In a metastudy, Chaloupka, Yurekli, and Fong (2012) analyze over 100 studies concerned with behavioral responses to tobacco excise taxes. They find that tobacco taxes are an effective tool to reduce tobacco use and at the same time provide a reliable source of revenues for governments. Several studies investigate the effects of higher soft drink prices through taxes or fees on the consumption of soft drinks: Fletcher, Frisvold, and Tefft (2010) find that the soft drink taxation in the U.S. led to a moderate reduction in consumption between 1989 and 2006 among children and adolescents. Smith (2010) estimates the price elasticity of demand for sweetened beverages. Powell and Chaloupka (2009) conducted a metastudy on pricing policies of unhealthy food and obesity: When studies reported a significant association between food prices and weight outcomes, these effects were generally small in magnitude but higher for low socioeconomic status populations. In a more recent article, Allcott, Lockwood, and Taubinsky (2019) review principles that determine the socially optimal sugar-sweetened beverage tax: health systems costs from sugary drink consumption (externalities), internalities of sugary drink consumption, and how much financial burden the tax imposes on the poor (regressivity). Other studies investigating the effects of sugar-sweetened beverage taxes are Andreyeva, Chaloupka, and Brownell (2011), Sharma,

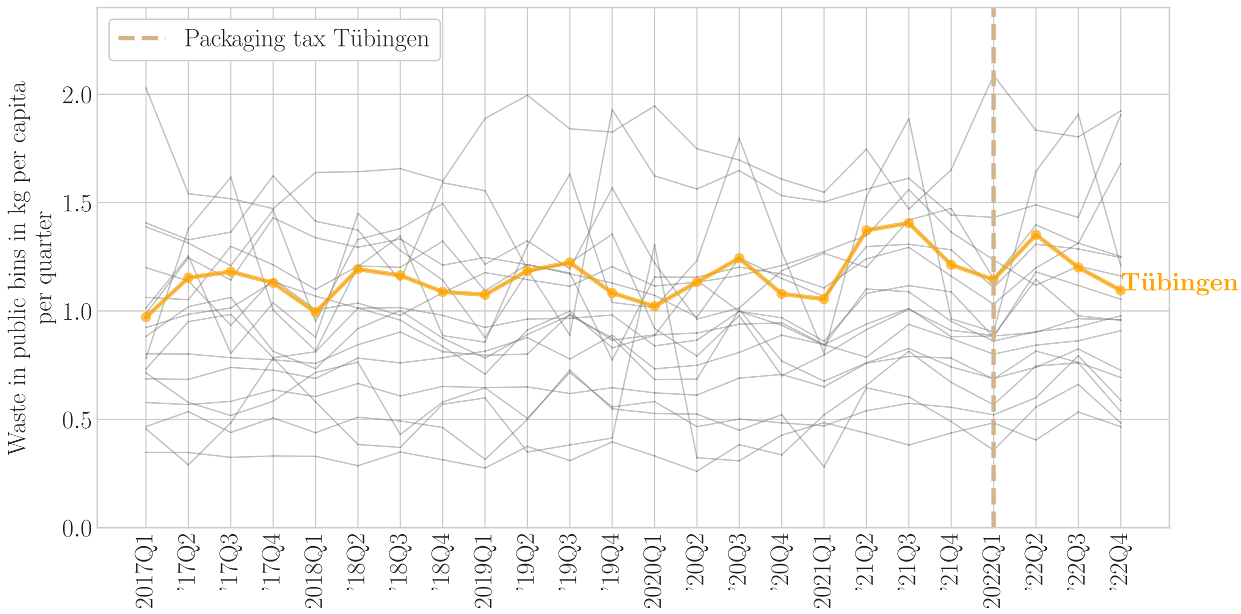

Figure 2: Visualization of the waste in kg per capita per quarter of the 19 cities in the sample from Q1 2017 to Q4 2022.

Hauck, Hollingsworth, and Siciliani (2014), and Cawley, Thow, Wen, and Frisvold (2019).

3 Data

To analyse the effects of the packaging tax, I rely on two data sets: First, the weight of the waste collected by Tübingen and other cities from public waste bins. Second, the participation of restaurants and snack bars in systems that offer reusable containers for foods and drinks.

3.1 Weight of the waste in public litter bins

The term *municipal waste* denotes waste mainly produced by households, commerce, offices, and public institutions. Agricultural and industrial waste are not included. The subject of this study, the waste collected from public litter bins, is part of the municipal waste category according to the definition by Eurostat (see recital 10 in Council of the European Union (2018)). Based on the cities in the sample, waste from public litter bins plays a minor role in overall municipal waste. For Tübingen, the average amount of waste from public litter bins is 1.16 kg per capita per quarter (see Table 8 in the Appendix). The overall municipal waste in Germany in 2020 was on average 175 kg per capita per quarter (Eurostat, 2022). Although the amount of waste in public bins and their proximity is small compared to overall municipal waste, it is worthwhile to study waste in the public space. Unclean neighborhoods are associated with an increased perception of risk (LaGrange, Ferraro, and Supancic, 1992) and a lower likelihood of physical activity (Shenassa, Liebhaber, and Ezeamama, 2006).

German cities usually commission their local public utility to manage the public litter bins. This includes the installation and maintenance of the bins and the regular waste collection. The waste is usually stored in a container on the municipal construction yard. From there it gets carted away daily, weekly, or monthly to a waste disposal company or directly to a waste incineration plant. The waste disposal companies charge the cities depending on the weight of the waste delivered. For the present study, I asked all cities with a population of more than 60,000 in the states of Baden-Württemberg,

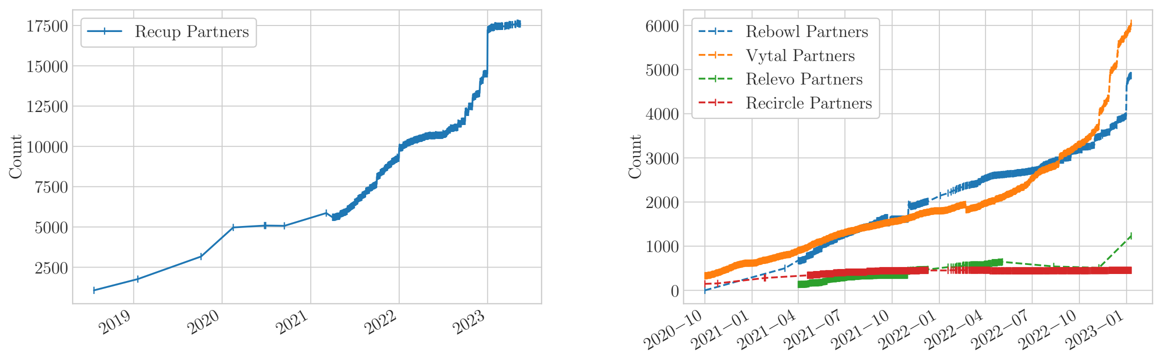

Figure 3: Partner count of *Recup* (left graph) and the four competitors for reusable food containers (right graph) in Germany. The values between the vertical line markers are interpolated. Canteens using the *Vytal* system are not included.

Bavaria, Hesse, Rhineland-Palatinate, Saarland, and Thuringia for the weight of their public litter bin waste. 19 cities, including Tübingen, out of 52 contacted cities were able to provide the required data. Among the cities which cannot provide data, the leading cause is that waste from public litter bins is not stored separately from waste collected from street sweepings. These especially include winter grit in spring and foliage in the fall.

To allow for a comparison between the cities, I calculate the waste in kg per capita. The yearly population data is sourced from the *Regionaldatenbank* online database and includes the number of inhabitants at the end of the year (Statistische Ämter des Bundes und der Länder, 2022). I use this number as the population number for the following year. In different specifications in this study, the waste quantities are aggregated to monthly and quarterly values. Some cities provide the exact dates of the waste deliveries. For these, I uniformly distribute the delivered waste among the delivery day and the previous days without a delivery. In doing so, deliveries at the beginning of a month (quarter) are partly allocated to the previous month (quarter). The sample starts in 2017 as some cities were not able to provide earlier data. Figure 2 shows the development of the quarterly waste quantity for the different cities in the sample. A seasonal pattern can be observed for Tübingen. There, more waste is recorded for the two warmer quarters Q2 and Q3 compared to Q1 and Q4 in every year since 2017.

3.2 Participation in return-refill systems

The market for reusable cups in Germany is dominated by one player (*Recup*) whereas four providers share the market for return-refill food containers (see Figure 3). All companies publish their partner facilities on either their websites or their smartphone applications so that consumers can find restaurants to buy food or drinks in reusable containers and give them back later. *Recup* and its associated division *Rebowl* as well as the *Recircle* system use a deposit scheme: the customer deposits €1 (*Recup*), €5 (*Rebowl*), or €10 (*Recircle*) at the restaurant and gets the deposit back after returning the container at any partner restaurant. *Vytal* and *Relevo* users record their borrowed containers in a smartphone app and have return them after a certain number of days. The market for return-refill systems has experienced substantial growth in the past years. This development could continue as all restaurants in Germany with a store area of more than 80 square meters are required to offer reusable food containers with the start of 2023 (Articles 33, 34 Verpackungsgesetz). However, it should be noted that the mere offering of reusable containers cannot be equated with the actual usage of those containers.

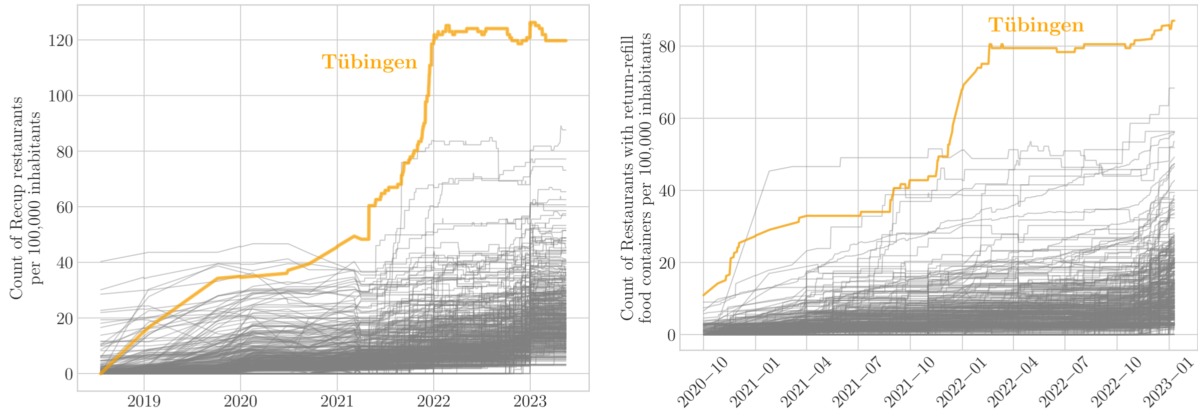

Figure 4: Left panel: Count of *Recup* restaurants per 100,000 inhabitants for 372 German cities, all with more than 30,000 inhabitants at the end of 2020. Right panel: Count of *Rebowl*, *Recircle*, *Relevo*, and *Vytal* restaurants per 100,000 inhabitants for 361 German cities, all with more than 30,000 inhabitants at the end of 2020.

The partner data was sourced from the company websites in the case of *Recup*, *Rebowl*, *Recircle*, and *Relevo*. For the time before April 2021, I rely on archived versions of the websites, provided by the digital library *Internet Archive*.[1] I interpolate the sum of return-refill partners for the periods between snapshots.

The start point for the reusable container analysis are all 399 German cities with a population of at least 30,000 at the end of the year 2020. After assigning the return-refill restaurants to the cities, 366 cities remain in the sample in the case of *Recup*. In the case of the food container restaurants, 302 cities remain in the data. To account for different city sizes, I compute the number of partner restaurants per 100,000 inhabitants. The population data is sourced from the state-run *Regionaldatenbank* online database (Statistische Ämter des Bundes und der Länder, 2022). Figure 4 shows the development of the number of return-refill restaurants per 100,000 inhabitants for German cities. For both categories, drinks and foods, Tübingen ranks highest as of January 2023. The strongest growth for *Recup* restaurants in Tübingen happened in the second half of 2021, just before the packaging tax entered into force in January 2022. For the case of reusable food container restaurants, a similar pattern can be observed: Here the strongest growth in Tübingen occured in November and December 2021. Tables A.3 and A.5 in the Appendix present summary statistics on the number of partner restaurants per city and regional demographic structures. The data on city demographics is sourced from the *Regionaldatenbank* database and the values refer to the year 2020 (Statistische Ämter des Bundes und der Länder, 2022).

4 Methodology and findings

A simple pre-post comparison of Tübingen to evaluate the packaging tax disregards other factors of influence. One factor possibly influencing both the public waste quantity and the participation in return-refill systems is the EU-wide ban of some single-use plastic items. Since July 2021, it is no longer allowed to market single-use plastic cutlery, plates, and swizzle sticks (Article 3 Einwegkunststoffverbotsverordnung). To account for this and other nationwide factors, I compare the developments in Tübingen to those of appropriate control groups. I employ the synthetic control method to identify sets of control cities for

[1] `https://archive.org/web/`. Note that not all archived snapshots of the websites include the partner data. Before downloading partner data from a snapshot it should therefore be checked if the partner data in that snapshot really is from the same date as the snapshot. This check can be done with the timestamp at the end of the HTML file.

the waste quantity and return-refill system participation.

The synthetic control method is frequently applied in comparative case studies in Economics. Its central idea is that the control unit is a weighted combination of several unaffected units, hence the name *synthetic*. Tübingen has recently been the subject of a study employing the synthetic control method: Diederichs, Glawion, Kremsner, Mitze, Müller, Papies, Schulz, and Wälde (2022) investigate a large-scale CoV-2 rapid testing program which was combined with the lifting of lockdown measures in March and April 2021. In their main specification, they build a synthetic control for Tübingen county, while I focus on Tübingen city. The procedure to build the synthetic control is data-driven and uses both observations of the variable of interest and observations of fundamental characteristics of the cities. It is important to note that only pretreatment observations can be used in the generation of the synthetic control (Abadie, 2021). I use R with its package *tidysynth*, written by Dunford (2021), to generate the synthetic controls for the different units of outcome of this study. I use the following expression:

$$\sum_{m=1}^{k} v_m \left(X_{1m} - \sum_{j=2}^{J+1} w_j X_{jm} \right)^2 \tag{1}$$

The number of cities in the sample is $J+1$ whereas Tübingen is the first unit ($j = 1$). For each city j, there is a k x 1 vector of predictors. In the present study, predictors are both demographic characteristics of the cities and preintervention values of the variable of interest itself, e.g. the weight of the waste in public litter bins. X_{1m} is the value for the m-th predictor for Tübingen and X_{jm} is the value for the m-th predictor for city j. w_j is the weight of the city j in the synthetic control. The choice of the weights defines the synthetic control and the weights are found by minimizing the expression with the restriction that the weights are non-negative and sum to one. v_m reflects the relative importance of the m-th predictor in determining the synthetic control. Following Abadie and Gardezabal (2003), the predictor weights $\mathbf{v} = (v_1, ..., v_k)$ are chosen such that the mean squared prediction error in the pretreatment period is minimized.

4.1 Synthetic control to evaluate the waste quantity

Does the introduction of the packaging tax impact the public waste quantity in Tübingen? The variable of interest to answer this question is the weight of the waste in public litter bins, aggregated to monthly values.[2] The year 2021 serves as validation period. Thus, all months of 2021, the year before the packaging tax entered into force, are not included in the process of building the synthetic control. Table 1 lists the composition of the synthetic control. As Tübingen, the cities of Freiburg im Breisgau, Heidelberg, and Konstanz are also located in the state of Baden-Württemberg and home to large universities. Landshut is located in Bavaria and also features a college student population, albeit smaller in terms of share of the total population. The population figures of the four cities with a relevant share lie in the range of 72 thousand (Konstanz) to 230 thousand (Freiburg im Breisgau). Table 6 in the Appendix shows the fit of the synthetic control with regard to the variables used to build the synthetic control.

Figure 5 presents the trajectories of the relative waste quantities for Tübingen and its synthetic control. The waste quantities show a similar development before the intervention. A good pretreatment fit is also prevalent in the validation period, indicating that the synthetic control is an appropriate control group. The packaging tax entering into force at the start of 2022 marks the intervention. In the first six months of 2022, the waste quantity of Tübingen is slightly higher than the waste quantity of the synthetic control. This reverses in the second half of 2022, where the waste quantity of Tübingen is slightly lower. However, the differences in the waste of Tübingen and the synthetic control after the intervention are not

[2]See Appendix A.2 for the analysis with quarterly values.

City	Weight
Landshut	0.331
Freiburg im Breisgau	0.279
Heidelberg	0.195
Konstanz	0.173
Pforzheim	0.021
Offenburg	0.001

Table 1: Control cities and weights for Figure 5 (weight of the waste in public bins).

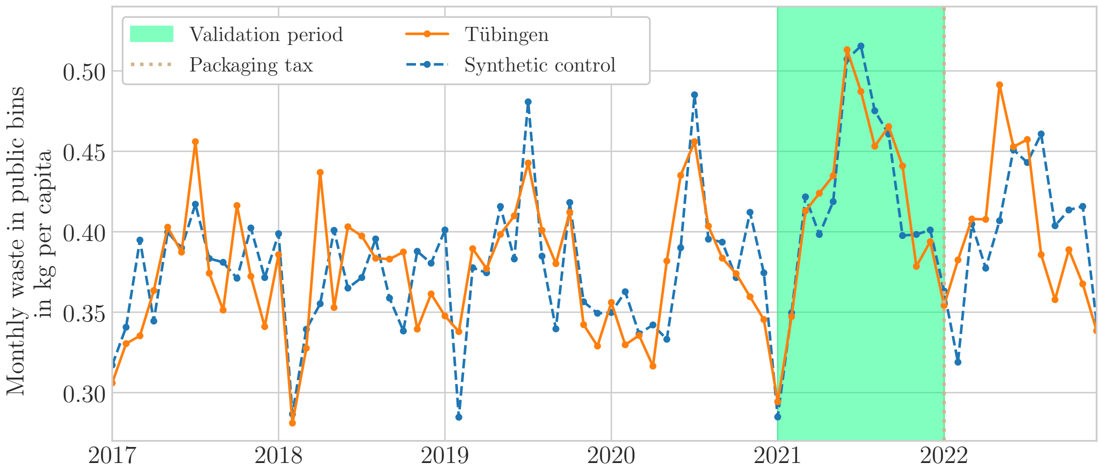

Figure 5: Comparison of Tübingen and the synthetic control with regard to the monthly waste in kg per capita. No observations from 2021 are used to build the synthetic control (validation period).

significantly different from the differences before the intervention. A discussion about possible reasons for why no reduction in the waste quantity occurs follows hereinafter.

One might ask how much of the waste in public litter bins is actually subject to the packaging tax. The German consultancy *INFA*, specialized on waste processing, investigated the composition of the public waste in 13 German cities (Institut für Abfall, Abwasser und Infrastruktur-Management GmbH, 2020).[3] In the case of medium-sized towns (population of 20,000 to 100,000), 33.7% of the volume of the waste in public street litter bins comes from single-use plastic packaging such as takeout food containers, takeaway cups, and carrier bags. Yet in terms of weight, these single-use plastic packaging stand for only 9.1% of the waste. The authors also quantify the share of a second group, namely packaging made of glass, cardboard, and metal. This group accounts for 30.3% in terms of weight and 30.5% in terms of volume of the waste in public street litter bins of medium-sized towns. It is unclear how much of these metal and cardboard items would fall under the packaging tax. A large share of the glass items however, are likely not subject to the packaging tax for the following reason: First, beer and lemonade is mostly sold in bottles with refundable deposit in Germany. Second, glass bottles without refundable deposit such as bottles of liquor are sold in supermarkets which are not subject to the packaging tax. It is not stated by the authors how much of the weight of the cardboard, metal, and glass waste group comes from glass. But the proportion could be large as glass bottles have a significantly higher weight compared to cardboard and aluminum items of similar volume.

Another examination of the composition of waste from public litter bins was conducted by the *bifa* institute (Bayerisches Institut für Angewandte Umweltforschung und -technik, 2020). The report states that 18.8% of the weight of the waste in public litter bins in Augsburg comes from single-use paper dishes, other packaging made of paper, and cardboard. On the other hand, 25.8% of the weight of the waste

[3]Tübingen is not part of the sample of the *INFA* study.

comes from glass, predominantly bottles for alcoholic beverages. Whereas the first group likely contains mostly items subject to the packaging tax, the second group including glass, as described above, does not fall under the packaging tax for the most part. Thus, the lower estimates for the share of the weight of waste in public litter bins being subject to the packaging tax are 9.1% (concluded based on the *INFA* study) and 18.8% (concluded based on the *bifa* study).

To gather anecdotal evidence about the composition of the waste in Tübingen's public litter bins, I accompanied an employee tasked with the waste collection for one day. Large parts of the waste were indeed not subject to the packaging tax. Among the items we frequently encountered were glass bottles and illegally disposed of bags of household waste.

A drawback of the present study is that I only analyze the weight of the waste and not the volume of different sorts of waste. Therefore, even if a reduction in single-use packaging might be present, the signal might be too weak to be significant. Lastly, one might also speculate about possible reasons for an increase in the waste in public litter bins after the introduction of a packaging tax. A possible explanation could be that some citizens disapprove the new tax and dispose of waste in public litter bins even more because they might feel that they have paid for this service with the packaging tax. However, this hypothesis needs to be investigated separately.

4.2 Synthetic control to evaluate the participation in return-refill systems

As visible in Figure 4, Tübingen has been among the highest-ranking cities in terms of return-refill restaurants since 2019. But extreme values in the variable of interest of the treated unit cannot be replicated by a weighted average of the control units. One possibility to approximate the trajectory of Tübingen would be to allow for extrapolation by lifting the convex combination restriction, i.e. no longer requiring that the weights of the control units are non-negative and sum to one. However, this comes at the cost of reduced transparency (Abadie, 2021) and overfitting. Therefore, I follow an approach proposed by Ferman and Pinto (2021) and demean the return-refill restaurant counts using information from the preintervention period. Thus, the posttreatment outcomes are measured in differences to the preintervention means.

City	Weight
Erlangen	0.578
Winsen (Luhe)	0.298
Heidelberg	0.123

Table 2: Control cities and weights for Figure 6 (*Recup*).

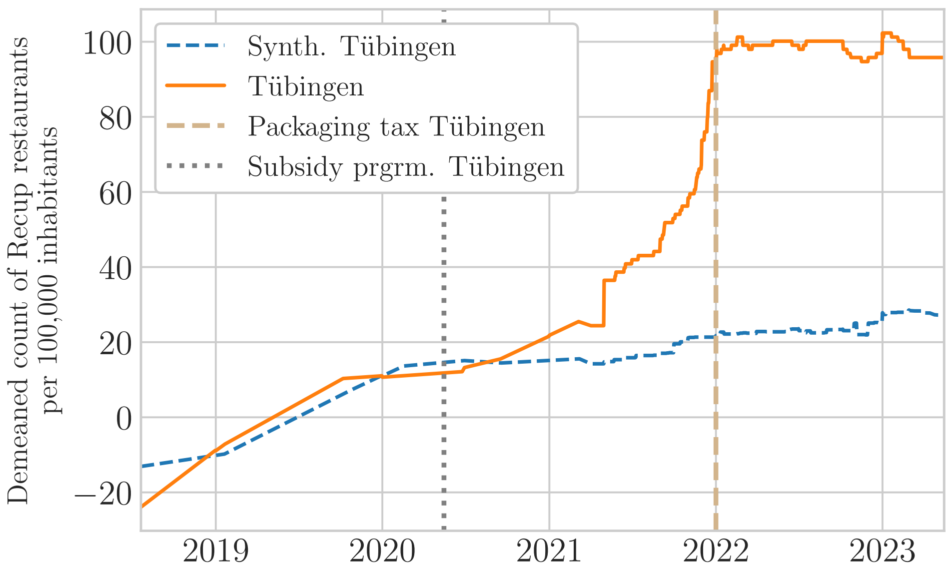

Figure 6: Comparison of Tübingen and the synthetic control with regard to the demeaned *Recup* restaurant count per 100,000 inhabitants. The lines for Tübingen and its control can be read as the difference in the partner count with respect to its preintervention mean. The intervention is set to May 2020 to account for the subsidy program by Tübingen put in place back then.

The packaging tax in Tübingen entered into force on January 1, 2022 and no other German city adopted such a tax during the period of investigation. In the case of return-refill system participation, it can be expected that at least some restaurants anticipated the tax introduction and already became part of a system several months earlier. Besides the tax, Tübingen promoted the introduction of reusable containers by restaurants with subsidies since May 2020. Therefore, it is unclear if the top position of Tübingen in terms of reusable container restaurants (see Figure 4) stems from the financial support program, the packaging tax, or a combination of both. In a first step, I try to find the combined effect of both the packaging tax and the subsidy program for the *Recup* partner count dataset. Therefore, I date the first intervention to May 15, 2020, the day when the subsidy program of Tübingen was published. To the best of my knowledge, only six other cities in the sample adopted a financial support program similar to that in Tübingen until the end of 2021. I exclude these cities (Bad Hersfeld, Fulda, Freiburg im Breisgau, Lübeck, Marburg, Rostock) from the control group for the evaluation of the combined effects of the packaging tax and the subsidies.[4] Thereby, I follow Abadie (2021) who suggests to drop those units from the donor pool that experience large idiosyncratic shocks that would not have affected the outcome of the unit of interest in the absence of the intervention. Figure 6 shows the comparison of Tübingen and its synthetic control, which is made up of the cities listed in Table 2. Aside from six lags at intervals of 30 days of the demeaned *Recup* partner count per 100,000 inhabitants, the sociodemographic variables listed in Table A.3 in the Appendix are used to match Tübingen as closely as possible. The outcome depicted in Figure 6 confirms the observation from Figure 3 that Tübingen was successful in establishing restaurants that offer reusable beverage containers. This development accelerated especially in the six months before the introduction of the packaging tax.

The data on the partner count of the four food container systems starts in October 2020. At this time, the financial support program in Tübingen described in the previous paragraph was already in place and therefore the food bowl partner count data is not suitable to evaluate the total combined effects of the subsidies and the packaging tax. There is also no other city in Germany that adopted a financial support

[4]In addition, four cities are dropped because only limited *Regionaldatenbank* data is available.

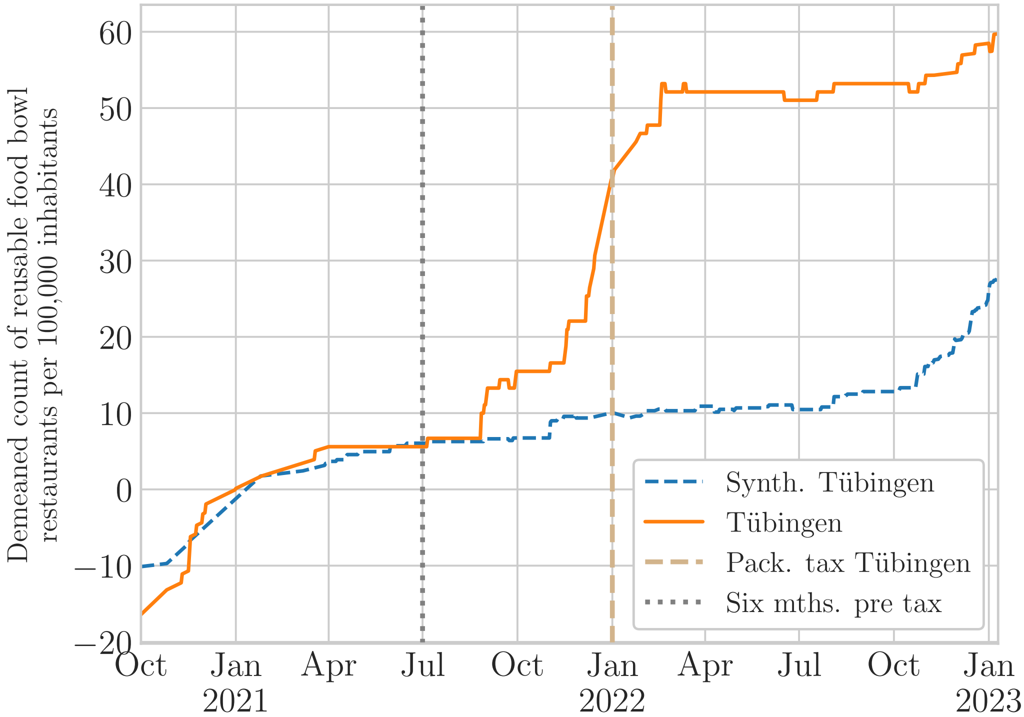

Figure 7: Comparison of Tübingen and the synthetic control with regard to the demeaned reusable food container restaurant count per 100,000 inhabitants. Six cities adopting subsidy programs for reusable containers are excluded from the sample. Included providers are *Rebowl*, *Recircle*, *Relevo*, *Vytal*.

program for reusable containers in 2020 and kept it in place until the packaging tax entered into force. For these reasons, I try to evaluate the effect of an *imminent* packaging tax combined with a subsidy program on return-refill system participation. To this end, I set the intervention to July 1, 2021, six months before the tax coming into force. The six cities adopting a subsidy program at some time are again excluded. The number of restaurants per 100,000 inhabitants is again demeaned using the preintervention mean. Also, six lags of the unit of interest at intervals of 30 days and the sociodemographic factors again make up the predictor set. Table 3 presents the composition for the synthetic control for the count of return-refill food bowl restaurants. Figure 7 depicts the outcome and shows that the combination of an imminent packaging tax and a generous subsidy program is extremely effective in promoting the offering of reusable food containers by restaurants. Table A.5 in the Appendix shows the descriptive statistics of the variables used in the food bowl partner analysis.

City	Weight
Gießen	0.320
Heidelberg	0.264
Kirchheim unter Teck	0.245
Bamberg	0.170

Table 3: Control cities and weights for Figure 7 (Food bowls).

The previous analyses have evaluated the combined effect of a packaging tax and a subsidy program being in place. However, as the main growth in Tübingen occurs in the last months of 2021, just before the commencement of the tax, the tax was likely the key driving factor. This is supported by the fact that the subsidy program was already in place for more than one year when the stark growth occurred.

But it may still be worthwhile to repeat the analysis with only the six cities that also adopted a subsidy program in the donor pool. The synthetic Tübingen in this case only consists of Marburg. Marburg has a population size and sociodemographic factors similar to those of Tübingen. A program in which the city fully refunded return-refill system fees for one year was put in place in July 2021 with an application period of only 1.5 months. Figure A.7 in the Appendix shows the outcome of the evaluation. The effect of the subsidy program in Marburg is clearly visible. In addition, new return-refill restaurants were added in Marburg in April 2022. The reusable food bowl partner count in Tübingen with respect to its preintervention mean is still higher as the value of this measure is for Marburg. But the difference only amounts to five restaurants per 100,000 inhabitants with respect to the preintervention mean. Thus, while in Tübingen the key driving factor for the rise of return-refill restaurants was the packaging tax, a similar increase was achieved by Marburg through a subsidy program.

5 Conclusion

As the only city in Germany, Tübingen has introduced a packaging tax on takeaway food containers in January 2022. This study evaluates the effects of this tax on the weight of the waste in public litter bins and the number of restaurants offering reusable cups and plates. Control groups are constructed using the synthetic control method (SCM). There is no reduction of the weight of the waste per capita in public litter bins for Tübingen in the year 2022. Waste analyses conducted by previous studies in other German cities indicate that the share of the items in public litter bins being subject to the packaging tax is low. Thus, even if there is a reduction in single-use packaging, the signal might be too weak to see in the data. With regard to the number of restaurants that offer reusable packaging options, Tübingen now ranks highest in Germany on a per capita basis. This applies for both reusable cups and reusable plates. The sharpest increase in the number of return-refill restaurants in Tübingen happened in the months before the commencement of the packaging tax. This indicates that the packaging tax, and not a subsidy program for restaurants introduced in 2020, was the main reason for the growth in Tübingen.

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A Appendix

A.1 Summary statistics for the waste quantity analysis, aggregated by months

in waste per kg per capita per month	Mean	S.D.	Min.	Max.
Darmstadt	0.34	0.11	0.06	0.66
Erfurt	0.15	0.06	0.08	0.30
Esslingen am Neckar	0.26	0.04	0.15	0.37
Frankfurt am Main	0.22	0.03	0.16	0.32
Freiburg im Breisgau	0.39	0.06	0.26	0.54
Fulda	0.43	0.11	0.22	0.78
Heidelberg	0.32	0.05	0.20	0.44
Jena	0.17	0.05	0.06	0.31
Kempten (Allgäu)	0.32	0.07	0.10	0.44
Konstanz	0.42	0.14	0.14	0.73
Landshut	0.39	0.06	0.26	0.55
Ludwigsburg	0.40	0.07	0.17	0.59
München	0.16	0.09	0.09	0.53
Offenburg	0.19	0.67	0.04	0.36
Pforzheim	0.58	0.11	0.30	0.86
Reutlingen	0.29	0.04	0.18	0.39
Saarbrücken	0.28	0.05	0.12	0.38
Schwäbisch Gmünd	0.49	0.10	0.27	0.83
Tübingen	0.39	0.05	0.28	0.51

Table 4: Descriptive statistics on the waste in kg per capita per month of the 19 cities in the sample from 2017 to 2022.

	Mean	S.D.	Min.	Max.
A: Waste in public litter bins (in 19 cities)				
Weight of the waste in public litter bins in kg per capita per month	0.33	0.14	0.04	0.86
B: Regional demographic structure (of 19 cities)				
Average age of the population (in years)	42.23	1.46	39.15	44.10
Female share in the population (in %)	50.91	0.81	49.08	52.36
Population density (inhabitants/km^2)	1447.1	991.12	507.0	4789.8
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	76.91	7.35	61.05	90.17
Employment rate (in %)	59.39	5.22	48.77	65.18
Average distance to supermarket (in meter)	555.1	150.35	329.0	901.0
Population density (inhabitants per km^2 settlement & traffic area)	3768.0	1086.5	2130.0	6377.0
Net migration ((influx - outflux) per 1000 of population)	4.08	3.42	-0.24	14.07
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	27.78	11.98	5.00	49.57
Students (students per 100 inhabitants aged 18 to 25)	138.03	72.12	55.37	326.78

Table 5: Descriptive statistics for the monthly waste quantity analysis depicted in Figure 5.

	Tübingen	Synthetic Tübingen	Donor sample
Average age of the population (in years)	39.15	41.61	42.40
Female share in the population (in %)	52.36	51.76	50.83
Population density (inhabitants/km^2)	842.84	1280.58	1480.72
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	88.22	80.31	76.28
Employment rate (in %)	50.72	55.42	59.87
Average distance to supermarket (in meter)	635.00	509.78	550.67
Population density (inhabitants per km^2 settlement & traffic area)	3685.84	4133.90	3772.99
Net migration ((influx - outflux) per 1000 of population)	7.94	6.54	3.87
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	32.77	24.98	27.50
Students (students per 100 inhabitants aged 18 to 25)	198.60	116.42	134.66
Weight waste public litter bins per month 2019-1	0.35	0.40	0.34
Weight waste public litter bins per month 2019-2	0.34	0.28	0.27
Weight waste public litter bins per month 2019-3	0.39	0.38	0.30
Weight waste public litter bins per month 2019-4	0.38	0.37	0.34
Weight waste public litter bins per month 2019-5	0.40	0.42	0.31
Weight waste public litter bins per month 2019-6	0.41	0.38	0.32
Weight waste public litter bins per month 2019-7	0.44	0.48	0.38
Weight waste public litter bins per month 2019-8	0.40	0.38	0.32
Weight waste public litter bins per month 2019-9	0.38	0.34	0.29
Weight waste public litter bins per month 2019-10	0.41	0.42	0.34
Weight waste public litter bins per month 2019-11	0.34	0.36	0.30
Weight waste public litter bins per month 2019-12	0.33	0.35	0.35
Weight waste public litter bins per month 2020-1	0.36	0.35	0.35
Weight waste public litter bins per month 2020-2	0.33	0.36	0.32
Weight waste public litter bins per month 2020-3	0.34	0.34	0.30
Weight waste public litter bins per month 2020-4	0.32	0.34	0.27
Weight waste public litter bins per month 2020-5	0.38	0.33	0.30
Weight waste public litter bins per month 2020-6	0.44	0.39	0.32
Weight waste public litter bins per month 2020-7	0.46	0.49	0.36
Weight waste public litter bins per month 2020-8	0.40	0.40	0.31
Weight waste public litter bins per month 2020-9	0.38	0.39	0.31
Weight waste public litter bins per month 2020-10	0.37	0.37	0.30
Weight waste public litter bins per month 2020-11	0.36	0.41	0.34
Weight waste public litter bins per month 2020-12	0.35	0.37	0.28

Table 6: Pretreatment predictor balance for the monthly waste quantity analysis presented in Figure 5.

A.2 Synthetic control for the waste quantity, aggregated by quarter

City	Weight
Freiburg im Breisgau	0.315
Landshut	0.273
Konstanz	0.204
Heidelberg	0.197
Fulda	0.011

Table 7: Control cities and weights for Figure 8 (weight of the waste in public bins, aggregated to quarterly values).

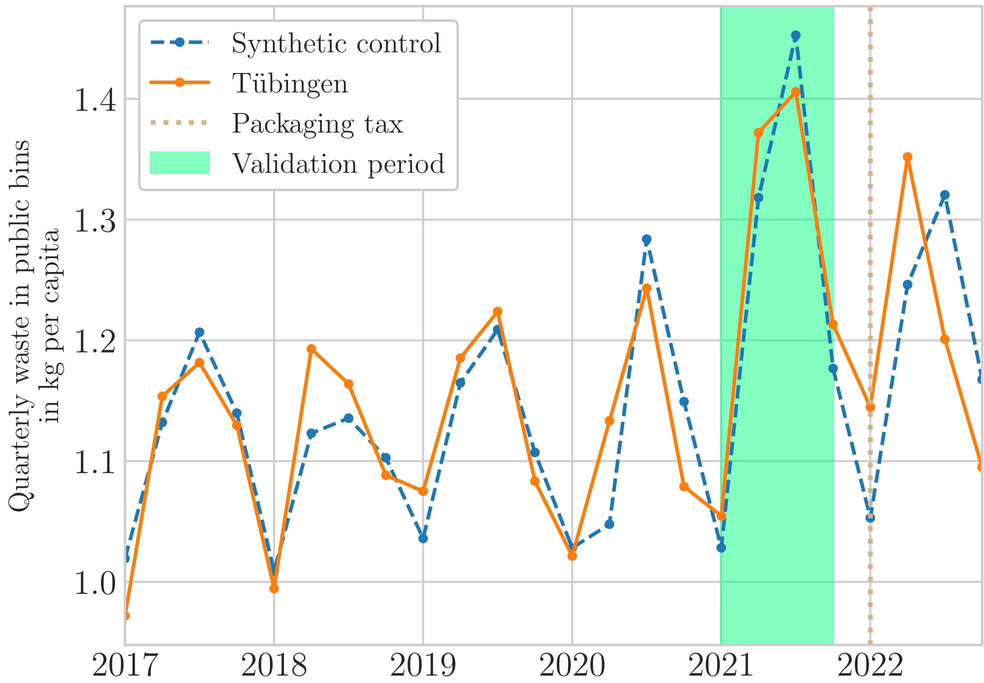

Figure 8: Comparison of Tübingen and the synthetic control with regard to the quarterly waste in kg per capita.

in waste per kg per capita per quarter	Mean	S.D.	Min.	Max.
Darmstadt	1.02	0.19	0.70	1.45
Erfurt	0.44	0.17	0.26	0.81
Esslingen am Neckar	0.80	0.07	0.68	0.94
Frankfurt am Main	0.67	0.07	0.57	0.81
Freiburg im Breisgau	1.18	0.10	0.97	1.32
Fulda	1.30	0.18	0.95	1.68
Heidelberg	0.97	0.08	0.84	1.14
Jena	0.50	0.10	0.28	0.73
Kempten (Allgäu)	0.95	0.13	0.71	1.18
Konstanz	1.25	0.36	0.78	1.91
Landshut	1.17	0.13	0.93	1.56
Ludwigsburg	1.20	0.13	0.77	1.43
München	0.49	0.21	0.29	1.31
Offenburg	0.58	0.10	0.43	0.79
Pforzheim	1.74	0.18	1.47	2.09
Reutlingen	0.87	0.07	0.76	1.01
Saarbrücken	0.83	0.12	0.68	1.06
Schwäbisch Gmünd	1.48	0.22	0.89	1.93
Tübingen	1.16	0.11	0.97	1.41

Table 8: Descriptive statistics on the waste in kg per capita per quarter of the 19 cities in the sample from Q1 2017 to Q2 2022.

	Mean	S.D.	Min.	Max.
A: Waste in public litter bins (in 19 cities)				
Weight of the waste in public litter bins in kg per capita per quarter	0.98	0.38	0.26	2.09
B: Regional demographic structure (of 19 cities)				
Average age of the population (in years)	42.23	1.46	39.15	44.10
Female share in the population (in %)	50.91	0.81	49.08	52.36
Population density (inhabitants/km^2)	1447.1	991.84	507.0	4789.8
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	76.91	7.35	61.05	90.17
Employment rate (in %)	59.39	5.23	48.77	65.18
Average distance to supermarket (in meter)	555.1	150.46	329.0	901.0
Population density (inhabitants per km^2 settlement & traffic area)	3768.0	1087.3	2130.0	6377.0
Net migration ((influx - outflux) per 1000 of population)	4.08	3.43	-0.24	14.07
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	27.78	11.99	5.00	49.57
Students (students per 100 inhabitants aged 18 to 25)	183.03	72.17	55.37	326.78

Table 9: Descriptive statistics for the waste quantity analysis depicted in Figure 8.

	Tübingen	Synthetic Tübingen	Donor sample
Average age of the population (in years)	39.2	41.5	42.4
Female share in the population (in %)	52.4	51.8	50.8
Population density (inhabitants/km^2)	843.0	1285.0	1481.0
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	88.2	81.2	76.3
Employment rate (in %)	50.7	54.6	59.9
Average distance to supermarket (in meter)	635.0	501.0	551.0
Population density (inhabitants per km^2 settlement & traffic area)	3686.0	4184.0	3773.0
Net migration ((influx - outflux) per 1000 of population)	7.94	5.83	3.87
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	32.8	25.6	27.5
Students (students per 100 inhabitants aged 18 to 25)	199.0	121.0	135.0
Weight of the waste in public litter bins in kg per capita 2019Q1	1.08	1.04	0.91
Weight of the waste in public litter bins in kg per capita 2019Q2	1.19	1.16	0.97
Weight of the waste in public litter bins in kg per capita 2019Q3	1.22	1.21	0.98
Weight of the waste in public litter bins in kg per capita 2019Q4	1.08	1.11	0.99
Weight of the waste in public litter bins in kg per capita 2020Q1	1.02	1.03	0.97
Weight of the waste in public litter bins in kg per capita 2020Q2	1.13	1.05	0.89
Weight of the waste in public litter bins in kg per capita 2020Q3	1.24	1.28	0.99
Weight of the waste in public litter bins in kg per capita 2020Q4	1.08	1.15	0.93

Table 10: Pretreatment predictor balance for the waste quantity analysis presented in Figure 8.

A.3 Summary statistics for the *Recup* analysis

	Mean	S.D.	Min.	Max
A: Reusable containers				
Count of *Recup* restaurants per 100,000 inhabitants	8.25	10.35	0.00	126.26
Count of *Recup* restaurants per 100,000 inhabitants (demeaned)	4.98	8.21	-29.73	102.34
B: Regional demographic structure				
Average age of the population (in years)	44.21	1.80	37.76	50.71
Female share in the population (in %)	50.94	0.70	47.78	52.67
Population density (inhabitants/km^2)	956.18	673.38	86.85	4789.84
Young-to-old population (persons aged 15-19 per 100 of persons aged 60-64)	68.87	9.27	41.35	102.55
Employment rate (in %)	61.38	4.23	45.64	70.85
Avg. distance to supermarket (in meters)	688.5	250.62	328.0	2227.0
Population density (inhabitants per km^2 settlement & traffic area)	2586.9	922.9	787.3	6376.7
Net migration ((influx - outflux) per 1000 of population)	3.97	4.46	-18.70	34.72
Net commuters ((inbound comm. - outbound comm.) per 100 employees)	1.51	33.43	-124.04	61.01
Students (students per 100 inhabitants aged 18 to 25)	44.67	68.06	0.00	499.20

Table 11: Descriptive statistics for the *Recup* without cities that also adopted a subsidy program for reusable containers (363 cities).

A.4 Balance table for the *Recup* analysis

	Tübingen	Synthetic Tübingen	Donor sample
Average age of the population (in years)	39.2	41.6	44.2
Female share in the population (in %)	52.4	50.6	50.9
Population density (inhabitants/km^2)	843.0	1121.0	956.0
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	88.2	82.6	68.8
Employment rate (in %)	50.7	62.1	61.4
Average distance to supermarket (in meter)	635.0	732.0	689.0
Population density (inhabitants per km^2 settlement & traffic area)	3686.0	3076.0	2584.0
Net migration ((influx - outflux) per 1000 of population)	7.94	6.86	3.96
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	32.8	31.7	1.42
Students (students per 100 inhabitants aged 18 to 25)	199.0	163.0	44.2
Recup restaurants per 100,000 capita 151 days pre intervention (demeaned)	10.9	10.3	1.56
Recup restaurants per 100,000 capita 121 days pre intervention (demeaned)	10.8	11.8	2.05
Recup restaurants per 100,000 capita 91 days pre intervention (demeaned)	11.0	13.5	2.55
Recup restaurants per 100,000 capita 61 days pre intervention (demeaned)	11.3	14.0	2.60
Recup restaurants per 100,000 capita 31 days pre intervention (demeaned)	11.5	14.3	2.62
Recup restaurants per 100,000 capita 1 day pre intervention (demeaned)	11.8	14.6	2.64

Table 12: Pretreatment predictor balance for the *Recup* analysis depicted in Figure 6.

A.5 Summary statistics for the food bowls analysis

	Mean	S.D.	Min.	Max
A: Reusable food containers				
Count of return-refill restaurants per 100,000 inhabitants	4.48	7.36	0.00	87.07
Count of return-refill restaurants per 100,000 inhabitants (demeaned)	3.05	5.42	-32.81	59.73
B: Regional demographic structure				
Average age of the population (in years)	44.17	1.80	37.76	50.71
Female share in the population (in %)	50.95	0.71	47.78	52.67
Population density (inhabitants/km^2)	974.51	677.86	86.85	4789.84
Young-to-old population (persons aged 15-19 per 100 of persons aged 60-64)	69.07	9.24	41.53	102.55
Employment rate (in %)	61.32	4.15	45.64	70.85
Avg. distance to supermarket (in meters)	680.2	248.19	328.0	2227.0
Population density (inhabitants per km^2 settlement & traffic area)	2616.0	920.18	787.3	6376.7
Net migration ((influx - outflux) per 1000 of population)	3.91	4.47	-18.70	34.72
Net commuters ((inbound comm. - outbound comm.) per 100 employees)	2.79	32.81	-114.08	61.01
Students (students per 100 inhabitants aged 18 to 25)	46.04	68.57	0.00	499.20

Table 13: Descriptive statistics for the food container SC analysis without cities that also adopted a subsidy program for reusable containers (349 cities).

A.6 Balance table for the food bowl analysis

	Tübingen	Synthetic Tübingen	Donor sample
Average age of the population (in years)	39.2	40.8	44.2
Female share in the population (in %)	52.4	51.1	50.9
Population density (inhabitants/km^2)	843.0	1218.0	975.0
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	88.2	81.8	69.0
Employment rate (in %)	50.7	53.2	61.4
Average distance to supermarket (in meters)	635.0	518.0	680.0
Population density (inhabitants per km^2 settlement & traffic area)	3686.0	3430.0	2613.0
Net migration ((influx - outflux) per 1000 of pop.)	7.94	5.81	3.90
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	32.8	33.4	2.70
Students (students per 100 inhabitants aged 18 to 25)	199.0	160.0	45.6
Bowl restaurants per 100,000 capita 151 days pre intervention (demeaned)	1.97	1.85	-0.205
Bowl restaurants per 100,000 capita 121 days pre intervention (demeaned)	3.23	2.33	0.04
Bowl restaurants per 100,000 capita 91 days pre intervention (demeaned)	5.60	3.67	0.50
Bowl restaurants per 100,000 capita 61 days pre intervention (demeaned)	5.60	4.79	0.82
Bowl restaurants per 100,000 capita 31 days pre intervention (demeaned)	5.60	5.72	1.29
Bowl restaurants per 100,000 capita 1 day pre intervention (demeaned)	5.60	6.05	1.60

Table 14: Pretreatment predictor balance: food container analysis without cities that also adopted a subsidy program for reusable containers (349 cities).

A.7 Synthetic control for reusable food containers among subsidizing cities

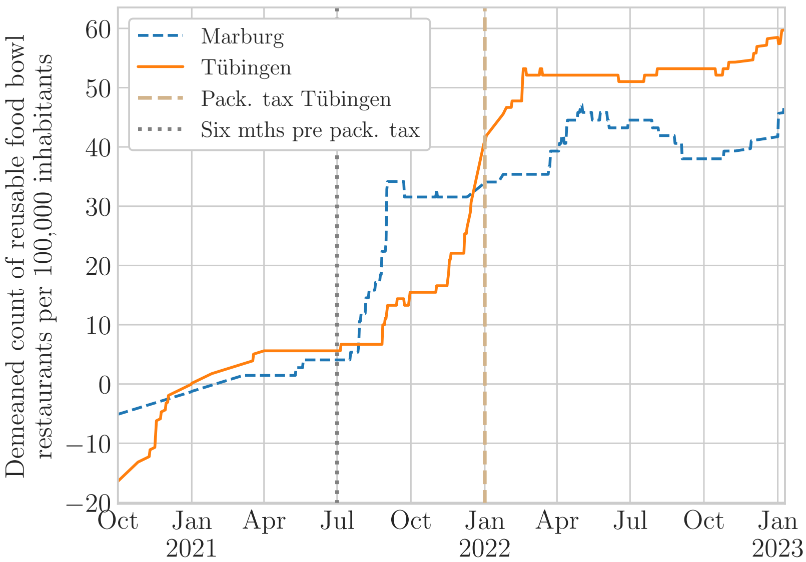

Figure 9: Comparison of Tübingen and the synthetic control with regard to the demeaned count of reusable container restaurants per 100,000 inhabitants. Besides Tübingen, only cities that have adopted subsidies for return-refill systems in the second half of 2021 are included (Bad Hersfeld, Fulda, Freiburg im Breisgau, Lübeck, Marburg, Rostock, Tübingen). The synthetic control fully consists of Marburg. The lines for Tübingen and its control can be read as the difference in the partner count with respect to its preintervention mean.

	Mean	S.D.	Min.	Max.
A: Reusable containers (in 7 cities)				
Count of food container restaurants per 100,000 inhabitants	18.84	21.20	0.00	87.07
Count of food container restaurants per 100,000 inhabitants (demeaned)	11.85	15.64	-16.41	59.73
B: Regional demographic structure (of 7 cities)				
Average age of the population (in years)	42.26	2.38	39.15	44.92
Female share in the population (in %)	51.65	0.68	50.75	52.36
Population density (inhabitants/km^2)	884.1	344.88	406.6	1509.0
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	77.19	12.28	61.83	95.00
Employment rate (in %)	55.94	5.16	47.53	61.62
Average distance to supermarket (in meters)	631.1	163.75	397.00	840.00
Population density (inhabitants per km^2 settlement & traffic area)	2924.0	909.7	1719.0	4665.0
Net migration ((influx - outflux) per 1000 of population)	3.82	2.30	0.87	7.94
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	33.49	12.08	13.17	49.57
Students (students per 100 inhabitants aged 18 to 25)	118.06	59.91	20.45	198.60

Table 15: Descriptive statistics for the food container SC analysis (7 cities that all adopted subsidy programs).

	Tübingen	Marburg	Donor sample
Average age of the population (in years)	39.2	39.6	42.8
Female share in the population (in %)	52.4	52.3	51.5
Population density (inhabitants/km^2)	843.0	617.0	891.0
Young-to-old working population (persons aged 15-19 per 100 of persons aged 60-64)	96.2	102.0	80.0
Employment rate (in %)	50.7	47.5	56.8
Average distance to supermarket (in meter)	696.0	679.0	600.0
Population density (inhabitants per km^2 settlement & traffic area)	3686.0	2750.0	2797.0
Net migration ((influx - outflux) per 1000 of population)	7.94	4.16	3.14
Net commuters ((inbound commuters - outbound commuters) per 100 employees in the city)	32.8	41.1	33.6
Students (students per 100 inhabitants aged 18 to 25)	199.0	181.0	105.0
Bowl restaurants per 100,000 capita 151 days pre intervention (demeaned)	1.97	0.02	-0.080
Bowl restaurants per 100,000 capita 121 days pre intervention (demeaned)	3.23	1.28	0.237
Bowl restaurants per 100,000 capita 91 days pre intervention (demeaned)	5.60	1.45	0.748
Bowl restaurants per 100,000 capita 61 days pre intervention (demeaned)	5.60	1.45	0.972
Bowl restaurants per 100,000 capita 31 days pre intervention (demeaned)	5.60	4.06	2.13
Bowl restaurants per 100,000 capita 1 day pre intervention (demeaned)	5.60	4.06	2.45

Table 16: Pretreatment predictor balance for the food container analysis depicted in Figure A.7. The synthetic control fully consists of Marburg. The donor pool consists of Bad Hersfeld, Freiburg im Breisgau, Fulda, Lübeck, Marburg, Rostock.