The Role of Excise Duties on Fuel in Reducing CO_2 Emission Levels from Road Transport: A Dutch Case Study

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Abstract: By design, excise duties are primarily a tax which serves to generate revenue for the central government. However, when they are placed on fuels they can, from a consumer point of view, be regarded as similar to carbon taxes. Carbon pricing, and carbon taxes in particular, are often championed by experts in relation to reducing carbon emissions. Based on these aforementioned notions, this research set out to investigate the role excise duties on fuel can play as an intervention employed by policy makers looking to reduce CO2 emissions. With this goal in mind, a Dutch case study is performed. This case study utilizes the synthetic control method to empirically investigate if the increase in Dutch excise duties on gasoline can be causally linked to CO2 emission reductions from road transport. Ultimately, the research found that an increase in the excise duty on gasoline can result in a significant decrease in per capita emissions. These findings resonate with the literature, and point towards how excise duties can play a part in strategically designed environmental policies. From a policy maker's perspective, this means that in combination with complementary environmental policies such as technology mandates, raising the price of excise duties on fuel could prove to significantly contribute to emissions reduction goals.

Keywords: *CO2 emission reduction, road transport, fuel excise duty, carbon pricing, environmental policy*

1. Introduction

1.1 The global challenge we face

Come 2021, climate change is on almost everyone's mind. With an example being that back in 2020, Joe Biden announced plans to spend 2 trillion on a climate plan (The New York Times, 2020). In order to comprehend the necessity of addressing the current climate crisis, one need only look at the facts: The 2019 temperature rise compared to the pre-industrial temperature sits between 1.1 and 1.3 degrees (Carbon Brief, 2020). When temperature levels rise to 2.0 degrees or more, this will result in changes in our natural environment unlike any we have seen in modern times. Including increased coastal flooding, beach erosion, salinization of water supplies and other impacts on humans and ecological systems (NASA, 2019). Realizing the severity of this man made problem, several international committees and initiatives were brought to life over the past decades. Such as the United Nations Environment Program (UNEP), the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol, and most recently the Paris agreement. The primary goal of the Paris Agreement was for countries to strive to reduce their domestic emissions, which has been cause for optimism. However, in the latest version of a yearly published report by the UNEP, it has become painstakingly clear that our current progress will not keep the overall temperature rise below 2 degrees. Nevertheless, more and more climate mitigation policies are being undertaken, with the US and the stewardship of Biden being a great example. However, both time and resources are limited (UNFCC, 2020), meaning that we could particularly benefit from a greater understanding of the impact certain policies may or may not have. This would in part entail looking at current policies, and how they have historically performed, to help shape future policies. Ultimately, enhancing our understanding will allow for better designed policies and more efficient allocations of resources.

In doing so, it therefor makes sense to evaluate current climate agreements, and the emphasize they place on certain policy designs. The most significant climate agreement to date is the

2015 multilateral Paris Agreement, which requires significant economic and social reformation, and works on a 5 year cycle. In trying to achieve this, the Paris Agreement relies heavily on Nationally Determined Contributions (NDC's) (UNFCC, 2020). Luckily, policy makers have a wide variety of tools available in relation to emission mitigation (Goulder & Parry, 2008). However, from this wide variety, carbon pricing is often identified by experts to be the most efficient policy tool (Nordhaus 2008, 2013 and Weitzman 2015, 2016). According to the High-Level Commission on Carbon Prices, which includes commission chairs Joseph E. Stiglitz and Nicholas Stern "carbon prices are intended to incentivize the changes needed in investment, production, and consumption patterns, and to induce the kind of technological progress that can bring down future abatement costs" (p. 1, 2017). Additionally, carbon pricing can be split up into emission permits or a carbon tax (Andersson, 2019; Heutel, 2020). Unfortunately, carbon taxes are often met with heavy public criticism, mostly because the taxes are regressive in nature (Heutel, 2020; Andersson & Atkinson, 2020). This is particularly unfortunate, as carbon taxes need widespread approval to be successfully implemented (Carattini, Kallbekken, & Orlov, 2019). Luckily, this can be mitigated by using information and evidence in favour of the policy (Carattini et al. 2017). The uneasy reality however is that while experts tend to champion the carbon tax, and that public approval can be won by showcasing the positive results, actual post-empirical evidence on the causal effect between a carbon tax and reduced emissions is scarce (Andersson, 2019). This is particularly worrisome as we must reduce emissions as soon as possible (UNFCC, 2020), and in order to do so we must understand the effects of the tools policymakers have at their disposal.

1.2 Looking for a potential solution

Aiming to address climate change is both highly complex and very challenging. In part because competing evaluation criteria exist for the choice of policy measures and interventions, meaning there will not be a single best in class solution (Goulder & Parry, 2008). Nevertheless, within a broader strategy for reducing GHG emissions, a well-designed carbon price should be all-important (High-Level Commission on Carbon Prices, 2017). Based on this notion, in combination with the realization that we must better understand the actual causal effects of implemented carbon pricing on emission reductions, Julius Andersson was motivated to perform a Swedish case study to address this (2019). In his research Andersson set out to determine the effect the Swedish carbon tax has had on CO2 emissions levels from road transport. He has been able to do so by setting up a comparative case study, researching what the Swedish emissions levels would most likely have been, had the carbon tax effecting fuel not been enacted in 1991. His results are very promising, as they are able to causally determine that the implementation of the carbon tax has resulted in a decline of CO2 emissions from transport of almost 6%. In his conclusion Andersson states that he would expect comparable emission reductions for countries which are similar to Sweden[1], based on a Sweden sized carbon tax. Testing this assumption will help to determine the external validity of his results and provide much valued additional insights into the workings of carbon pricing methods. Ultimately, this motivates the research direction of this thesis, to determine how the taxes placed on fuel in the Netherlands have helped to reduce Dutch domestic CO2 emissions from road transport. More specifically, while Andersson studied the 1991 implementation of a carbon tax, this research will focus on the excise duty price increase on fuel.

[1] The similarity must be with regard to the key predictors for road transport emissions, which Andersson (2019) identified as GDP per capita, gasoline consumption per capita, vehicles per 1000 people and the level of urbanization. These key predictors will be addressed in more detail in the following chapters.

1.3 A Dutch case study

While an excise duty on fuel, and a carbon tax affecting fuel differ in design (Surbhi S, 2015), they are similar from a consumer point of view, as they result in an increased gasoline or diesel retail price. Therefore, if the goal is to reduce emissions by discouraging the uses of road transportation by increasing the costs, both policies can have the same effect. Since a 2003 European directive all countries in the European Union have a required minimum excise duty price on gasoline of €0.36 per litre (Tax Foundation, 2019). However, the excise duty on gasoline in the Netherlands has been in place since 1931 (Belasting & Douane Museum, 2018), and is currently the highest in Europe (Tax Foundation, 2019). When adjusting for inflation, the excise duty has stayed largely unchanged for the majority of the 20th century. Nevertheless, some significant increases have been made. The most notorious of which has been the excise duty price increase on gasoline in 1991, commonly known as "Het Kwartje van Kok", which translates to "the quarter of Kok". Referencing Wim Kok, the then minister of finance and the supposed price increase of a quarter gulden[2]. Studying what the effect of this policy intervention has been on Dutch road emissions will help to better shape the understanding off the effectiveness of taxes or duties paid over fuel as policy interventions.

1.4 Research questions

Based on expert consensus regarding the central role carbon pricing should play in a well-designed environmental strategy, in combination with the lack of ex-post empirical research into the causal effects between carbon pricing and reduced emissions, as well the promising results of the Andersson case study (2019), the following research question has been developed:

How effective is an excise duty on gasoline, in reducing CO2 emissions from road transport?

Sub-Questions

The main research question shall be answered by means of a Dutch case study. In order to give the overall research more structure and depth, this research question shall be broken down into several sub-questions. This shall entail looking at the specific characteristics of the Dutch fuel excise duty, and how this relates to other carbon pricing mitigating policy tools. Additionally, a comparative case study shall shed light on the actual causal effect of the Dutch excise duty on reduced emissions. Consequently, an assessment of whether the results of Dutch case study can be generalized for other countries shall be given. Ultimately, this leads to the following specified sub-questions:

1. *What are the key characteristics of the Dutch gasoline excise duties and its historical development?*
2. *How does an excise duty on fuel relate to other carbon mitigating policy tools?*
3. *What would Dutch road emissions have been without the fuel excise duties?*
4. *Can the results from the Dutch excise duty on fuel realistically be generalized for other countries?*

[2] The gulden was the Dutch national currency up until 2002.

1.5 Research design

In order to better understand the key characteristics of the Dutch fuel excise duty, and how this relates to other carbon mitigating policy tools, a broad Literature Review chapter will be set up. Within this review, both the advantages and disadvantages of carbon pricing will be addressed, as discussed within the literature. Furthermore, this literature review will provide the necessary context and background for the entire thesis. The subsequent Methodology & Data chapter will detail both the methodology and the usage of data. This means an elaborate delineation will be given of the comparative case study employed in this research, or more specifically, the Synthetic Control Method (SCM). This research will use the experimental set-up as deployed by Andersson as starting point. This means that the Methodology & Data chapter, and the subsequent Analyses & Results chapters will express what the similarities, but more importantly, the differences between the two case studies are. Ultimately, as shown by the Analyses & Results chapter, Andersson's experimental use of the SCM and original dataset prove to be a great platform for the Dutch case study. However, several methodological challenges inevitably arise during the analyses, which will be constantly addressed throughout the Analyses & Results chapter, and summarized in the Discussions chapter. Ultimately, this will lead to the final Conclusion & Reflection chapter, in which the identified research questions are answered.

2. Literature review

This chapter will provide a more in depth overview of the problem. Firstly, a short introduction to the most current climate agreements and frameworks are given. By doing so, the necessary context will be given to introduce how new policies measures can and should be developed. From this broader context, a more specific commentary on carbon pricing as a policy tool will be given. Ultimately, the literature review will address both the severity of climate change, the urgency to act, and the tools we have at our disposal to do so. From this understanding, the link to the paper *"Carbon Taxes and CO2 Emissions: Sweden as a Case Study"* by Julius Andersson (2019), will be introduced. Following this introduction, in order to properly set up this research, the relevant sources and findings from Andersson's paper will be discussed, in relation to the focus point of this thesis. Which is the Dutch case study. Finally, the relevant research for the Dutch excise duty on fuel for automotive transportation, in relation to the construction of a synthetic control method will be made clear.

Documentaries and Snowballs: An Overview of the Development of the Climate Change Debate

The term climate change was first introduce over 1975 years ago by Wallace Broecker. Yet the effects and the urgency of the problem haven't always been clear over the past 45 years (Broecker, 1975). Nevertheless, Broecker was clear in his initial warning, stating that our efforts to understand and eventually to predict these changes must be redoubled" (p. 463). It took some years for this warning to catch on; Eleven years later, and an increase in the human population of one billion, the Intergovernmental Panel on Climate Change (IPCC) formed in 1988, to collect and evaluate evidence on climate change (BBC, 2013). Another decade later, the Kyoto Protocol was designed, with the goal to commit industrialized countries to limiting greenhouse gases (GHG) emissions. However, in the years following, both the public and political debate never reached a clear consensus on the actual urgency of limiting GHG's to stop further global warming; While 1998 became the hottest year on record, in relation to the mean period of 1961-90, president George W. Bush withdrew the United States from the Kyoto protocol in 2001 (BBC, 2013). Luckily, the other side of the debate began the gain traction in the face of scepticism. Al Gore, who lost the president election to George W. Bush jointly won the Nobel Peace prize in 2007, together with the IPCC "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (The Nobel Peace Prize 2007, 2021). A year after Gore first released the notorious documentary 'An Inconvenient Truth'. A documentary which, according to a public survey, was responsible for increasing the percentage of Americans who attribute global warming to human activity from 41% to 50% in the months following the documentary's release. Unfortunately, the documentary has also been criticized by experts for being unreliable (Cook, 2016). Something which is unfortune, seeing as how in the effort to convey a message containing an inconvenient truth, scientific credibility is extremely important, particularly because it can also be easily lost (Rosling, 2018). This is especially important in a debate in which scientific reasoning can sometimes be hard to find. As demonstrated by US senator James Inhofe, who in 2015 brought a snowball onto the senate floor (CNN, 2015). Thereby singlehandedly debunking global warming. At least, according to him.

Luckily, a snowball on the senate floor wasn't the highlight of the year, as in 2015 the Paris Agreement brought all nations together to combat climate change. The main aim of the agreement was for countries to strive to reduce their domestic emissions (UNFCC, 2020). Thus acknowledging the nature of the problem. Nevertheless, the Paris Agreement definitely isn't an unnecessary luxury. Approximately 50 years after Broecker first lifted the veil on the effects of man-made global warming, the effects of changes in the global temperature are a mystery no more; The 2019 temperature rise compared to the pre-industrial temperature sits between 1.1 and 1.3 degrees (Carbon Brief, 2020). The severity of this problem is illustrated by NASA (2019), who state that when the temperature rises 2 degrees, more than 70 percent of Earth's coastlines will see sea-level rise greater than 0.2 meters, resulting in increased coastal flooding, beach erosion, salinization of water supplies and other impacts on humans and ecological systems. Recognizing the urgency, Enno Schröder and Servaas Storm (2020) noted how the Paris Agreement was cause for optimism, however 'post-Paris publications by climate scientists are nothing short of sounding the alarm bells.' (p. 153). One of which is the yearly Emissions Gap Report, published by the United Nations Environment Program (UNEP). This report addresses the emission gap, which serves as an indication of how well we are doing, on a global scale, in relation to taking care of the planet we inhibit. The report is very clear on our progress; we are absolutely not on track to keep the overall temperature rise below 2 degrees. The UNEP is extremely aware of this crisis situation, with their Executive Director urging "governments, businesses and individuals – particularly those with the greatest climate footprint – to take this opportunity to protect our climate and nature for decades to come" (p. 13, 2020).

The Role of Carbon Pricing within Nationally Determined Contributions

Over five years after the initiation of the Paris Agreement, global emission targets are still not being met. Mitigating efforts have been slow to take off, with for example the largest Dutch political party, the VVD, receiving heavy criticism for having unambitious and poorly calculated climate mitigation plans (FD, 2021). An even more extreme example is of course the US under the stewardship of Donald Trump, who withdrew the United States entirely from the Paris Agreement in 2020 (BBC, 2020). Something which has luckily been rectified under Trumps successor Joe Biden, who immediately pledged to re-join the agreement (The Guardian, 2021). Examples of slow or even wavering national climate policies are right to be met with heavy criticism. Although imperfect, the Paris Agreement is the most prominent instigator of global climate change mitigation, and relies heavily on national policies; "Nationally determined contributions (NDCs) are at the heart of the Paris Agreement and the achievement of these long-term goals" (UNFCC, 2021). Currently, the challenge for national governments is to turn the Paris Agreement's greenhouse gas emissions pledges into both strong and feasible domestic policies (Carattini, et al., 2017).

As noted by Lawrence Goulder and Ian Parry (2008), the toolkit of environmental instruments is extensive, and the choice of pollution control instruments is not to be underestimated. However, despite the wide variety of mitigation measures, researchers often champion carbon pricing in the battle against emissions (Nordhaus 2008, 2013 and Weitzman 2015, 2016). For example, Nobel Laureate Joseph Stiglitz and Lord Nicholas Stern, Co-Chairs of the High-Level Commission on Carbon Prices comment that "a well-designed carbon price is an indispensable part of a strategy for reducing emissions in an efficient[3] way" (p. 1, High-Level Commission on Carbon Prices. 2017). Furthermore, within carbon pricing, the distinction can be made between tradeable emission permits and a carbon tax (Andersson, 2019; Heutel, 2020).

Justification for government interference in the form of carbon pricing can be traced back to a century ago, when Arthur Cecil Pigou published his work *"The Economics of Welfare"* (1920). Based on neoclassical economic theories, Pigou established the notion that negative externalities can create market failures. By which he means that economic transactions or activity can lead to (unintended) external costs, which haven't been taken into account in the actual market price, with pollution being

[3] "Efficiency" is relatively hard to measure, yet often used as a buzzword in the High-Level Commission on Carbon Prices report. What efficiency entails in relation to carbon pricing will be addressed in the discussion of this report.

of course a prime example. However, these cost can be easily mitigated by calculating the negative costs and incorporating them into the market price. A pricing policy which results in either taxes or subsidies, which have now come to be known as Pigouvian pricing (Garth Heutel, 2020).

Keeping in mind the notion that effective climate change mitigation policies balances both the costs of actions and the assumed economic damages of inactions, the view of expert economist should be valued. While the scientific consensus is that immediate mitigation efforts are needed, economist are often portrayed to be more conservative than scientist. The reasoning being that economist are much more inclined to focus on costs of mitigation and free market driven adaption. Nevertheless, economist express levels of concern about climate change that are higher than those of the general public. Furthermore, the vast majority believes that a carbon tax is an economically efficient way to combat national emissions (Howard & Sylvan, 2015). This expert consensus became even more accentuated when in 2020 the "Economist' Statement on Carbon Dividends" was signed by over 3.500 economists, including 28 Nobel Laureates. The letter states that "a carbon tax offers the most cost-effective lever to reduce carbon emissions at the scale and speed that is necessary. By correcting a well-known market failure, a carbon tax will send a powerful price signal that harnesses the invisible hand of the marketplace to steer economic actors towards a low-carbon future." (Climate Leadership Council, 2020).

Besides correcting the market failure with environmental effectiveness at a relatively low cost, the policy also plays a role in enhancing the social and political acceptability of climate policy. Something which will prove to be very important (Baranzini et al., 2017). Because although carbon pricing is a popular environmental measure within the literature (Nordhaus 2008, 2013; Weitzman 2015, 2016; High-Level Commission on Carbon Prices. 2017), it isn't perfect. Looking back at the Pigouvian argument for carbon pricing; truly mitigating the negative externalities of emissions are only realised when the market price is equal to the marginal external damages. Or in other words, when the negative externalities are fully internalized in the market price. Anything shy of this price level will mean that the tax is not set at the efficient level, which will result in the efficient level of pollution not being realized (Heutel, 2020). However, even more critical than the level of effectiveness is the actual implementation of a carbon pricing policy measure, with the success of these policy measures depending on widespread public approval. Unfortunately, carbon pricing measures are often met with heavy resistance, meaning new taxes are rarely implemented. An example being Swiss voters, who in 2015 rejected a tax on non-renewable energy with an overwhelming majority of 92%. Similarly in 2016 and again in 2018, a carbon tax was opposed by over half the voters in Washington (Carattini, Kallbekken, & Orlov, 2019). However, perhaps the most vivid example of the public aversion to a carbon tax is the "*movement de gillets jeunes",* the French protest movement known as the yellow vests. The movement was sparked by the announcement of President Macron to put a tax on motor fuels to curb emissions, which prompted over a quarter of a million people to protest on 17 November 2018, bringing large parts of France to a standstill (World Economic Forum, 2020). Something which is paradoxical, as not only was France the birthplace of the Paris Agreement, there also exists general support among the French population for climate change mitigation policies (Heutel , 2020). Nevertheless, the protest is not without merit; An important source for the resistance is the fact that carbon taxes are often regressive in nature, which means that a relative large burden will be placed on low-income households (Heutel, 2020; Andersson & Atkinson, 2020). Unsurprisingly, the literature suggests that the acceptability of climate mitigation policies is largely dependent on policy designs that protect low-income-households. Consequently, one of the main reasons 92% of Swiss voted against such a tax were their concerns about income inequality (Baranzini et al., 2017). Unfortunately, the reason carbon taxes are often regressive in nature is because in order to reduce emissions, taxes must be placed on goods which are necessities, such as fuel and electricity (Andersson & Atkinson, 2020). Additionally, concerns about inequality can be magnified by the fact that people still underestimate the benefits of lower emissions and overestimate drawbacks such as job losses. However, when policies are enacted and benefits become more clear, opposition tends to fade (Carattini, Kallbekken, & Orlov, 2019). This is especially true when information and evidence are used to showcase the positive effects (Carattini et al. 2017).

Unfortunately, the battle for public support isn't the only limitation and challenge to carbon pricing. Other drawbacks are that the nature of the problem requires a drastic change, for which carbon pricing will not be enough, in part because it is unlikely to trigger the necessary scale of change. Furthermore, millions die of air pollution each year, thus more stringent regulation might be a more suitable and effective way to combat the loss of live on such a global scale (Hepburn, Stern & Stiglitz, 2020). Nevertheless, these limitations should not undermine the fact that carbon pricing should play a central role in climate change mitigation. Climate change is an extremely complex problem, meaning that choosing from the variety of policy measures is inherently difficult, simply because competing evaluation criteria apply. This means that there won't be a single solution clearly superior along all the different relevant dimensions (Goulder & Parry, 2008). However, the consensus remains that carbon pricing should be an import tool in the overall climate change mitigation toolkit. Largely because it is both environmentally and cost effective, bringing about incentives which have an effect up and down supply chains, while also generating useful public revenue. This revenue can in turn be utilized to transition to a more sustainable economy (Hepburn, Stern & Stiglitz, 2020).

Carbon taxes in practice: A Swedish case study

The preceding paragraphs establishes several notions. First, climate change is a large and immediate threat. Second, based largely on the Paris Agreements, we rely on nationally designed and implemented policies, such as carbon pricing. Unfortunately, in order to successfully implement carbon pricing policies, wide spread public approval is needed. Which has shown to be lacking at the moment. Nevertheless, the literature also shows that when presented with fact based evidence in favour of carbon taxes, the public becomes more susceptive to such a policy implementation. Regardless, in a 2019 research, Julius Andersson notes how there is a lack of ex post empirical studies on the causal effect of carbon taxes on emissions. Paradoxically, out of the large toolbox available to policy makers, experts champion carbon pricing, while in reality the empirical and quantitative evidence in favour of the policy is scare.

Based on the aforementioned points, the conclusion Andersson draws is clear and concise; "Correctly estimating the effectiveness of carbon taxes empirically is thus important for shoring up much needed public support, as well as ensuring that environmentally and economically efficient mitigation policies are adopted across countries by the diffusion of lessons from existing national climate policies" (p. 2, 2019). In trying to better understand the influence a carbon tax has on the actual reduction of CO2, Andersson proposes a Swedish case study. In his research, he investigates empirically "the environmental efficiency of carbon taxes by analysing the Swedish experience of introducing a carbon tax on transport fuels in the early 1990s." (p. 3, 2019). Sweden was one of the first to introduce such a carbon tax, and therefor makes for an interesting case study. Furthermore, the Swedish transport sector is relevant, as it is heavily affected by the carbon tax., with around 90% of the revenues from the carbon tax coming from the consumption of motor diesel and gasoline (Ministry of Finance, 2017).

In order to determine what the effect of the Swedish carbon taxes has been, Andersson makes use of the synthetic control method. This method entails that from a deliberately selected control group of OECD countries, a counterfactual is created; the "synthetic Sweden". This version is "a comparable unit consisting of a weighted combination of countries that did not implement carbon taxes or similar policies during the treatment period and that prior to treatment[4] resemble Sweden on a number of key predictors of CO2 emissions in the transport sector and have similar levels and paths of these emissions" (p. 2, 2019). Consequently, a comparison between the synthetic version and reality can be made. Or in other words, what reality would have looked like, had the policy measures not been introduced, thereby illustrating the effect carbon pricing has had on total transport emission. This analysis has resulted in the figure below.

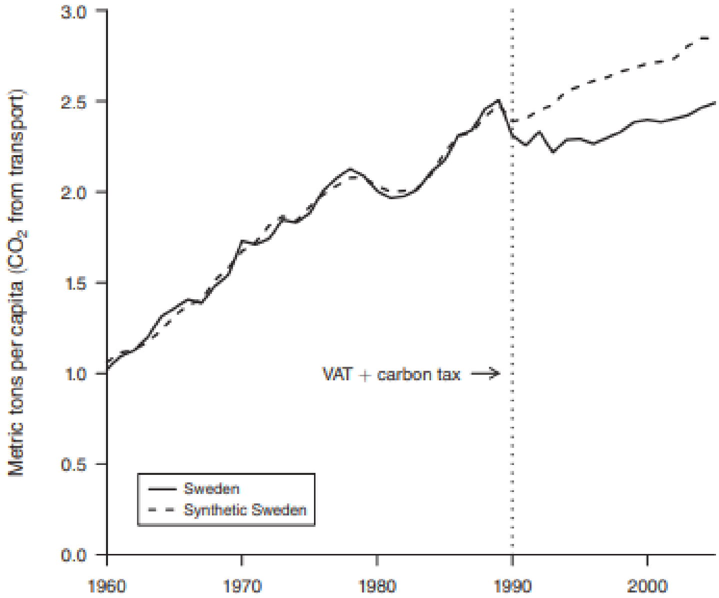


Figure 1. Path Plot of Per Capita CO2 emissions from transport (1960-2005); Sweden vs. Synthetic Sweden (Andersson. 2019)

Explanatory note: *The graph shows how the synthetic unit, which is portrayed by the plotted dotted line, is able to accurately resemble the pre-treatment emission levels of Sweden. The vertical dotted line resembles the treatment, which therefor is also the point at which the divergence between Sweden and Synthetic Sweden becomes clear, illustrating how the implementation of the treatment has led to lower emission levels.*

Initially, figure 1 shows the ability of Synthetic Sweden to closely follow the CO2 emissions levels from transport of Sweden. This points to the successful execution of the synthetic control method, as the credibility of the estimator depends on its ability to accurately "track the trajectory of the outcome variable for the treated unit for an extended pre-intervention period" (p. 17, Abadie, 2020). This pre-treatment accuracy, in combination with a variety of validity tests, means that the results of the study post-treatment show what the effect of the Swedish carbon tax has been on significantly decreasing the CO2 emission output in the country. Andersson is thus able to show that the implementation of a carbon tax and VAT on transport fuels in Sweden have resulted in a decline in CO2 emissions from transport. This result is apparent in the figure, as the year 1990 saw the implementation of the Swedish carbon tax, and is thus the starting point for the divergence between Sweden and Synthetic Sweden. To be precise, Andersson's analysis shows that the introduced carbon tax and VAT have resulted in a decline in emissions from transport of nearly 11% in an average year,

[4] Within this thesis, the concepts "treatment", "policy measure" and "intervention" will be used interchangeably

from which 6% is the carbon tax alone (2019). In addition, the paper is able to give more detailed insights into the workings of the policy measure, in relation to consumer behaviour. Furthermore, Andersson mentions that the utilization of the synthetic control method provides noteworthy advantages, when it comes to the evaluation of the environmental effects of carbon taxation. Firstly, there is no need for a simulation approach to estimate changes in the emissions from transport, as the method makes use of ex post empirical data as the outcome variable. This is in contrast to previous studies on the same topic, which generally used ex ante simulations.

In summary, Andersson has been able to construct an accurate counterfactual, by employing the synthetic control method. His thought-out research design has resulted in the empirical finding that the Swedish carbon tax has been environmentally efficient[5], while also capturing the more nuanced dynamics relating to consumer behavioural responses. These results can help to shape new policies in Sweden, or similar ones abroad, thereby contributing to the effectiveness with which climate change is mitigated. In addition, it can play a role in the public debate, showing the clear positive effects of an carbon tax on fuels. Thereby hopefully paving the way for more carbon pricing policies to be implemented, based on improved public sympathy towards the measure.

Replicating Andersson's synthetic control method: A Dutch case study

In theory, carbon pricing should be a fan favourite among policy makers who are serious about mitigation emissions. In practice however, the ex-post empirical evidence showcasing the success of implemented carbon pricing policies is relatively scarce. Addressing this issue are the findings published by Andersson (2019). Unfortunately, one swallow does not make summer just like one successful carbon pricing policy intervention doesn't justify a worldwide generalization. Andersson's Swedish case study on the influence which a carbon tax placed on transport fuels has on CO2 emissions, is validated by the reasoning that empirical evidence is needed both to shore up the much needed public support, and to be able to draw lessons from it to help shape both existing and new policies. Ultimately, this means that a replication of the research done by Andersson for Sweden, for another country, would make for an interesting and relevant study. When such a research is able to produce similar results, it will further validate the evidence in favour of a carbon tax to mitigate emissions. In contrast, different results could help shed light on potentially interesting nuances caused by different circumstances. Either way performing a synthetic control method to define the effect a carbon pricing intervention has had on a countries carbon emissions will help to further the general understanding of implementing such policy measures and the results they yield.

The synthetic control method, as applied by Andersson, is a comparative case study. However, built on the notion that a combination of units provide a better suited comparison than a single unaffected unit alone. This means that a counterfactual; an unit which has been unaffected by the intervention that is the focus of the study, needs to be constructed based on a sample group (Abadie, 2020). Andersson originally started with a sample group op 24 OECD countries. Which is reduced to a donor pool consisting of 14 countries, including: Australia, Belgium, Canada, Denmark, France, Greece, Iceland, Japan, New Zealand, Poland, Portugal, Spain, Switzerland, and the United States. Like Finland and Norway, the Netherlands is excluded based on the fact that a carbon tax which covers the transport sector was enacted during the sample period. Using such a country to construct a synthetic version would skew the accuracy of the counterfactual. However, it does mean the Netherlands is a potentially interesting and viable country for an independent case study.

[5] Andersson literally uses the phrase *environmentally efficient.* However, while effectiveness can be quantitatively measured, efficiency much less so. This will be addressed in the discussion of this thesis.

In the discussion Andersson states that "countries that are similar to Sweden will likely experience comparable emission reductions from the same level of carbon tax" (p. 26, 2019). However, it is important to take into account the definition of 'similar'. The analysis is built on the synthetic control method, which utilizes key predictors. These key predictors determine the development of the dependent variable, in this case CO2 emissions from transport, without a policy measure being implemented. Therefore, when talking about 'similar' countries, the term applies to those nations who have comparable levels for the key predictors. As key predictors for CO2 emissions from the transport sector, Andersson has identified GDP per capita, number of motor vehicles, gasoline consumption per capita and percentage of urban population. The reasoning behind this being that the literature links the level of GDP per capita to GHG emissions, while OECD countries with a lower level of urbanization tend to have a higher usage of motor vehicles (Neumayer, 2004). Looking at a side by side comparison of both the urban population and GDP per capita, it shows that the Netherlands shows similarities with Sweden.

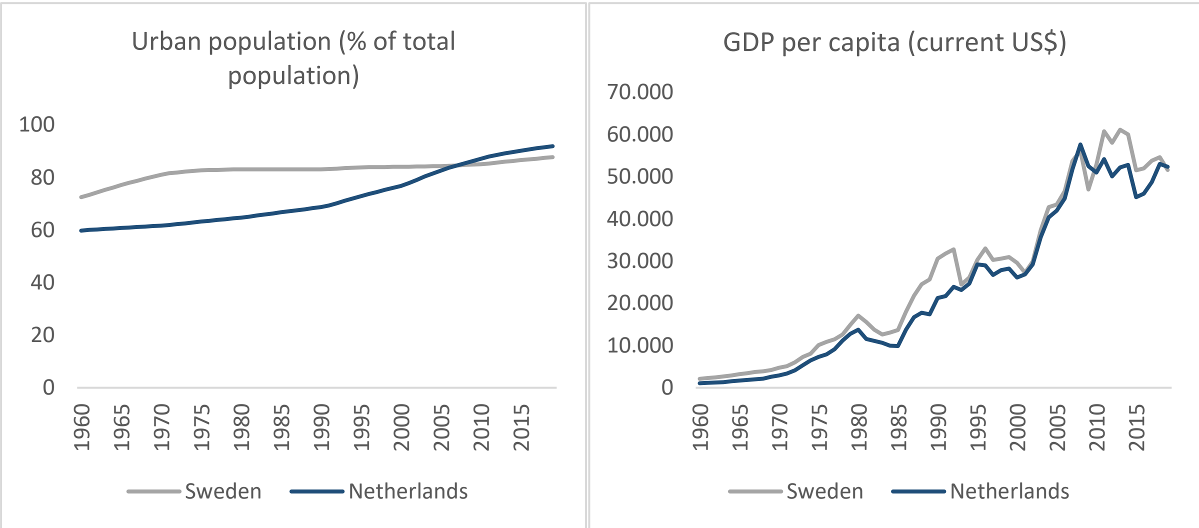


Figure 2. Side by side comparison of key predictors for CO2 emissions form transport, for Sweden and the Netherlands (World Bank, 2021)

In terms of the relevance of addressing the emissions from road transport, figure 3 shows a breakdown of emission levels from both Sweden and the Netherlands. The Netherlands and Sweden have a comparable carbon emission composition, with road being responsible for around 20% of total emissions. This means that by addressing the emission from road transport fuel, you are addressing 20% of the total emissions.

Figure 3. the composition of CO2 emissions from energy use by sector (OECD, 2016)

The similarities between the two countries, and the fact that the Netherlands was excluded from Andersson sample group on the basis of the country having enacted a carbon pricing policy during the sample period, make the Netherlands an ideal candidate for a replication of Andersson's research.

Excise duties in the Netherlands

Although the Netherlands and Sweden showcase similarities, the actual fuel carbon pricing deployed differs between the two nations; In the Netherlands, you have to pay excise duties (or "accijns" in Dutch) on alcoholic beverages such as beer and wine, tobacco products such as cigarettes and cigars, and mineral oils such as petrol, diesel and LPG (business.gov. 2020). These excise duties are set by the government and incorporated in the price a consumer pays. Figure 4 gives an overview of the current fuel price breakdown. The VAT is a fixed percentage set by the government, which is paid over the total costs. The VAT has changed over time but currently sits at 21% for fuel. However, when incorporated into the total fuel price, the percentage which remains is 17%[6].

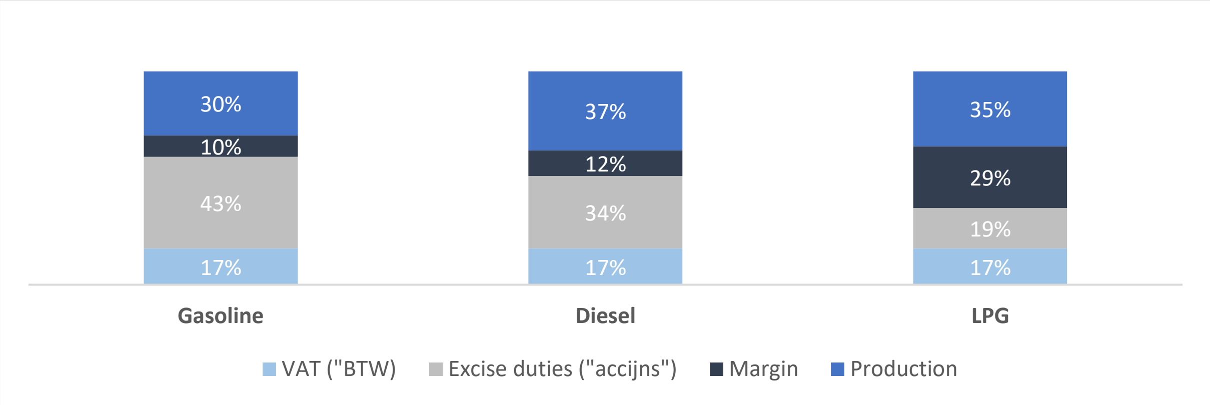


Figure 4. Breakdown current fuel price components (UnitedConsumers, 2021)

The Dutch excise duty on fuel has been around since as early as 1931 (Visser, 2003). However, the first decades after its implementation, it's price has remained relatively stable. With any increases being related to keeping its price level constant with inflation. However, the most notable real increase came in the early 90's, when the Dutch government faced a gap in their budget. Aiming to close the gap, the government looked for ways to (temporarily) increase their income. Ultimately, one of their propositions included increasing the excise duty on fuel for car transportation. Besides the increased revenue for the Dutch government, this policy measure had an additional motive, as the Minister of transportation, Maij-Weggen, was looking to restrict car use in general. The rise in variable cost seemed like a good way to achieve this. The argument was that the decrease in the use of automobiles for transportation would result in energy conservation and environmental protection. Which would then in turn lead to less health issues and so on (Barrois, 2019). The measure was met with heavy criticism, primarily from branch organisations in the automotive and transportation sector. As the policy measure would supposedly led to an increase of around 25 gulden cent (in reality it was no more than 20), they dubbed it as the "Kwartje van Kok". Which translates roughly to the quarter of Kok. Named after the then current Minister of Finance, Wim Kok. Under whom the increase in taxation was enacted in 1991 (Trouw, 2012).

In the decades following the initial implementation, the Kwartje van Kok found its way back into the public and political debate on numerous occasions. Grounds for its reappearance was that when first enacted, the policy was meant to be a temporary solution for the gap in the government's budget. Over the years, several prominent Dutch politicians, including Jan-Peter Balkenende, Pim Fortuyn, and Geert Wilders all made a case for the original (supposed) quarter of an eurocent to be

[6] For example; when the pre-VAT retail price of a product is 10 euro, and VAT is 21%, the retail price after taxes becomes 12,10 euro. However, 2.10 is 17% of 12.10. Meaning that when the VAT is incorporate in the price, its corresponding percentage to the total post tax price will become 17%.

"given back" to motorists. Especially since the original conditions under which it was implemented were no longer valid. The country wasn't looking to close the gap in its budget any longer (Trouw, 2012). However, although the policy has been cause for debate and dissatisfaction, public resistance never reached the levels of those by the French yellow vests, who paralyzed the nation with their protests in 2018. Although the underlying cause for the yellow vest to protest were based on a broad dissatisfaction and frustration, the spark that initially ignited the protests was an increase in the fuel price (World Economic Forum, 2020). Meanwhile, push back on the Dutch excise duty increase mostly came from branch organisations.

The 1991 increase in the excise duty on gasoline has gotten the most attention. Both during its proposal, implementation, and the three decades that have passed since. However, this wasn't the first real increase in the price of the excise duty. Looking at figure 5, which shows both the actual excise duty development and the real excise duty price development (2005 as base year), it is clear that 1984 also shaw a rather significant increase in price. Overall, the 1984 real price increase amounted to 8 eurocent, while 1991 saw an increase of 10 eurocent. This means that there are potentially two interventions which can be evaluated by means of the synthetic control method.

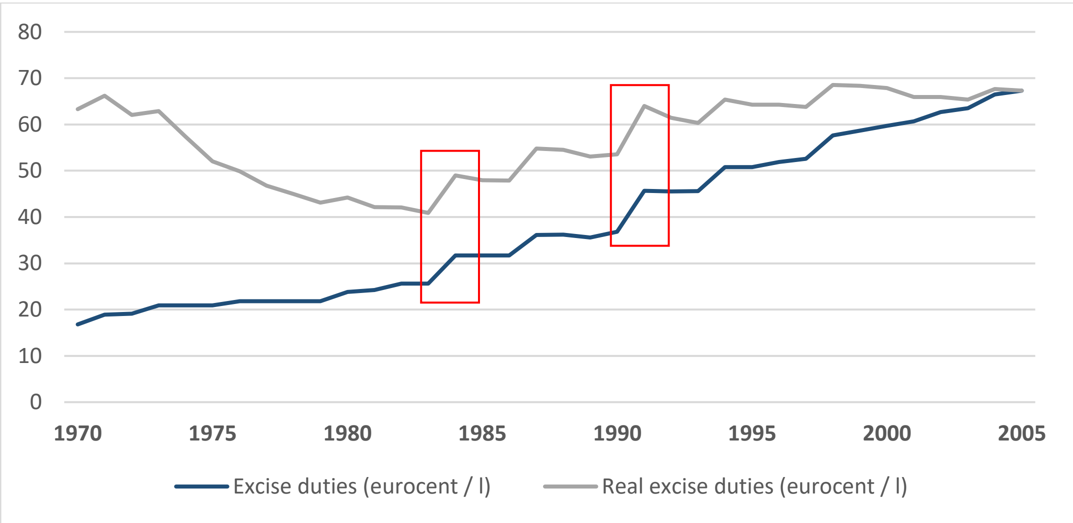


Figure 5. Historical development of Excise duty on gasoline (Bovag,, 2019).

Explanatory note: *The Netherlands adopted the Euro in 2002, switching from their national currency the Gulden. All the excise duty prices are in figure 5 are in euro's, to provide a better overview of the development of the pricing.*

Ultimately, when first introduced the main purpose of the excise duty on fuel was to generate additional revenue for the Dutch government (Visser, 2003). However, over time excise duties have also developed to discourage the use of the product on which the excise duty is placed (Europa Nu, 2018; Hepburn, Stern & Stiglitz, 2020). With regards to the initial argument; The CBS gives great insight into the received revenues from fuel excise duties, which in 2017 amounted to 4.293 million euro. Thus, it can be safely concluded that the excise duty is successful in contributing revenue to the Dutch central government. Thereby validating at least part of the reason the price for excise duty on fuel was increased in 1991. With regards to the discouragement argument, this research aims to shed light on the actual environmental effects, as mentioned by the Dutch minister of Transportation.

Swedish carbon tax versus the Dutch excise duty: key differences

As explained by the Report of the High-Level Commission on Carbon Prices: "The carbon price is generally normalized to the amount of GHG that would lead to the same equivalent warming as a ton of CO2 over a specific period, and is specified as a price per ton of CO2 emissions (or CO2 equivalent)" (p. 9, 2017). This has been the overall reasoning behind the Swedish carbon tax. The rate has changed over time, but the taxes levied on fuel are currently set at a rate which corresponds to their carbon content (Andersson, 2019). Meaning that according to Pigouvian theory, the tax is set at an optimal level, as it captures negative externalities in its price. This illustrates the key difference with the Dutch excise duty on road transportation fuels, as its initial design was purely to generate additional revenue for the Dutch government. Although the Dutch excise duty has evolved to also discourage consumers from purchasing the products it is placed on, such as alcohol, tobacco and fuel (business.gov. 2020), the Kwartje van Kok was first and foremost a method for acquiring more income for the Dutch government.

When looking at the more specific definitions for both excise duties and taxes, the most common explanation is that a tax has a wider scope compared to a duty. Subsequently, a duty can be regarded as a subtype of taxes. Ultimately, the key difference lies within the fact that taxes are paid over wealth, income, services, sales, etc., while duties are paid over goods and financial transactions (Surbhi S, 2015). Ultimately, while their definitions and explanations may differ, a carbon tax and excise duties are relatively similar. Apart from generating revenue, they both aim (to some extend) to reduce negative externalities. An important difference however is, that a carbon tax is more specifically designed to do this, while energy preservation and environmental protection only seemed to be a side note to the government revenue that the Kwartje van Kok was supposed to generate (Barrois, 2019).

Additionally, one of the arguments in favour of carbon pricing is that it takes into account that "in making purchasing decisions, most consumers are most influenced by prices than by environmental concerns" (p. 5, Baranzini et al., 2017). However, this means that regardless of their specific design, from a consumer point of view carbon taxes and excise duties on gasoline and diesel can be regarded as similar, as they merely increase the fuel price. Ultimately, the consumers emit CO2 by means of fuel combustion every time they use their car. Thereby, if the aim is to reduce emission levels from transport, a carbon tax which affects road fuel and an excise duties on gasoline and diesel can have the same effect. However, it is important to note that because of how the excise duty is designed, the actual price is always passed on to the consumer. Currently, the European union has set a minimum of €0.36 per litre on gasoline, which is paid at the pumpstation (Tax Foundation, 2019). For a carbon tax, this has not be the case based on tax incidence, which relates to how a tax burden is distributed (Investopdia, 2021). This is precisely why Andersson (2019) has to investigate whether or not the Swedish carbon tax is actually passed on to consumers.

Emission mitigating interventions available to policy makers

In passing, the preceding paragraphs in this literature review have addressed several different policy tools, which are available to policymakers who aim to reduce GHG emissions. While carbon pricing is a popular intervention measure in the literature (Nordhaus 2008, 2013 and Weitzman 2015, 2016), it is only one aspect of the much broader toolkit policy makers have at their disposal (Goulder & Parry, 2008). Additionally, it is stressed that carbon pricing and technology policies are largely complementary and are therefore best used in combination with each other (Baranzini et al., 2017). Therefore, even within the scope of this research, it is important to look beyond just carbon pricing, to give relevant context in relation to the potential implications for policy makers.

Firstly, carbon pricing can be divided into tradeable emission permits, and carbon taxes (Andersson, 2019; Heutel, 2020). Tradeable emission permits, more commonly known as a cap-and-trade system limit "the total allowable volume of emissions in a particular time period from a specified set of sources (the so called cap on emissions), and allows economic actors to trade their emission right" (High-Level Commission on Carbon Prices. 2017). Secondly, apart from carbon pricing, tools available to policy makers include performance standards, technology mandates, subsidies for emissions reductions and subsidies for R&D relevant for emissions reductions, such as "clean" technologies (Goulder & Parry, 2008). The reason an excise duty on fuel largely escapes the literature when it comes to environmental policies (it is hardly mentioned in the High-Level Commission on Carbon Prices report), is because excise duties in principle, are not specifically designed as a policy tool. As discussed in the previous paragraph.

The use of both gasoline and diesel

Both the Swedish carbon tax and the Dutch excise duty effect the gasoline and the diesel price. Although diesel emits more pollutants per combustion than gasoline, diesel vehicles tend to be more efficient (ICCT, 2019). Which overtime led to a substitution effect of diesel for gasoline. Even though Andersson only uses gasoline consumption as a key predictor for emissions in his research, by focussing on total emissions from road transport, he is able to capture the substitution effect. As shown in figure 6. This is something earlier studies don't take into account (Andersson, 2019).

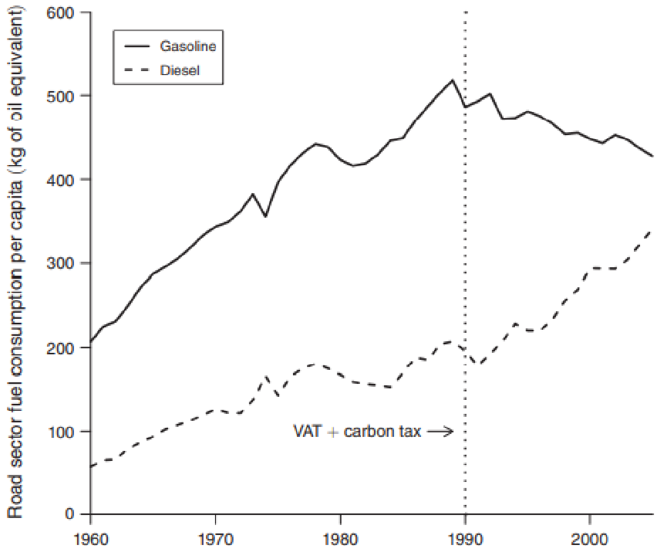


Figure 6. Road Sector Fuel Consumption Per Capita in Sweden (1960-2005) (Andersson. 2019)

Meanwhile, the Dutch excise duty on gasoline and diesel are set by the government and change independently, as shown in figure 7. The difference between the development of the excise duty pricing on diesel and gasoline could prove to pose methodological challenges. When identifying a specific gasoline excise duty increases as the policy intervention, the difference between gasoline and diesel prices means it could be difficult to isolate a specific treatment effect. Nevertheless, the Dutch excise duties make for an interesting case study. Both in relation to the causal effects on decreased CO2 emissions from transport, and its policy implications as a results of its place within the public debate.

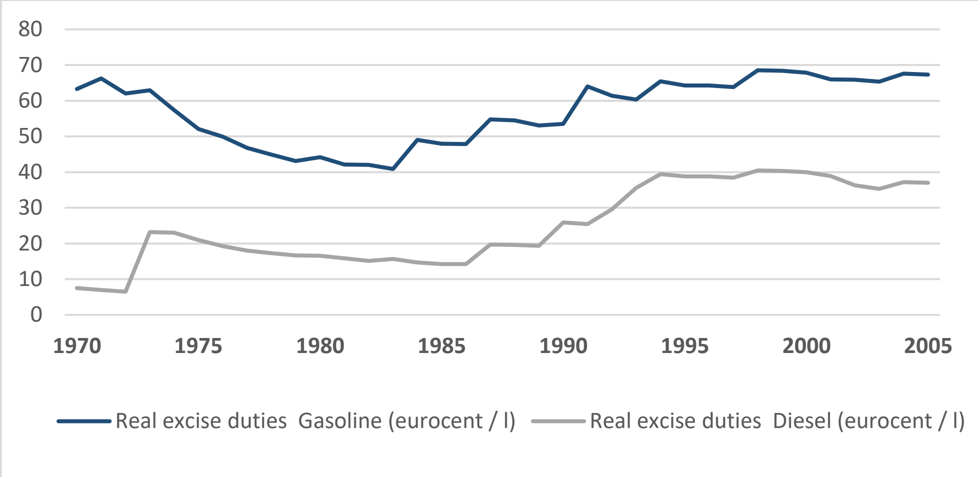


Figure 7. Side by side comparison gasoline and diesel excise duty pricing development (Bovag, 2019).

Explanatory note: *The prices are set at the 2005 level, showing the difference between the real excise duty for gasoline and diesel, over the period 1970 to 2005.*

The demand for diesel and gasoline: Insights into consumer behaviour

With regards to policy interventions designed to raise the cost of consumer goods, consumer behaviour is an important aspect. More specifically, when examining the consumer response to changes in fuel prices, you are dealing with the price elasticity of demand for fuel. The price elasticity of demand is a way to asses to what extend the level of consumption of a product changes, based on a change in the price of the same product. The price elasticity of demand is calculated as follows (Dietz, Heijman & Marks, 2015):

Price Elasticity of Demand = % Change in Quantity Demanded / % Change in Price

Necessary goods, such as fuel, are typically inelastic and therefor have a price elasticity of demand of between 0 and 1. This means that when the price changes, the demand doesn't change in a proportionate fashion. This is because when fuel prices increase, people will still have a need for the product, for example to use their car to get to work.

The literature which attempts to estimate the responsiveness of fuel consumption to changing prices is extensive, going back several decades (Gillingham, 2011). Within the more recent literature findings, Gillingham, Jenn, and Azevedo (2015) found a short-run gasoline price elasticity of driving demand of -0.10[7]. This means that when the price of gasoline rises by 10%, the demand only decreases with 1%. This indicates that the change in demand is disproportionally smaller than the change in price, pointing towards the inelasticity of gasoline. In other words, despite higher prices, people will still buy fuel because they have a need for it.

Nevertheless, the actual consumer response can differ for different individuals. When examining this heterogeneity in consumer responsiveness, more nuances appear. For example, the fuel economy and age of a vehicle influence the elasticity, with the most economical vehicles displaying entirely inelastic responses to gasoline price changes (Gillingham, Jenn, & Azevedo, 2015). Additionally, personal income, geographic and demographic variables all show to influence the responsiveness (Gillingham, 2011). Furthermore, "when gasoline prices change, either due to exogenous events or a policy, we would expect to see a response that increases as we move from the short-term to the long-term. Correspondingly, it is essential to define the time frame of any given

[7] Gillingham, Jenn, and Azevedo note how their findings are in line with the general literature.

elasticity estimate" (p. 6, Cillingham, 2011). Taking the timeframe into account is important, because consumers can adapt along two different margins, being the intensive margin (e.g. how much people actually drive) and the extensive margin (e.g. the different types of vehicles consumers use and buy). In the short-run, consumers are most likely to adapt along the intensive margin, by for example simply driving less. However, in the long-run, consumers are more likely to make significant changes along the extensive margin, for example by buying and utilizing more fuel efficient vehicles. Ultimately, in the short-run, the price elasticity of demand for fuel is therefore more inelastic than in the long-run (Cillingham, 2011). This notion is important because it also resonates with the distinction between changes in fuel prices as a result of mere market fluctuations, or as a result of a policy intervention. Retail gasoline prices are influenced to a large extend by crude oil prices and the level of supply and demand. Ultimately this means that on its own, gasoline prices tend to fluctuate (U.S. Energy Information Administration, 2020). However, policy interventions such as a carbon tax or an excise duty, designed to increase fuel prices, are much more persevering and therefor tend to have a more pronounced effect on the overall fuel demand, than simple price fluctuations as a result of normal market mechanisms. This is in part because a more persistent price change encourages adoption along the extensive margin, meaning households are more inclined to for example switch to more fuel efficient vehicles. Additionally, price changes based on policy interventions are often followed by media coverage, which could help to increase public awareness and consequently alter consumer behaviour (Davis & Killian, 2010).

3. Methodology & Data

In this chapter, the methodology which is deployed to answer the research question is elaborated on. In addition, what data has been used to perform the analysis and from what sources it has been retrieved will be detailed. Furthermore, the results from the analysis performed by Andersson in "Carbon Taxes and CO2 Emissions: Sweden as a Case Study" (2019) will be used to illustrate how the method is put to practice and the results it is able to produce.

3.2 Performing an ex post comparative case study

The goal of this research is to determine the causal effect the Dutch excise duties on fuel have had on CO2 emission from transport. Doing so will entail an ex post empirical research, looking at the emission levels from transport in the Netherlands with policy intervention and without. Thereby establishing the actual treatment effect. However, in order to do so, two scenarios must be created: One with the intervention and one without, to allow for a comparative study. In doing so, the challenge lies in creating a scenario without the intervention, which is able to give a good representation of how Dutch C02 emissions form transport would have evolved without the influence of the excise duties on fuels. Reality however is that there is only one scenario, being the Netherlands with the policy measure. Thus a comparative case needs to be constructed. Two different methods exist that allow for such a construction by means of a control group, being the Difference-in-Difference Method (DiD) and the Synthetic Control Method (SCM).

The Difference-in-Difference is a research design that allows for causal effects to be estimated. The method has a long history, dating back to 1855, when it was first used to in a research studying the transmission of cholera in London. Over time, the method has been applied in different fields, such as psychology (Lechner, 2011). Currently, the method is very popular for comparative case studies in general and the most commonly used method for evaluating the effects of carbon taxes. The DiD approach is straightforward. First, a control group that has not been effected by the policy intervention is put together. Secondly, a counterfactual is constructed, by means of an unweighted average of the outcome variable from the control group. Consequently, the "treatment effect" (in this case an emission reduction) is identified by evaluating the change in the outcome variable pre- and posttreatment, both for the treated unit and the control group (Andersson, 2019). The widespread use of the DiD method is largely based on its simplicity (Bertrand, Duflo, & Mullainathan, 2002). This simplicity entails that the sample group is averaged, as opposed to the synthetic control method, which attributes weights to the countries contributing to the sample group. The difference is apparent in Anderson's results, when looking at a side by side comparison of the OECD sample and the synthetic version, with the latter being far more accurate in tracking the pre-treatment emission levels (figure 8). Therefore, this research will utilize the Synthetic Control Method, in favour over the Difference-in-Difference method

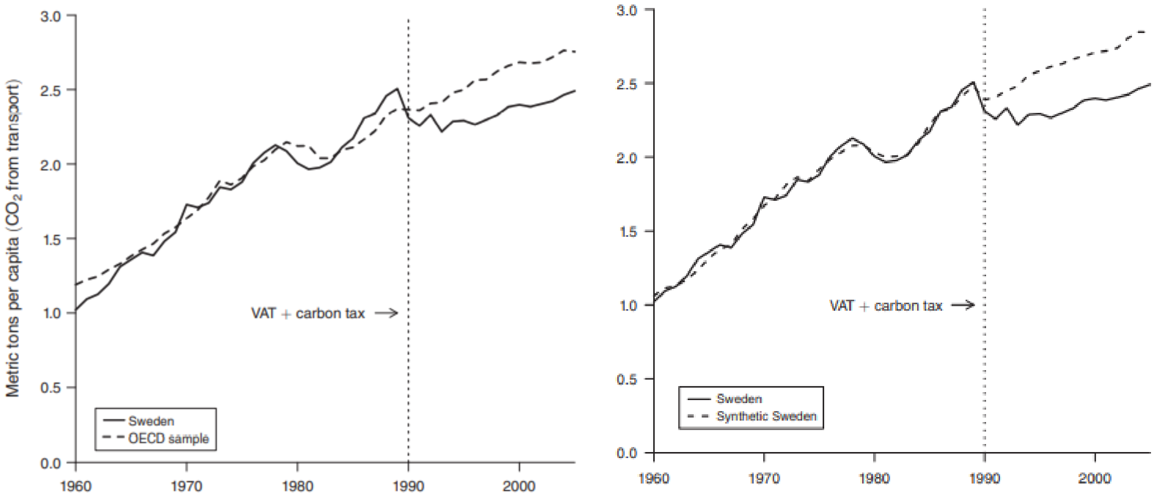


Figure 8. Path Plot of Per Capita CO2 emissions from transport (1960-2005); Sweden,. OECD average and Synthetic Sweden (Andersson. 2019)

3.1.1 Development of the Synthetic Control Method

The Synthetic Control Method was first developed in a 2003 study, looking to define the effect of terrorism on aggregate income (Abadie & Gardeazabal, 2003). As defined by Cunningham (2017), the "synthetic controls models optimally choose a set of weights which when applied to a group of corresponding units produce an optimally estimated counterfactual to the unit that received the treatment. This counterfactual, called the 'synthetic unit,' serves to outline what would have happened to the aggregate treated unit had the treatment never occurred." The method of applying weights is a simple, yet very powerful generalization of the DiD method (Cunnigham, 2017). Unsurprisingly, it has become very popular in empirical research, across a number of disciplines. In 2017, it was even heralded as "arguably the most important innovation in the policy evaluation literature in the last 15 years" (p. 9, Athey & Imbens, 2017). Nevertheless, the method does have certain data and contextual requirements, as well as methodological issues which relate to the empirical application of the synthetic controls (Abadie, 2020).

When looking at traditional regression analysis techniques, the requirements are larges samples and numerous observed instances of the event or treatment of interest. This leads to them being poor candidates to estimate the causal effects of unusual events, such as policy interventions on aggregate units. Additionally, comparative case studies are based on the notion that the effect of an policy or intervention can be deduced from a comparison between the development of the dependent variable of interest, between an case or unit exposed to the intervention and a collection of unites or cases, which are both similar to the affected unit, but unaffected by the actual intervention. This form of analysis has been widely applied, across different fields. However, it is not without certain disadvantages and weaknesses. For example, the actual composition of the comparison unites is not formalized and frequently depends on informal statements of affinity between the affected and comparison units. Furthermore, if it is the case that the units of observation are comprised of several aggregate entities, as for example regions or countries, it can be so that no single unit on its own may provide a solid comparison for the actual affected unit (Abadie, 2020). In contrast "the synthetic control method is based on the idea that, when the units of observation are a small number of aggregate entities, a combination of unaffected units often provides a more appropriate comparison than any single unaffected unit alone. The synthetic control methodology seeks to formalize the selection of the comparison units using a data driven procedure" (p. 4-5, Abadie, 2020).

3.1.2 Formal aspects of the Synthetic Control Method

The setting: Suppose that with regards to the sample group, we obtain the relevant data for $J + 1$ units, then: $j = 1, 2, ..., J + 1$. We can then assume that the first unit (j = 1), is the unit affected by the policy intervention (the treated unit), without the loss of generality.[8] The donor pool which will combine to form the synthetic unit will then be $j = 2, ... , J + 1$. Thereby forming a sample group of units unaffected by the policy intervention being studied. Furthermore, the assumption is made that the data spans T periods, with the first T_0 periods being before the introduction of the treatment. For every unit j, and time t, we observe the outcome of the dependent variable Y_{jt}, which in this case is the emission level of CO_2 from transport. Additionally, as already established, the SCM makes use of a set of key predictors, k, of the outcome.

Ultimately, for every time period t, and each unit t, the potential response of the outcome variable without intervention will be defined as Y^N_{1t}. In response, the affected unit ($j = 1$), and the post intervention period ($t > T_0$), the potential response of the outcome variable will be defined as Y^I_{1t}. Consequently, the effect of the policy measure on the affected unit, within the sample period will be (Abadie, 2020):

$$\tau_{1t} = Y^I_{1t} - Y^N_{1t}.$$

Estimation: The aim of the comparative case study is to reproduce Y^N_{1t}, being the value of the dependent variable, which would have been observed had the intervention not been implemented for the affected unit. Where the SCM differs from more traditional comparative case studies is that it is based on the notion that in order to generate the most accurate approximation of the characteristics of the affected unit, a combination of units within a sample group are better equipped that a single unit alone. Additionally, the units within the donor pool are weighted to further optimize their predictive power. Ultimately, the SCM can therefore be represented by a J x 1 vector of weights:
$\boldsymbol{W} = (w_2, ..., w_{J+1})$. Which leads to (Abadie, 2020):

$$\widehat{Y}^N_{1t} = \sum_{j=2}^{J+1} w_j Y_{jt},$$

and

$$\widehat{\tau}_{1t} = Y_{1t} - \widehat{Y}^N_{1t}.$$

"The goal of the synthetic control is to approximate the trajectory that would have been observed for Y1t and t > T0 in the absence of the intervention" (p. 8, Abadie, 2020). Thus, it follows logically that the weights are chosen in such a manner that they result in a synthetic version which best achieves this aim. This can be achieved by chosen them so that they minimize:

$$\|\boldsymbol{X}_1 - \boldsymbol{X}_0\boldsymbol{W}\| = \left(\sum_{h=1}^{k} v_h \left(X_{h1} - w_2 X_{h2} - \cdots - w_{J+1} X_{hJ+1}\right)^2\right)^{1/2}$$

[8] "Without the loss of generality" is a term used in proofs, to illustrate that an assumption is being made, without it introducing new restrictions to the actual problem ("Art of Problem Solving," 2012)

In which case X_1 is the treated unit, X_0W is the synthetic unit and k are the predictors. Additionally, the constraint which remains is that the weights $w_2, \ldots, w_{J+1}$ *are positive and* sum up to one. Consequently, the estimated treatment effect for the treated unit at time $t = T_0 + 1, \ldots, T$ is (Abadie, 2020):

$$\widehat{\tau}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}.$$

The potential choice of weights $\boldsymbol{V} = (v_1, \ldots, v_k)$ results in a synthetic control $\boldsymbol{W}(\boldsymbol{V}) = (w_2(\boldsymbol{V}), \ldots, w_{J+1}(\boldsymbol{V}))$. Ultimately, as iterated by both Anderson (2019) and Abadie (2020) the weights $\boldsymbol{W}$ and $\boldsymbol{V}$ are chosen in such a manner that mean squared prediction error (MSPE) of the dependent variable are minimized, over the entire pre-treatment period.

3.1.3 Contextual requirements for the Synthetic Control Method

In order for the Synthetic Control Method to perform well, certain contextual requirements must be met. The following requirements that will be addressed apply not just to the SCM, but to comparative case studies in general. Ultimately, these contextual requirements will help to determine the appropriateness of the SCM for a given evaluation, as well as providing ways to alter the analysis in a situation when the conditions aren't fully met (Abadie, 2020).

Size of the effect and volatility of the outcome: As already established, the general goal of comparative case studies is to determine the effect a policy measure on the unit in question. In this case, the excise duty on fuel for the Netherland. Typically, comparative case studies aim to achieve this by focussing on a single, or a small number of treated units. However, "the nature of this exercise, which focuses on a single treated unit or on a small number of treated units, indicates that small effects will be indistinguishable from other shocks to the outcome of the affected unit, especially if the outcome variable of interest is highly volatile" (p. 26 Abadie, 2020). However, when combined with a scenario in which the effect of the intervention is also relatively small, or of the same scale as the volatility, the actual effect on the outcome will be difficult to detect.

Availability of a comparison group: It is within the essence of comparative case studies that statistical inference based on these methods is dependent on the availability of a good fitting comparison group. On the implications concerning this contextual requirement is that the units in the comparison group haven't enacted similar treatments or policies during the sample period. Based on this requirement Andersson excluded Finland, Norway and the Netherlands. Consequently, it is also precisely the reason that Sweden will not be included in the sample group within this research. Additionally, the comparison group should be constructed based on similar characteristics to those of the affected unit. Therefore, Andersson choose an original sample of OECD countries, from which he then eliminated for example Ireland, based on the countries extraordinary economic growth during the 1990's.

No anticipation: The SCM research designs makes use of time variation in the dependent variable to causally estimate the effect of an enacted policy measure or treatment. However, the method may be biased when certain elements of the treatment are implemented (in part), before the actual treatment. In the case of the Dutch excise duty on fuel, this will be an important aspect. As figure 5 has shown that the excise duties didn't switch on overnight. They have been around since the 1930's and have slowly mutated over time. Taking this into account will therefore be an important aspect of the analysis. A way to mitigate this is by backdating the intervention.

No Interference: The no interference requirement relates to the fact that there shouldn't be spill over affects between units, to avoid any form of bias. In other words "units' outcomes are invariant to other units' treatments" (p. 28, Abadie, 2020).

Convex hull condition: The convex hull condition quite simply means that once the synthetic control unit is constructed, the differences between the characteristics of the affected unit and the synthetic version are small.

Time horizon: It can take time for the effects of an intervention to become apparent. The most evident way to mitigate this is of course to wait for the effects of the enacted treatment to appear. This is especially relevant for this research, as the literature review has shown how consumers tend to respond more to fuel price changes in the long-run (Cillingham, 2011).

3.1.4 Data requirements for the Synthetic Control Method

When it comes to data requirements, a breakdown of three different criteria can be made. Much like the contextual requirements, these specific data requirements aren't exclusive to synthetic control methods but apply to comparative case studies in general (Abadie, 2020). These requirements are as followed:

Aggregate data on predictors and outcomes: In order to be able to perform, the synthetic control method relies on data for the outcome of the dependent variable and the key predictors, for both the unit affected by the treatment and the comparison group which consist of units unaffected by the same treatment. For data at an nationally aggregated level, such as GDP levels, government agencies, multilateral organizations and private entities often provide good quality data. With good examples being the World Bank Indicators, the Penn World Table and the Dutch CBS (Centraal Bureau voor Statistiek).

Sufficient pre-intervention information: The validity of the predictive power of the synthetic control method lies in its ability to accurately track the dependent variable levels, pre-treatment. To put it plainly, when the pre-treatment period is relatively short, a close fit of the predictor variables can be obtained spuriously. Meaning that the SCM set-up might appear to perform well, while actually producing a highly inaccurate prediction of post-treatment levels. This means that for the validity and accuracy of the results it is of paramount importance that ample data for both the affected unit and unaffected sample group is collected.

Sufficient post-intervention information: This data requirement can be derived from the *Time horizon* contextual requirement in the previous section. The post-intervention data must both be relevant for the policy measure which is being studied and included outcome measures which are potentially affected by the enacted policy. If no forward looking measures of the dependent variable are available, this could cause issues when the effect of the policy is likely to arise gradually over time. Throughout the execution of the synthetic control method, the appropriateness of both the method and the data input will be iteratively evaluated, in relation to the contextual and the data requirements.

3.1.5 The Synthetic Control Method in practice

The difference the applied weights in the SCM make, is illustrated in table 1, taken from Andersson's research (2019). From table 1, the same conclusion can be drawn as from figure 8, as it shows the ability of synthetic Sweden to closely mimic both the key predictors levels of Sweden, and the pre-treatment emissions levels. Especially in comparison to the average OECD sample

Variables	Sweden	Synth. Sweden	OECD sample
GDP per capita	20,121.5	20,121.2	21,277.8
Motor vehicles (per 1,000 people)	405.6	406.2	517.5
Gasoline consumption per capita	456.2	406.8	678.9
Urban population	83.1	83.1	74.1
CO_2 from transport per capita 1989	2.5	2.5	3.5
CO_2 from transport per capita 1980	2.0	2.0	3.2
CO_2 from transport per capita 1970	1.7	1.7	2.8

Table 1. CO2 Emissions from Transport Predictors Means before Tax Reform (Andersson. 2019)

Explanatory note: *In Andersson's (2019) experimental set up, all the key predictors are averaged over the pre-treatment period of 1980 to 1989. Additionally, the lagged CO2 emission variables are chosen for the years 1989, 1980 and 1970. Furthermore, the Sweden column are the real values for Sweden, the Synth. Sweden column shows the values that are produced by the synthetic unit, as constructed by the synthetic control method, and the OECD sample column shows the population weighted averages for the countries in the sample group.*

The strong similarities between Sweden and Synthetic Sweden also illustrate the discrepancy between Sweden and the averaged OECD sample. However, while the match between Sweden and its synthetic version are apparent, a relative large difference can be spotted within the Gasoline Consumption per Capita key predictor. However, this can be explained by the fact that the synthetic control method assigned a rather low weight to this key predictor (0.010).

In addition to the key predictors, the countries within the sample group are also weighted. As extrapolation is not allowed within the synthetic control method, all weights are between 0 and 1, and sum up to 1 exactly. Within Andersson's analysis, the best reproduction of Sweden's CO2 emission levels from transport is constructed mostly from Belgium, Denmark, Greece, New Zealand, Switzerland and the United States. As can be seen in table 2. By far the largest contribution to synthetic Sweden comes from Denmark, which, as Andersson reasons, isn't unsurprising. Considering that Denmark and Sweden share many similar social and economic characteristics.

Country	Weight	Country	Weight
Australia	0.001	Japan	0
Belgium	0.195	New Zealand	0.177
Canada	0	Poland	0.001
Denmark	0.384	Portugal	0
France	0	Spain	0
Greece	0.090	Switzerland	0.061
Iceland	0.001	United States	0.088

Table 2. Country Weights in Synthetic Sweden (Andersson. 2019)

Explanatory note: *As discussed in the paragraph 3.1.2. Formal aspects of the Synthetic Control Method, the total of all weights sums up to 1.*

Ultimately, by attributing weights to the most relevant sample country and utilizing the key predictors as best as possible, the synthetic control method is able to closely track pre-treatment levels of the dependent variable. This in turn validates the models ability to accurately predict wat the post-treatment dependent variables had been, had the treatment not been enacted. This ability is highlighted in figure 9, which plots the difference between Sweden and Synthetic Sweden, for both pre- and post-treatment levels within Andersson's research (2019).

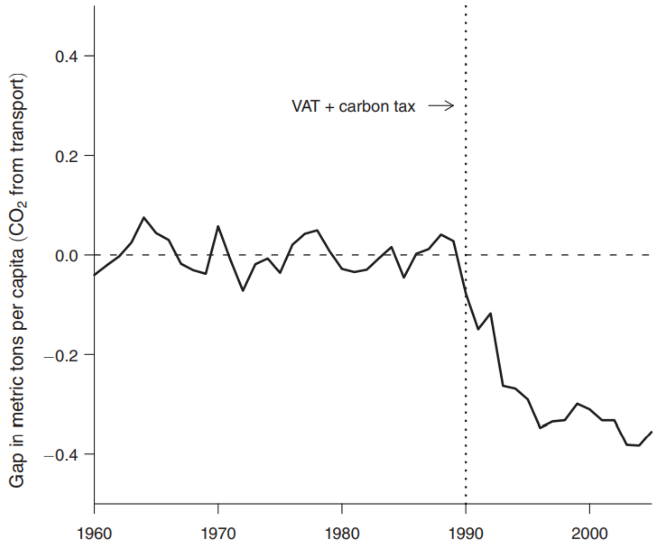


Figure 9. Gap in Per Capita Emissions From Transport Between Sweden and Synthetic Sweden (Andersson. 2019)

Explanatory note: *This graph is plotted by subtracting the emission level values from Sweden, with those of the emission levels of the synthetic unit.*

3.1.6. Advantages and challenges surrounding the Synthetic Control Method

As established over the course of the previous sections and chapters, the synthetic control method is able to leverage key predictors and the attributing of weights to optimize its predictive power. The results of which, are clearly shown in figure 9. Nevertheless, as with any serious application of statistical procedures, the level of diligence applied to application of the method are decisive for the eventual credibility of the results. Furthermore, taking into account both the data and contextual requirements play a key role (Abadie, 2020). As already established, numerous challenges will arise when applying the method to the Dutch case study. With the contextual requirement of *No anticipation* being a good example. As noted by Abadie in 2020, who first pioneered the method in 2003, "mechanical applications of synthetic controls that do not take into account the context of the investigation or the nature of the data are risky enterprises" (p. 46, 202). Therefore, not only identifying challenges as the present themselves, but also being extremely aware of all the interacting elements within the analyses will be a key part of this thesis. As they should be for all scientific research.

3.2 Data usage and availability

As addressed in the previous section, the data and contextual requirements are of paramount importance. Within both, the choice of sample period or 'time horizon' is crucial, both ample pre- and post-treatment data is needed (Abadie, 2020). The dataset Andersson employs goes from 1960 till 2005. The Swedish tax reform was implemented in 1990-1991. Consequently, the dataset should work for the Dutch treatment, as the Kwartje van Kok was enacted in 1991. However, the first real price increase was in 1984. Evaluating the effect of this increase by means of the SCM will mean a careful and mindful application, as this could mean the pre-treatment data isn't sufficient.

Additionally, the motivation to have the dataset not go beyond is based on the fact that 2005 was "the start of the European Union Emissions Trading System (EU ETS), one of the main building blocks of the EU's climate change policy, and also because many countries in the sample implemented carbon taxes or made marked changes to fuel taxation from 2005 onward" (p. 8, Andersson, 2019). Ultimately, this means that the sample period provides 14 years post-treatment data and 30 for the 1991 treatment and 24 for the 1984 treatment.

3.2.1 Defining the sample group

One of the key points of the synthetic control method is of course the construction of the sample group. Andersson initially starts with a sample group of 25 OECD countries, including Sweden. This selection is simply based on the 24 countries which were OECD members in 1990 (the treatment year in Andersson's research), with the addition of Poland. Who became a member in 1996 and is in close geographical proximity to Sweden. The OECD is of course first and foremost an organisation focussed on Economic Cooperation and Development, which contributes to the similarities between the member states. With the additional benefit that OECD data is generally of high quality, making this a original sample group a good starting point for the selection of the comparison units.

As clearly addressed in the previous section, being diligent in the application of the method is crucial for the actual credibility of the results. A key point within the contextual requirements is the *Availability of a comparison group*, build upon the notion that the elements within the comparison unit most not have enacted a policy which relates to the pricing of fuels for transportation. Based on this criteria, Finland, Norway and the Netherlands are excluded by Andersson. Similarly, this research will exclude Finland, Norway and Sweden. Furthermore, the comparison group most showcase strong similarities on the key predictors. Therefore, countries which show unordinary behaviour in relation to the key predictors and dependent variable are excluded. Based on this notion, Austria and Luxembourg are excluded due to "fuel tourism", Turkey based on extremely low pre-treatment emission levels, and Ireland based on their unusual economic development in the 1990's. Since the Dutch case study will look at the same sample period as the Swedish case study (1960-2005), and at a similar treatment[9], the arguments put forward by Andersson for the construction of his sample group still hold. Ultimately, this results in a sample group consisting 14 different countries, being Australia, Belgium, Canada, Denmark, France, Greece, Iceland, Japan, New Zealand, Poland, Portugal, Spain, Switzerland and the United States.

However, Andersson gives no further insights into what the policies enacted by Finland, Norway and the Netherlands are, which give basis for their exclusion[10]. Norway for example enacted

[9] As discussed in the literature review, the Dutch excise duty and the Swedish carbon tax are similar enough to be regarded as comparable treatments within the scope of the synthetic control method and this research

[10] I reached out to Andersson with this question. However, at the time of writing, I have not yet received a response.

a carbon tax in 1991 (Bellona Europe, 2021). However, what Andersson fails to take into account is that apart from a more general carbon tax, numerous countries in his sample group implemented an excise duty price on gasoline. Starting in 1993, back when the European Union only had twelve member states, the EU has been setting minimum tax rates for petrol and diesel used in road transportation (European Federation for Transport and Environment, 2011). Data on the historical development of excise duty pricing is generally hard to come by. However, figure 10 gives an overview of several countries within the sample group. The data for figure 10 is based on a combination of the European Commission's Weekly Oil Bulletin and national databases.

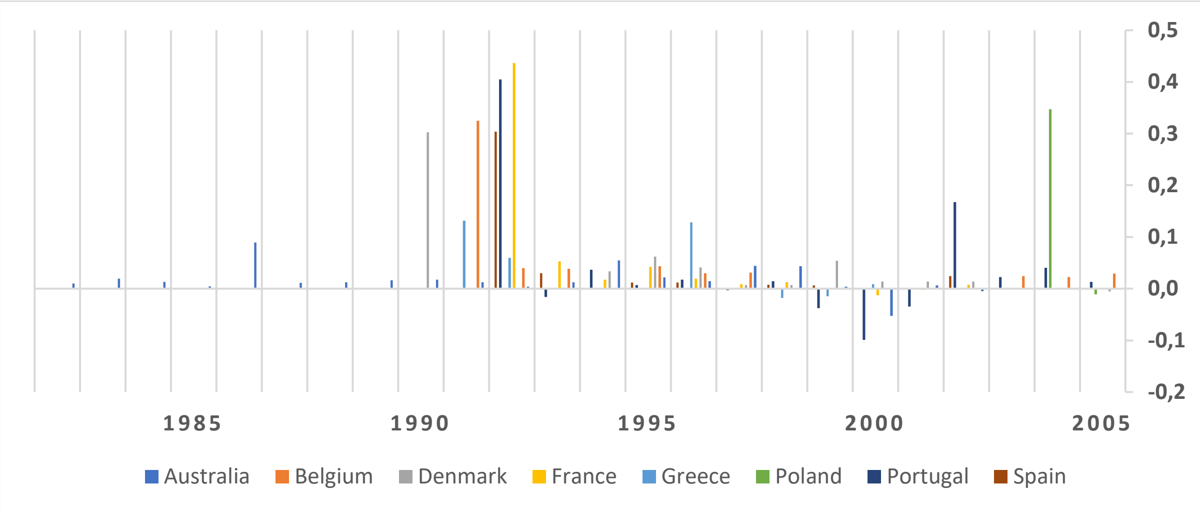


Figure 10. Overview selected sample group countries year on year change in excise duty pricing on gasoline (European Commission 2019; Australian Taxation Office, 2021)

Explanatory note: *All excise duty prices on gasoline are converted to euro's. Additionally the year on year change is simply calculated by subtracting the value of the excise duty in a given year, with the value of a preceding year.*

Major changes in the year on year changes of the excise duty pricing on gasoline are especially noticeable in the early 1990's, which is something that violates the *Availability of a comparison group* contextual requirement. Most likely, this will lead to an underestimation of the actual effect the Dutch excise duty on gasoline has had on emissions from road transport, as it will be compared to a synthetic version which includes countries enacting similar policies interventions.

3.2.2 Synthetic Control Method Data Input

The data that is used as input for the synthetic control method consists of the dependent variable, and the key predictors which are used to predict the values post treatment for the dependent variable. In this case the dependent variable is the CO2 emissions from transport per capita, measured in metric tons. For all countries within the dataset as composed by Andersson, "transport emissions are calculated based on empirical data on the sale of transport fuels and their carbon content, with the data typically available from national statistical agencies" (p. 8, 2019). Focussing on CO2 emission form the combustion of all transport fuels, the potential substitution between different fuels can be captured. Table 3. gives an overview of the four key predictors used in the SCM. Additionally, Appendix A. provides a complete overview of all the different metrics and their sources used by Andersson in his research.

Key predictors	Description	Source
CO2 emissions from transport	Measured in metric tons per capita.	The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.
Motor Vehicles (per 1000 people)	The number of motor vehicles per 1000 people, within a given country	Dargay, Gately, and Sommer (2007), ”Vehicle Ownership and Income Growth, Worldwide: 1960-2030”.
Gasoline and Diesel consumption per capita	Measured in kg of oil equivalent	The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.
Urban Population	Measured in percentage of total population of a given country	The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.

Table 3. Overview of key predictors (Andersson, 2019)

Explanatory note: *the Motor Vehicles are based on the research “Vehicle Ownership and Income Growth, Worldwide: 1960-2030”, by Dargay, Gately and Sommer (2007). In order to obtain the datasets containing the per country motor vehicle levels, Andersson had personal contact with the authors. In turn, I had personal contact with Andersson to obtain the input he used for his datasets*

3.2.3. Dutch fuel price components

The introduction of the excise duty and the 1991 price increase were in part based on the goal to discourage the use of cars. However, in order to determine how consumers have reacted to prices as the gas station, it is important to distinguish the actual elements of the real gasoline price. Figure 11 showcases the historical development of the real price of gasoline pre-taxes (euro / litre, with 2005 as base year)[11], the real excise duty (euro / litre), and the contribution of the BTW (or “VAT” in English). Within this formula, the *real gasoline price* is the price levied by levied by the gasoline companies. Upon this, the excise duty is added. The resulting sum is multiplied by the *BTW percentage,* which then in turn leads to the *Total real gasoline price* consumers pay at the pump.

$$Total\ real\ gasoline\ price = (real\ price\ pre\ taxes + real\ excise\ duty) * BTW\ percentage$$

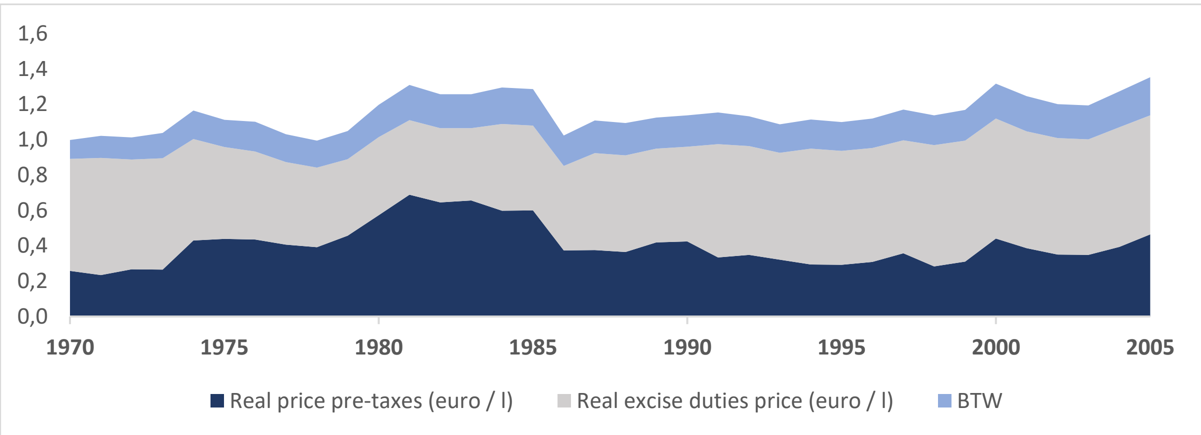


Figure 11. Dutch fuel prices historical breakdown, euro p litre (CBS, 2010; Bovag, 2019)

[11] The real prices with 2005 as base level are calculated using the Dutch consumer price index (CBS, 2021)

3.3 Choosing between policy interventions: "Kwartje van Kok" versus the 1984 real increase in excise duty pricing

From figure 5. we know that while the "Kwartje van Kok" in the early 1990's received the most attention in the public and political debate, the Netherlands also saw two significant increase in the excise duty on gasoline in both 1984 and 1987. (See Appendix B for an overview of the yearly increase of the real excise duty on gasoline price). This means that the Netherlands has several different policy measures, at different times. In relation to the proper use of the SCM, this poses a problem in relation to the contextual requirements of the method. Particularly to the '*no anticipation'* requirement (as discussed in 3.1.3 Contextual requirements for the Synthetic Control Method). As the method makes use of time variation in the dependent variable to causally estimate the effect of the implemented policy measure, the method can be biased when the policy measure isn't implemented at once, but instead introduced overtime. This is the case for the Dutch excise duty on gasoline, which has originally been implemented in 1931. However, when adjusting the price to 2005 levels, figure 5 shows how the 1984 price change can be regarded as the first significant increase in relation to the preceding years. In contrast, 1991 sees several prior instances in which the excise duty has been increased, meaning it violates the no anticipation requirement.

Apart from the choice of the actual policy intervention, the construction of the synthetic version based on the identified sample group is also subject to the contextual requirements of the SCM. With it being of great importance that the group is composed of units that haven't enacted similar treatments or policies during the sample period. However, figure 10 established that numerous countries within the sample group increased the excise duty pricing on gasoline during the sample period, especially during the early 1990's. Thereby violating the contextual requirements relating to the *Availability of a comparison group.* The most noticeable changes are in 1990 for Denmark, who enacted a 30 eurocent per litre increase, 1991 for Belgium and Greece with 32 and 13 eurocents increases respectively, and in 1992 with France, Portugal and Spain increasing 44, 40 and 30 eurocent respectively[12]. As the Kwartje van Kok was enacted in 1991, any change made in 1990 and 1991 within the sample group will result in a diminished predictive power of the synthetic version post-treatment, while any changes made after 1991 will most likely result in an underestimation of the Dutch treatment effect.

Ultimately, when taking into account the contextual requirements of the Synthetic Control Method, it makes sense to look at the 1984 increase, as this policy intervention has both less 'anticipation' then the 1991 intervention, and the sample group will be more likely to exercise more predictive power and less of an underestimation of the actual treatment effect in the years immediately following the treatment. Therefore, from this point on the research will recognize the 1984 excise duty increase as the policy intervention being studied.

[12] The different adaptions from local currencies to the Euro have been taken into account. Ultimately, all excise duty prices are adjusted to euro prices, based on the currency exchange rate at the time of a countries adoption of the euro.

4. Analysis & Results

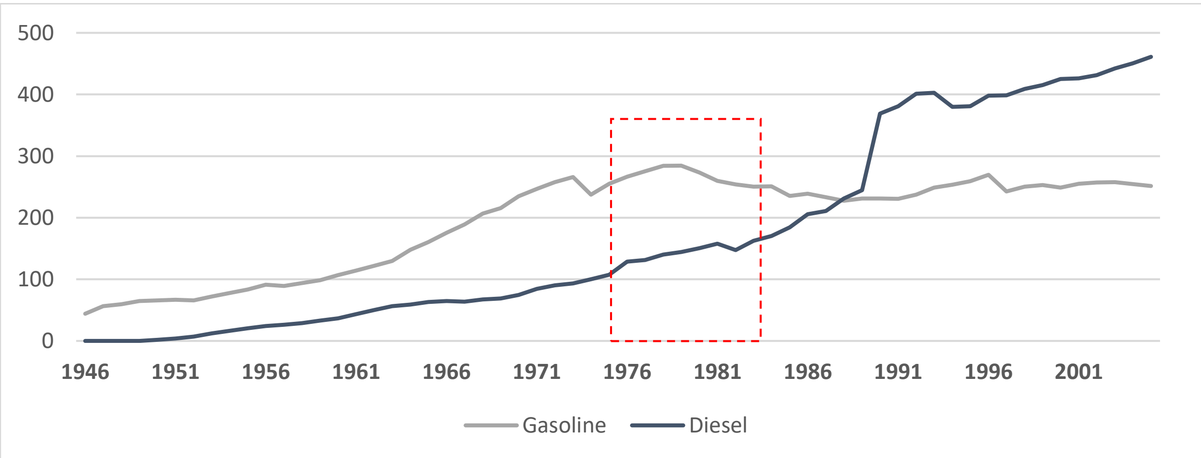
Using the synthetic control method as research method, with the 1984 excise duty price increase as policy intervention, a cumulative reduction of 56.9 million metric tons of CO2 is realized over the period 1984 to 2005. This equates to an averaged yearly per capita reduction of 0.170 metric ton. How these results came to be will be detailed in this chapter. Additionally, the final paragraph will serve as a conclusion to the chapter, by also addressing the overall validity of the results.

4.1 Setting up the Synthetic Control Method

The following paragraph will detail how the set-up for the synthetic control method is designed, while motivating the different choices that have been made which ultimately lead to the construction of a 'synthetic' Netherlands. For the execution of the synthetic control method, both Andersson and I make use of a statistical package, written for RStudio, called 'Synth' (Abadie, Diamond, and Hainmueller 2010).

4.1.1 Revaluating the key predictors for CO2 emissions from road transport

As the dataset utilized in this research is based on the one composed by Andersson (2019), the key predictors have the same characteristics as within his research. Being that "GDP per capita is purchasing power parity (PPP)—adjusted and measured in 2005 US dollars. Gasoline consumption is measured in kilograms of oil equivalent. Urban population is measured as percentage of total population. CO2 emissions are measured in metric tons" (p. 13, Andersson), as shown in table 3 of the previous chapter. However, the use of gasoline as a key predictor is not clearly motived by Andersson. This raises two questions. The first being that the argument can be made that gasoline consumption is driven, to some extent, by the policy intervention and thus is not exogenous. Additionally, in the years prior to 1984, Dutch gasoline consumption was significantly lower than the OECD mean. A reason for the relatively low gasoline consumption in the Netherlands during this period could be the rate at which the Dutch switched to Diesel, as shown in figure 12. The different diesel adoption rates within the sample group means that only using gasoline consumption per capita as a key predictor could lead to an uncomplete analysis[13].



[13] The highlighted period between 1975 and 1983 is the period over which the key predictors are averaged in the execution of the synthetic control method. This means that the shift from gasoline to diesel in this period is important to take into account.

Figure 12. Historical Development Gasoline and Diesel Consumption per Capita

In relation to the synthetic control method, the motivation for the use of individual key predictors should be well established. This is because the sum of the assigned weights always sums to 1, meaning that when a key predictor is assigned a certain weight, it is always at the expense of another. Therefore, exploring the influence of gasoline consumption as a key predictor, as well as the potential influence of diesel consumption will prove to give relevant insights. Exploring these hypothesis leads to the following conclusions:

Including Diesel consumption per capita as key predictor

In order to determine if the Dutch adoption of diesel, at the expense of gasoline consumption during the averaged prediction period within the synthetic control analysis (1975-1983), has an impact on the outcome of the method, diesel consumption per capita is also incorporated as a key predictor. Leaving all the other parameters constant[14], it shows that including both gasoline and diesel consumption as key predictor means that the synthetic version is better able to reproduce the pre-treatment emission levels of the Netherlands, as compared to the experimental set-up which only included gasoline consumption. The validity of the results from the Synthetic Control Method are to a large extend based on the pre-treatment similarities of the emissions levels, for the Netherlands and the synthetic counterpart. This means that adding diesel consumption as key predictor leads to more trustworthy predictions. However, it should be noted that an excise duty is also levied on diesel, albeit much smaller compared to gasoline. Nevertheless, the excise duty on diesel is increased in both 1987 and several times in the early 1990's, as can be seen in figure 7. These increases could inspire consumers to decrease not only their gasoline but also their diesel consumption. When examining the 1984 gasoline excise duty increase, this means that the treatment effect could be overestimated.

Excluding both diesel and gasoline consumption per capita as key predictors

Despite the fact that including both diesel and gasoline consumption as key predictors produces promising SCM results, a good argument can be made for their exclusion as key predictors. This is because the excise duty on fuel is incorporated in the retail price paid by consumers and fuel consumption is to a large extend driven by its price. Therefore, gasoline consumption per capita can be regarded as driven by the policy measure, which means it is not exogenous. This means that the inclusion of fuel consumption as a key predictor seriously violates the validity of the research. In order to mitigate this, both gasoline and diesel consumption are excluded as key predictors. Instead, gasoline consumption is included ad lagged variable[15]. Furthermore, within this experimental set-up, the synthetic unit is able to accurately track the Dutch pre-treatment emission levels. Ultimately, this methodological setup is able to produce results based on a pre-treatment MSPE value of 0.0018. The MSPE value focusses on the gap between the pre-treatment emission levels of the Netherlands and the synthetic unit. This entails that the predictive power of the synthetic control methods is most valid when the mean squared regression error is minimized, without violating the contextual and data requirements of the method. Compared to the other experimental set-ups, excluding both diesel and gasoline consumption as key predictor, and adding gasoline consumption as lagged variable produces the same MSPE value as when both diesel and gasoline consumption are included as key predictor and not as lagged variable. Ultimately however, the most important fact is that excluding the fuel consumption variables as key predictors means that the experimental set-up is much less biased.

[14] Changes in for example the lagged years did not result in a better result.

[15] Including diesel consumption as lagged variable does not yield better results.

4.1.2 Construction of the synthetic Netherlands

The experimental set-up should focus on minimizing the MSPE value, while strictly adhering to the contextual and data requirements. This is the case when the original set-up as proposed by Andersson, is modified by excluding gasoline as a key predictor. Instead, gasoline consumption is added as lagged variable, for the years 1983 and 1970. Additionally, CO2 emission is used as lagged variable for the years 1983, 1980 and 1970. Furthermore, the key predictors are averaged over a pre-treatment period, which in this research is the period 1975-1983. Based on the resulting MSPE value and the more stringent adherence to the method requirements, the analysis from this point on will be performed using the aforementioned combination of parameters.

Table 4. shows the composition of Synthetic Netherlands, which is largely based on Denmark (0.646), Japan (0.140), Portugal (0.131), Iceland (0.060), and Switzerland (0.014). Additionally, Poland (0.008) and the United States (0.001) make up the rest of the sample group. The remaining sample countries all have negligible weights attributed to them.

Weights	Sample country	Weights	Sample country
0.000	Australia	***0.140***	**Japan**
0.000	Belgium	*0.000*	New Zealand
0.000	Canada	***0.008***	**Poland**
0.646	**Denmark**	***0.131***	**Portugal**
0.000	France	*0.000*	Spain
0.000	Greece	***0.014***	**Switzerland**
0.060	**Iceland**	***0.001***	**United States**

Table 4. Country Weights in Synthetic Netherlands with Diesel included as key predictor

Explanatory note: *Once again the sum of all attributed weights to each different country amounts to 1.*

As can be seen from table 5 the Synthetic Netherlands is better able to reproduce pre-treatment levels for most key predictors, as well as the lagged years. However, there are still noticeable difference between the key predictor levels for the Netherlands and the synthetic version. Most noticeable is the fact that the urban population levels of the synthetic version are farther away from the actual Dutch levels than the OECD mean. This however can be explained by the fact that this key predictor receives a negligible weight and is there for the least important in predicting the trajectory of the dependent variable. Furthermore, it is noteworthy that the method puts heavy emphasize on the lagged years, as opposed to the key predictors. In total, the five lagged years receive 99.5% of the total assigned weight. Additionally, the lagged years for gasoline consumption show the large difference between consumptions levels in the Netherlands and the OECD mean. In 1970, the gasoline consumption in the averaged sample group was 50% higher than in the Netherlands. Nevertheless, the synthetic version is able to closely mimic the gasoline consumption levels. Which is remarkable, considering how the synthetic version is composed from the OECD sample.

	Weights	Netherlands	Synthetic NL	OECD mean
Key predictors				
GDP per capita	0.002	18765.2	17701.4	17102.6
Vehicles p. 1000	0.002	325.0	302.2	347.8
Urban population	0.000	64.5	76.7	73.8
Lagged years				
CO2 from transport 1983	0.121	1.5	1.5	2.0
CO2 from transport 1980	0.134	1.6	1.6	2.1
CO2 from transport 1970	0.399	1.2	1.2	1.6
Gasoline consumption 1983	0.110	250.0	253.0	413.2
Gasoline consumption 1970	0.231	232.4	234.5	348.2

Table 5. CO2 Emissions from Transport Predictor Means Pre-Treatment Levels with diesel included as key predictor

Explanatory note: *The Netherlands column are the real values for the Netherlands, the Synthetic NL column shows the values that are produced by the synthetic unit, as constructed by the synthetic control method, and the OECD sample column shows the population weighted averages for the countries in the sample group. Furthermore, all the key predictors are averaged over the pre-treatment period of 1975 to 1983. Additionally, the lagged CO2 emission variables are chosen for the years 1983, 1980 and 1970. In contrast to Andersson's experimental set-up, this execution of the synthetic control method excludes gasoline consumption as key predictor and instead uses the consumption levels as lagged variable for the years 1983 and 1970.*

Ultimately, based on the aforementioned set-up, the effect of the 1984 excise duty increase is shown in figure 13. It shows how the synthetic Netherlands version is able to quite accurately track the pre-treatment emission levels of the Netherlands. From 1984 onwards, it shows how the synthetic emission levels increase as compared to those of the Netherlands. The difference between the two lines therefor is the treatment effect[16]. Or in other words, the effect the increase in the excise duty in 1984 has had on the Dutch emission levels. Based on figure 13, we can therefor state how the use of the synthetic control method clearly points to how the treatment has been able to reduce emission levels. In the coming paragraphs, the extend and validity of this treatment effect will be elaborated on.

[16] The actual difference between the synthetic and Dutch emission levels is plotted in figure 15.

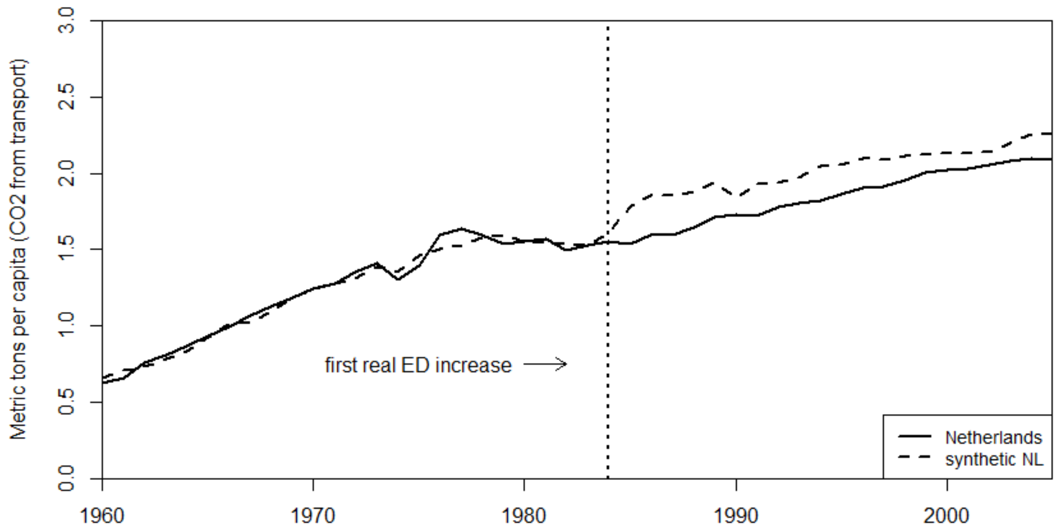


Figure 13. CO2 emissions from transport for the Netherlands and synthetic NL, 1984 treatment, Diesel consumption included as key predictor

Explanatory note: *The vertical line indicates the 1984 gasoline excise duty increase. Pre-treatment, the emission levels for the Netherlands and synthetic NL follow each other closely. Post-treatment, the divergence becomes clear, with the emission levels for synthetic NL being higher for the entire post-treatment period. This difference is the 'treatment effect'.*

4.1.3 Excise duty development within Synthetic Netherlands

From figure 10, we know that the countries within the sample group also established excise duty pricing on gasoline during the sample period. Based on the selected countries as shown in table 4, figure 14 provides an overview of the year on year difference in excise duty pricing[17]. Showing that both Denmark, Portugal and France significantly increased their excise duty pricing in the early 1990's. It is not unlikely that this could lead to the emission levels of the synthetic version to remain relatively low from the early 1990's onwards. Meaning the actual treatment effect of the Dutch excise duty pricing increase in 1984 will be underestimated. In relation to the contextual and data requirements, this means that the *Availability of a comparison group* is potentially violated, as the sample countries enact similar policies during the sample period. In analysing and discussing the results, this will be an import aspect to take into consideration.

[17] A historical overview of the excise duty development of Canada, New Zealand, Switzerland and the United States has not been found after an elaborate search.

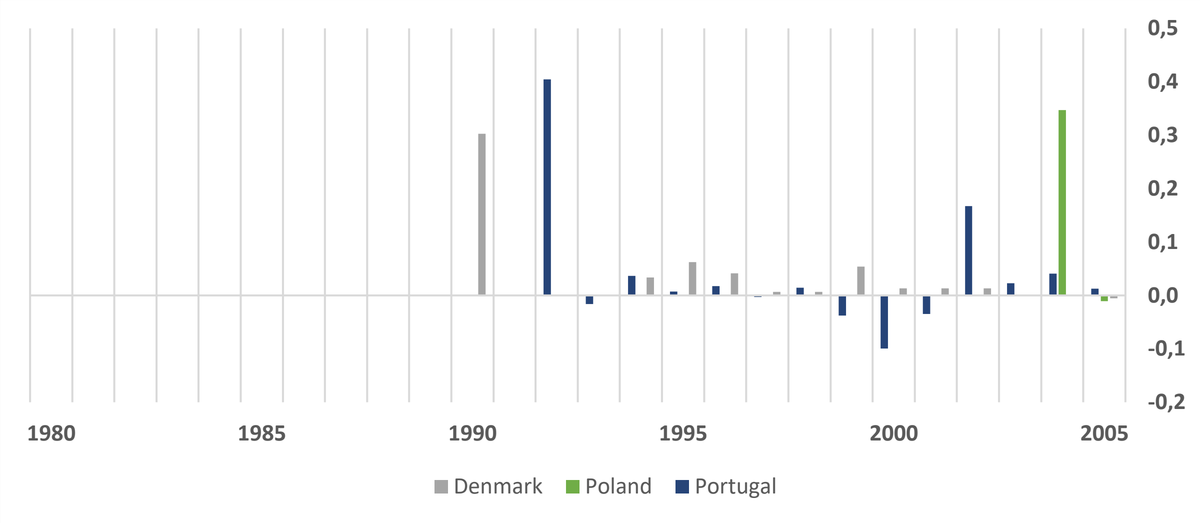


Figure 14. Year on year difference excise duty pricing, selected control countries (eurocent / litre)

4.2 Emission reduction results from the Synthetic Control Method

Ultimately, the result of the treatment is the difference between the emissions levels from the Netherlands and the Synthetic Netherlands, from 1984 onwards, as shown in figure 13. The actual gap between the two units is plotted in figure 15, showing how the emission levels for the two units are relatively similar pre-treatment, and how they diverge post-treatment. The relatively large differences between the mid- and late 1970's can also be observed in figure 13, where the emissions levels for the Netherlands, first sharply decline and then increase.

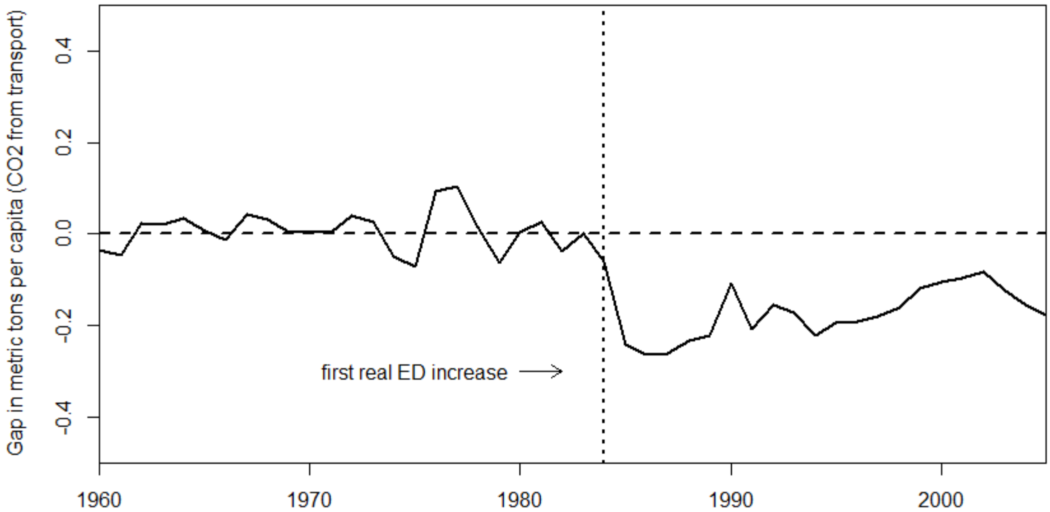


Figure 15. Gap in CO2 emissions from transport between the Netherlands and synthetic NL, 1984 treatment

Explanatory note: *The gap in emissions is calculated by subtracting the emission levels from the Netherlands, with those of synthetic NL. In doing so, the general similarity pre-treatment, and the large divergence post-treatment are illustrated clearly.*

Over the period 1984 to 2005, the total accumulated CO2 emissions from transport per capita in the Netherlands amounted to 40,515 metric tons. For the same period, the cumulative emission levels per capita in the Synthetic Netherlands amounted to 44,248 metric tons. Meaning that the excise duty intervention in 1984 has resulted in an accumulated decrease of emissions in transport of

3,733 metric ton per capita over the period 1984 to 2005. When assessing what this accumulation means for an average year, it shows that the CO2 emissions from transport per capita are 0,155 metric tons per capita lower. For a complete overview of the post-treatment levels of the Netherlands and the synthetic version see Appendix D.

Over time, the total emission gap changes. After showing some more pronounced peaks and dips around 1990, the gap slowly begins to decrease from the mid-90's until after the turn of the century. The average gap in the period 1984-1989 is -0.21, in 1990-1999 is decrease to -0.17, and in 2000-2005 it decrease even further to -0.12. This could to some extend confirm the suspicion that by violating the *Availability of a comparison group* contextual requirement, the actual effects of the treatment are biased. This could potentially be mitigated by changing the time span of the analysis to be shorter and thus exclude the effect the excise duties enacted by the sample group potentially have. However, this could in turn violate the *Time horizon* and *Sufficient post-intervention information* requirements. This potential mitigation method will be addressed in detail in paragraph 4.5.

4.3 Performing placebo tests

The results produced by the SCM, as shown in figures 13 and 15 are very promising and highly interesting. However, based on the composition of the synthetic unit and the potential violation of the contextual requirements, it is extremely important to validate these results. An easy and accurate way to do this is by first performing different kind of placebo tests.

4.3.1 Placebos-In-Time

The statistical package as developed for Rstudio by Abadie, Diamond, and Hainmueller (2010) easily allows different placebos tests to be run, one of which is the in-time test. This test entails that within RStudio, a treatment is assigned prior to the actual intervention which is studied (in our case the 1984 excise duty increase), and consequently verifying if the trajectories of the synthetic unit and treated unit follow the same point in time (Abadie, Diamond, and Hainmueller 2010). When choosing a placebo treatment ten years prior to the actual treatment, there is no real divergence beyond the arbitrary point, which is encouraging. As can be observed in figure 16.

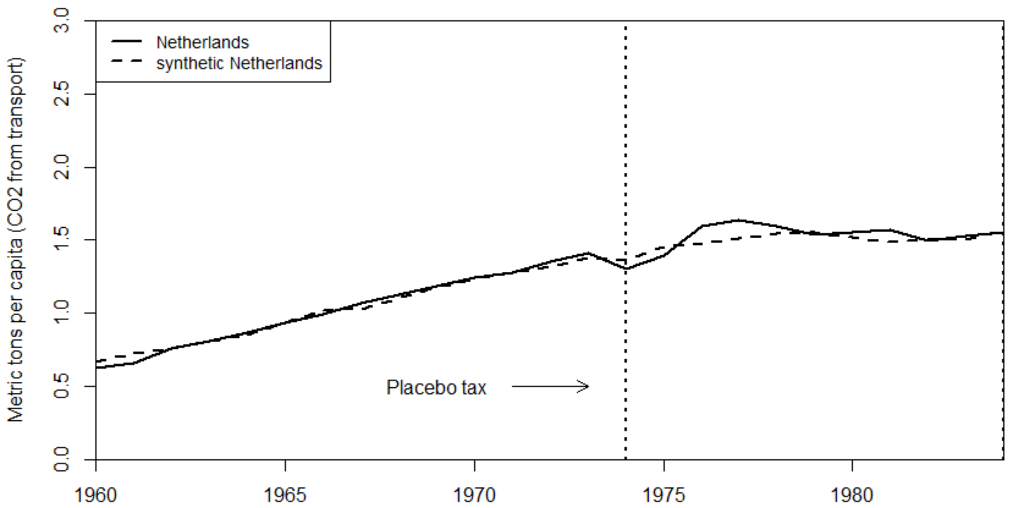


Figure 16. 1974 Placebo-In-Time test

4.3.2 Placebos-In-Space

Another method to test the validity of the SCM results is by iteratively applying the method to all the individual countries in the donor pool, to determine whether the results for the Netherlands are actually unusually large (Abadie, Diamond, and Hainmueller 2010). This analyses results in figure 17, in which the grey lines are the emission gaps for the control countries, and the black line is the Netherlands.

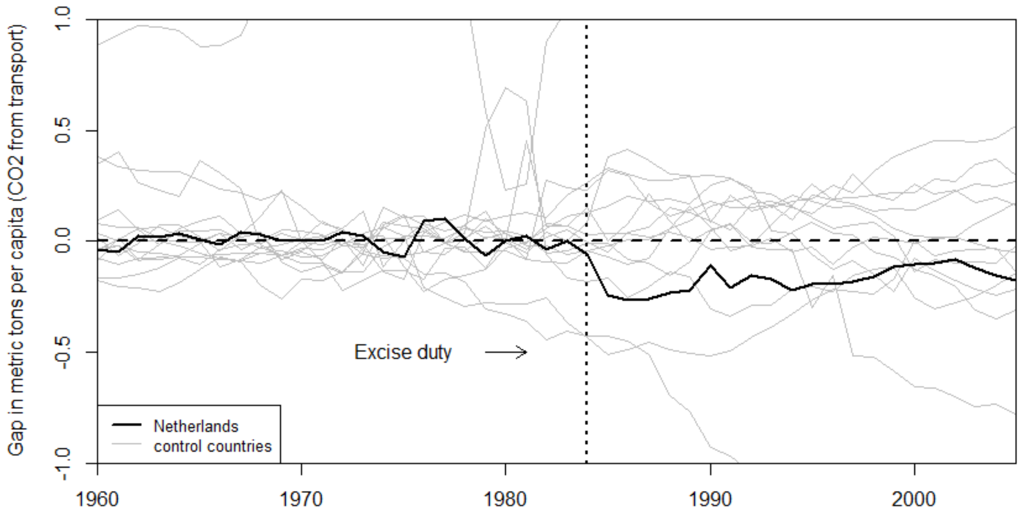


Figure 17. Placebo-In-Space results, all control countries

However, as figure 17 illustrates, there are several countries with abnormally large divergences in the pre-treatment emission gap levels. In order to get a more insightful picture, the control countries with a pre-treatment MSPE value more than 20 times larger than that of the Netherlands are eliminated. Ultimately, this means that Canada, Iceland, Poland and the United States are excluded[18], resulting in figure 18. Within the figure, the largest divergence is from Portugal. However, this gap was already well developed before the treatment was enacted, as Portugal's averaged pre-treatment MSPE is 0.031, significantly larger than that of the Netherlands (0.0018) and countries such as Australia (0.0164), Denmark (0.0025), and France (0.0025). Controversially, Portugal is assigned the third largest weight in the SCM, only behind Denmark and Japan. Furthermore, apart from the Portugal divergence, it is clear that in the first years after the treatment, until the mid-90's, the negative gap for the Netherlands is clearly the largest. However, from the mid-90's onwards the Dutch MSPE is overtaken by several countries. One of these countries is Japan. Something which could be another potential sign pointing towards the violation of the SCM's contextual requirements.

[18] Together, Canada, Iceland, Poland, and the United states only make up a combined 6.9% to the synthetic unit.

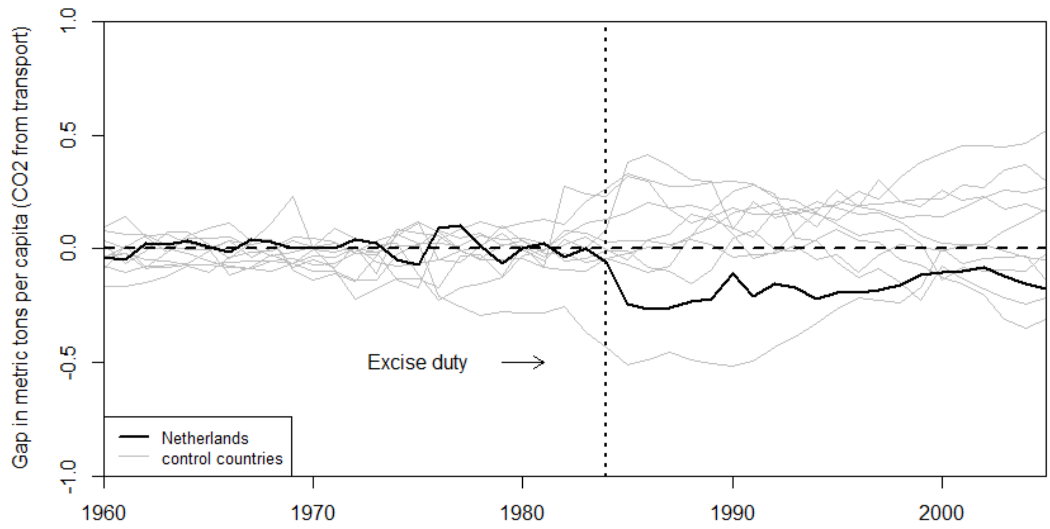


Figure 18. Placebo-In-Space results, control countries with pre-treatment averaged MPSE < 20 times the Netherlands.

A more quantitative approach of looking at the different gaps in emission is by using the ratio of post-treatment MSPE to pre-treatment MSPE (Abadie, Diamond, and Hainmueller 2010). The assumption being that the higher the ratio, the more causal effect can be attributed to the treatment. This is quite simply because the ratio takes the post-treatment MSPE and divides it by the pre-treatment MSPE. This means that a high ratio is a result of a synthetic unit which is able to closely track the real dependent variable levels pre-treatment, in combination with a large divergence post-treatment. Which is a scenario that would illustrate a treatment effect. In addition, comparing the different MSPE ratios in the sample group, based on the placebo-in-space test, will determine if the observed treatment effect for the Netherlands is indeed exceptionally large, and therefor significant. This comparison is made in figure 19.

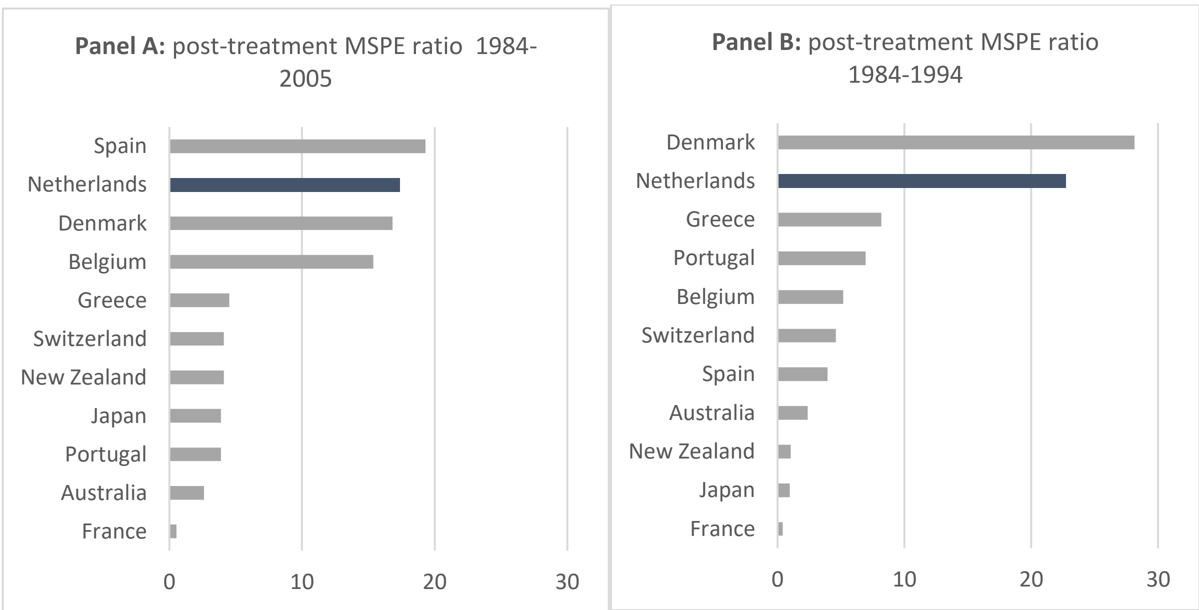


Figure 19. Post-treatment MSPE / Pre-treatment MSPE ratios; [1984-2005] and [1984-1994]

Explanatory note: *Panel A shows the MSPE ratio's for the entire post-treatment sample period, being from 1984 to 2005. Additionally Panel B illustrates the MSPE ratio's with a shortened post-treatment period, being from 1984 till 1994.*

Within figure 19, Panel A. shows the ratios with the post-treatment MSPE ranging from 1984 to 2005[19]. These ratios are relatively in line with what we have seen so far: The Netherlands ranks high, but not exceptionally. The Dutch ratio actually falls short of Spain, and is closely followed by both Denmark and Belgium. However, when changing the time horizon to only 10 years post treatment, The Dutch ratio is significantly higher than the aforementioned countries. Only Denmark scores similarly high. In trying to identify the reason behind the large Danish ratio, figure 20 shows some insight into the development of the countries emission gap. The figure shows an enormous surge in 1985, coincidentally the year after the Dutch treatment was implemented

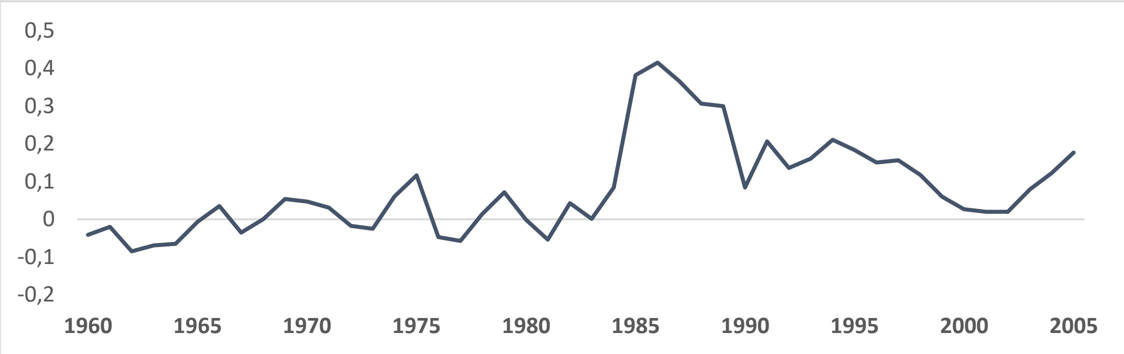


Figure 20. Danish emission gap in metric tons per capita (CO2 from transport)

Explanatory note: *This figure is based on the outcome of the Placebo-In-Space test, in which the synthetic control method is applied to Denmark.*

When examining the actual Danish emission levels from transport, it is clear to see that immediately after the Dutch treatment, emission levels surge from 1.81 metric ton per capita in 1984 to 2.10 in 1985. This dramatic increase, in combination with the significant weight attributed to Denmark in the SCM, most likely explains the large divergence between the Dutch real life emissions levels and the synthetic version's in the years immediately following the treatment. This unusually high spike in Danish emission levels is in itself no cause for bias. However, the unexplained spike could potentially lead to an overestimation of the treatment effect. Especially with the Danish emission levels between 1984 and 1990 strongly resembling the trajectory of Synthetic Netherlands, as shown in figure 13.

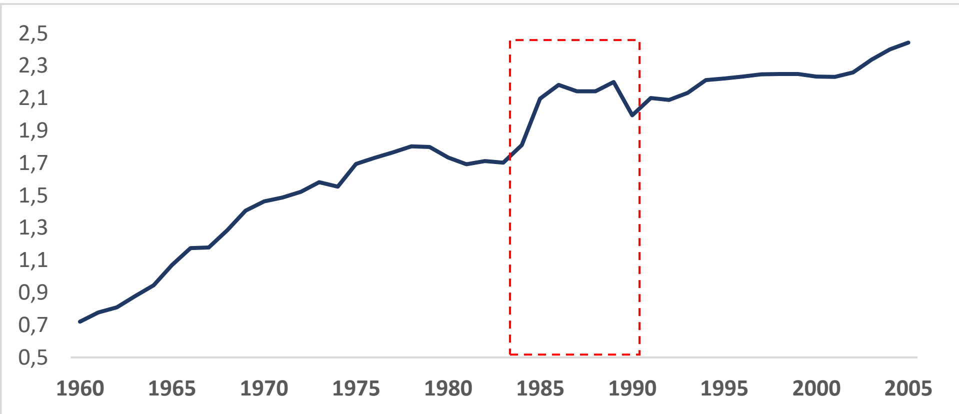


Figure 21. CO2 emissions from transport in metric tons per capita Denmark

[19] Countries with an MSPE ratio 20 times larger than that of the Netherlands are excluded from the figure.

Inspecting the individual key predictors for Denmark provide some additional context, but fails to give any definite answers as to why the Danish emissions from transport sharply increased in the years following 1984. In the early 1980's leading up to the treatment, all key predictors apart from the urban population saw yearly decreases. However, in the years 1983 to 1985, al key predictors suddenly began to rise, coinciding with the implementation of the treatment. For a full overview of the development of the Danish key predictors see Appendix E.

4.4 Excluding Denmark

An additional analyses shall test the hypothesis that the large gap between the early pre-treatment trajectories of the Netherlands and Synthetic Netherlands is, to a large extent caused by the bump in Danish CO2 emissions from transport, during the same period. As shown in figure 21. Figure 22 shows the result when the SCM is ran, ceteris paribus, with Denmark excluded from the sample group[20]. The pre-treatment MSPE with Denmark excluded comes down as 0.0034, which is higher than with Denmark included (0.0018). Additionally, the countries which are assigned weights are entirely different with, Japan (0.557), Portugal (0.232), the United States (0.091), New Zealand (0.065), and Poland (0.029) being assigned the largest weights[21]. However, more importantly, figure 22 seems to verify the suspicion that the irregular Danish emission levels caused the large post-treatment divergence in the period 1984-1989. While this experimental setup does lead to a clearly pronounced treatment effect, it is only from 1990 onwards that the emission levels truly start to diverge.

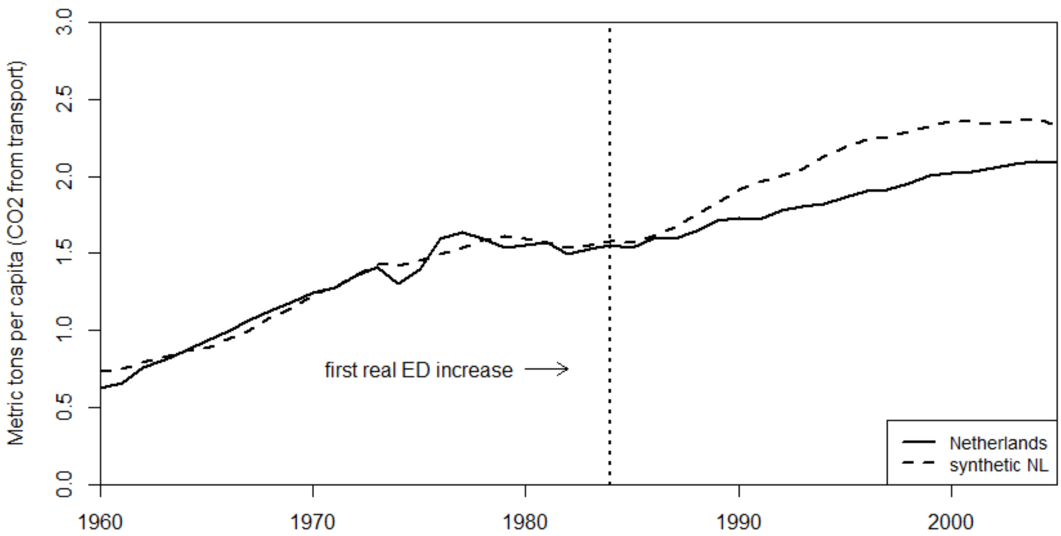


Figure 22. CO2 emissions from transport for the Netherlands and synthetic NL, Denmark excluded

[20] Changing the lagged years does not result in a significantly lower MSPE (LOSS V) value.
[21] For a complete overview of the results from the SCM with Denmark excluded see Appendix F.

4.5 Adjusting the time span while excluding Denmark

Based on the preceding paragraphs, the setup of the experiment is changed to exclude Denmark from the sample group, and shorten the timeline to adjust for the increased excise duty prices within the sample group post-treatment. Denmark is excluded on the grounds that their post-treatment data showcased unusual swings, which in combination with the high weight attributed to them in the synthetic unit (based on their pre-treatment similarities) potentially leads to an overestimation of the treatment effect, particularly in the years immediately following the treatment. Additionally, the post-treatment time span is shortened to exclude the distortion starting in the late 1990's, which is most likely caused by a variety of countries increasing their excise duty pricing on gasoline, starting in the mid 1990's. In doing so, the suitability of the sample group should be increased, in turn increasing the validity of the results. Thereby adhering to the *Availability of a comparison group* contextual requirement. Furthermore, by shortening the time span, caution will be applied to the analysis of the results, based on the *Sufficient post-intervention information* data requirement. Ultimately, the post-treatment time will be simulated until 1994, which will give us 10 years of post-treatment data. Bearing in mind that countries started to significantly raise their excise duty pricing on gasoline from 1990 onwards.

When excluding Denmark while shortening the post-treatment timeline, the mean squared prediction error loss of 0.0034[22] of course remains the same. However, the MSPE ratio does change, as excluding Denmark from the sample group, and having the post-treatment period run until 2005 results in a MSPE ratio of 18.50. When shortening the post-treatment period to 1994, this results in an MSPE ratio of 8.76. Ultimately, both are lower, then when Denmark is included. Which is logical, as the inclusion of Denmark leads to both lower pre-treatment and higher post-treatment levels, which naturally leads to a higher MSPE ratio. However, it is interesting to note that the largest ratio can be attributed to the longest time line. Looking at figure 22 it should not entirely come as a surprise, as opposed to figure 13 the divergence is slow to take off. This however raises the question how long it takes for consumers to respond to a significant price increase in fuel prices. The logical assumption would be that the since the change in price is immediate consumers would also respond immediately. However, as shown by the literature, the price demand for gasoline is inelastic. Meaning that consumers respond disproportionately less to price changes. Nevertheless, consumers tend to adapt to increased prices in the long-run, especially if price changes are a result of policy interventions (Cillingham, 2011). Therefore, over time the treatment effect can become more pronounced. Based on this, the results we see in figure 22 are actually in line with the literature.

Another potential reason for the divergence slowly picking up pace after the 1984 treatment is that in 1987 and 1991 the excise duty price was further increased, thereby potentially adding to the change in consumer behaviour. However, it is also in line with the literature, which points towards how consumers tend to hardly react to changing fuels prices in the short-run, but that they tend to adapt in the long-run. Which means that the actual treatment effect can take time to materialize (Cillingham, 2011).

[22] Changing the lagged years yielded no significantly different results.

4.6 Identifying the influence of sample countries with high MSPE ratios

The analysis in 4.3.3 has shown that both Belgium, Denmark, and Spain all have a similarly high 1984-2005 MSPE ratio. This ratio means that for these countries, there is small gap in emission levels pre-treatment, and a high divergence post treatment. This entails that a potentially similar treatment effect can be witnessed in these countries, which would mean that the observed Dutch effect is not unique. However, when examining figure 23, it shows that the three sample countries have a positive gap. This means that their respective emissions only increased post treatment. Meaning no treatment effect comparable to the Netherlands can be observed.

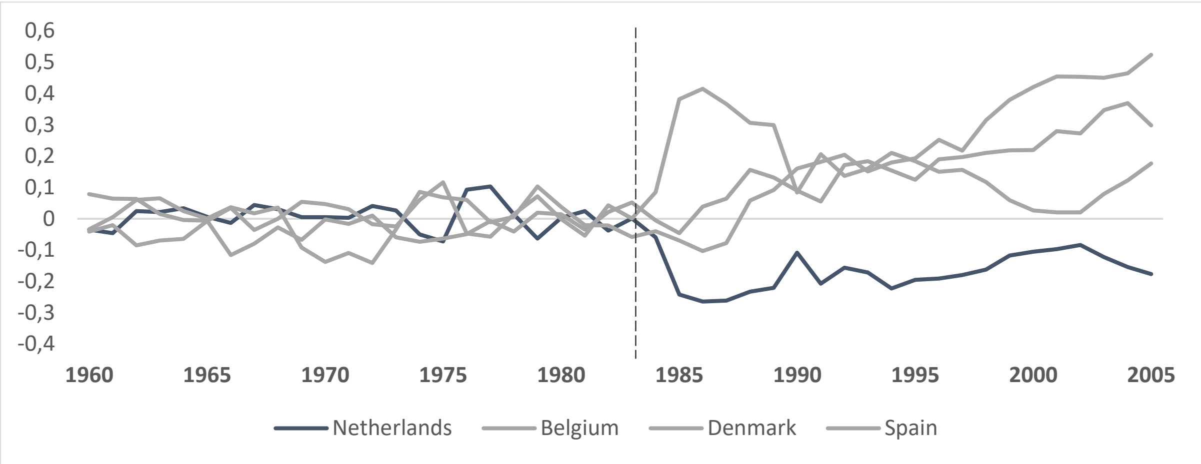


Figure 23. Overview of emission gaps for high MSPE ratio countries

Explanatory note: *This figure is a stylized version of figure 18, showing only a selection of countries, based on the sample countries with high MSPE ratio's, as shown in figure 19 panel A. It shows that while these four countries have similar MSPS ratio's, as based on the placebo-in-space test, only the Netherlands has a truly negative emission gap.*

4.7 The ability of the Synthetic Control Method to predict what would have been

In judging the excise duty pricing on gasoline as a policy measure with the aim of reducing emissions from road transport, the synthetic control method plays a central role. In general, the method is able to perform an ex-post empirical comparative case study, in a scenario in which no true comparative case exists. It does so by constructing a counterfactual based on a sample group, thereby creating a comparable 'synthetic' unit, with which reality can be compared. As expounded upon in the methodology section, the SCM is very popular due to its ability to more accurately predict a treatment effect, compared to for example the DiD method. Nevertheless, the method has several requirements, both in relation to the data which is used as input, and the contextual settings. This paragraph will serve as a conclusion to the analysis, by discussing how the synthetic control method has been set-up, and how it has been able to showcase what the potential influence of the excise duty on gasoline has been on Dutch road emissions.

4.7.1 Setting up the Synthetic Control Method

The excise duty on gasoline has been around since the early 1930's, and has constantly changed since then. However, going back in time to look at the public and political sphere debating its most significant increases only yields one clear result: "Het kwartje van Kok", which relates to the 1991 increase, under the then minister of Finance Wim Kok. The increase, which amounted to 10 eurocent per litre gasoline in real 2005 prices, was a rather blatant attempt to close the gap in the Dutch government's budget, at the expense of Dutch motorists. As a consequence, it received pushback mainly from road transportation related branch organisations such as the Bovag and the ANWB. The ensuing debate never really disappeared, as Dutch politicians kept bringing it up in the subsequent years. Due to the attention it received, and the fact that motorists paid noticeably more for gasoline at the pumpstation, it is reasonable to assume this measure translated to changes in consumer behaviour and therefor ultimately to reduced emissions from road transport, thereby making it a good policy intervention to study. However, the 1991 excise duty was not the first significant increase, although the media attention and it's quotable nickname made it seem as such. In actuality, the data points towards 1984 being the first real significant increase. Based on several contextual requirements of the SCM, the 1984 increase proved to be a more viable treatment to study, and is therefore the focus point of this research.

Apart from identifying the correct policy intervention, the construction of the synthetic unit based on the sample group is crucial. The availability of the case study based on the Swedish carbon tax on fuel (Andersson, 2019) proved to be extremely helpful. The initial sample group constructed for this research could be copied, as the reasoning behind its composition largely applied to the Dutch case study. Being that OECD countries were chosen based on similarities to Sweden, which remained true for the Netherlands. Additionally, countries which either enacted carbon taxes that cover the transport sector, or made large changes to fuel taxes were excluded from the sample group, on the condition that these countries would bias the results. However, Andersson failed to take into account the excise duty pricing on gasoline which were enacted by several countries during the sample period, as shown by figure 10. From a consumer viewpoint, both the carbon tax on fuel and the excise duty on gasoline result in higher prices, meaning they can be regarded as the same treatment. Unfortunately, the contextual requirement *Availability of a comparison group* clearly states that units in the sample group must not have enacted similar treatments or policies during the sample period, which is clearly the case. Regrettably, data on the historical development of excise duty pricing for specific countries is relatively hard to come by. Nevertheless, it can be concluded that at least Australia, Belgium, Denmark, Greece were included in Andersson's synthetic version of Sweden, while also having enacted an excise duty price increase on gasoline during the sample period[23]. In relation to the Dutch case study, figure 14 shows the year on year difference for excise duty pricing of countries included in the synthetic Netherlands version, with Denmark enacting an increase of 30 eurocents per litre in 1990 and Portugal 40 eurocent in 1992. This violation of the *availability of a comparison group* is most likely to lead to an underestimation of the treatment effect, as these changes are all made post-treatment and are likely to drive down the emission levels of the synthetic Netherlands.

A potential way to mitigate the enacted excise duty pricing by countries in the synthetic unit is by shortening the time line. Unfortunately, both the contextual and data requirements specify that significant post-treatment data is available, in order to be able to make a good assessment of the treatment effect.

[23]The author of this report reached out to Andersson, to ask about his reasoning and insights surrounding the excise duty pricing on gasoline enacted in the sample group. However, no response was given.

4.7.2 The role Denmark plays

Ultimately, the synthetic Netherlands which has been constructed from the sample group shows to be highly dependent on Denmark, with Denmark having an assigned weight of 0.646. This means that based on Denmark, together with Japan (0.140), Portugal (0.131), Iceland (0.060), Switzerland (0.014), Poland (0.008) and the United States (0.001), the pre-treatment emissions levels of the synthetic version most closely resemble those of the Netherlands. Naturally, this combination of countries is also responsible for the post-treatment levels of the synthetic Netherlands. However, Denmark's high weight in combination with an unusual high spike in the county's emission levels in the earliest pre-treatment years, as shown in figure 21, raises some questions about the role Denmark plays in the synthetic unit. This is further illustrated by Denmark's extraordinarily high MSPE ratio with 1984-1994 as post-treatment MSPE period (figure 19). Thereby, it would seem that Denmark's unusual emission levels are to a large extend responsible for the treatment effect witnessed in the years 1984 till 1990, thus potentially resulting in an overestimation of the treatment effect in the first post-treatment years. This hypothesis is tested in figure 22, showing that excluding Denmark from the sample group does indeed result in a lower gap in emissions during 1984-1990. However, the pre-treatment levels are less accurate, meaning that these results in itself are less trustworthy. Resulting in a uncertain situation, which illustrates how although the SCM has an excellent reputation, its results should not be taken at face value. The analysis that eventually lead to the results are based on a variety of variables, meaning that the driving factor of the results can be tricky to locate. However, doing so is important as it can lead to a more nuanced picture. Both in terms of the validity of the results, and their magnitude.

4.7.3 Shortening the post-treatment period

Based on figures 10 and 14, it is clear that within the sample group, policies similar to the Dutch excise duty being studied are enacted. However, as they are mostly a minimum of 5 years past the Dutch treatment, they are only likely to result in an underestimation of the treatment effect in the last 15 years of the sample period. Therefore, shortening the time frame will most likely paint a more accurate picture. However, keeping in mind that it is uncertain when the policy will have full effect, the time horizon cannot be too short. Therefor the time horizon is simulated to 1994 to still give ample post-treatment data (10 years). As mentioned in the preceding paragraph, this additional analysis only makes sense when Denmark is excluded, as Denmark potentially overestimates the immediate treatment effect. As suspected, shortening the timeline while excluding Denmark does not result in a more significant treatment effect. While we already established that excluding Denmark results in a less accurate prediction in itself.

4.7.4 Validity of the results

Despite the imperfect nature of the experimental SCM setup, as discussed in the preceding paragraphs, several tests do point to some validity of the results. Both the in-time and the in-space placebo tests are encouraging. Additionally, while the MSPE ratios as shown in figure 19 raise questions, subsequent analysis show that these do not necessarily endanger the general validity of the results.

4.7.5 All models are wrong

The synthetic control method is not perfect. The dependency on a good sample group, ample pre- and post-treatment data, as well as a good insight and understanding into the key predictors means that there are plenty of factors that can pose methodological challenges. Nevertheless, the contextual and data requirements provide an excellent roadmap, which proves very useful in navigating and identifying challenges (Abadie, 2020). This is important because real world scenarios are not perfect lab conditions. In relation to the Dutch case study, this is especially true, as we are mostly dealing with a combination of units on national aggregate levels, over a time period spanning two different centuries. Thereby leaving enough room for changes in variables which are difficult to explain. Something for which the Danish emission spike in the 1980's makes a good example. While the results have proven not to be immune to changing experimental setups, this is not necessarily unrealistic and by reviewing the data used as input, it is almost always possible to identify were certain changes originate from. Ultimately, the popular aphorism remains true: "All models are wrong, but some are useful". With regards to the SCM, the model certainly has proven to be useful by producing results which provide relevant insights. However, as with any model, there were several challenges in relation to the data and contextual requirements. Nevertheless, Abadie's criteria and requirements allow for a level of self-criticism that only further validate the results by addressing its short comings.

5. Discussion of the results

The analyses and results as presented in chapter 4 provide several interesting insights. However, as expressed throughout the entire report, in studying the SCM outcomes, the validity of the results should be addressed. This chapter will discuss how the synthetic control method has performed under the given parameters, and what the results it has produced are able to tell us.

5.1 The effect of the Dutch excise duty on road emission levels

As discussed in the preceding chapter, the SCM is not able to give a singular answer with regard to the effect the 1984 excise duty increase has had on CO2 emissions from road transport. This is due to the uncertainty arising from different experimental set ups, in combination with the violation of different contextual requirements. Nevertheless, the method is able to provide a good indication of what the reduction could have been. This reduction is based over the period 1984 to 2005, as a result of the 1984 excise duty price increase and potentially the consequent increases, particularly in 1991. Overall, figure 24 shows the key findings of this research. Illustrating the different trajectories of the emission levels in the Netherlands as we know it, and a synthetic version in which the 1984 excise duty has never been increased.

Panel A: Emission levels Netherlands and Synth. NL ***Panel B: Emission level gap NL vs Synth. NL***

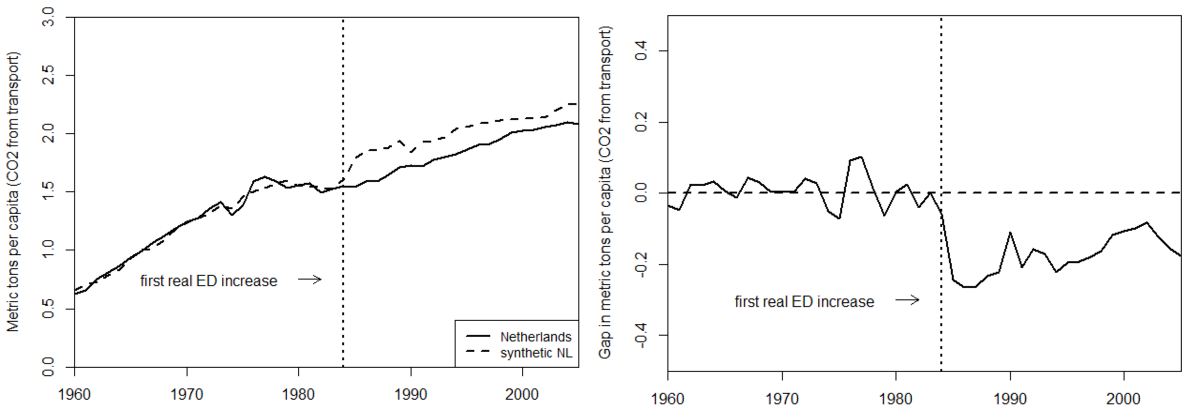


Figure 24. The effect of the 1984 excise duty increase on Dutch CO2 emissions from road transport

Explanatory note: *Panel A illustrates the CO2 emission levels from road transport, for both the Netherlands (solid line) and the synthetic Netherlands (dotted line). Additionally, the vertical dotted line illustrates the 1984 excise duty increase, or in other words, the policy treatment. Panel A clearly shows the divergence between the Netherlands and its synthetic counterpart post-treatment. Panel B in turn illustrates the actual gap between the two, by subtracting the synthetic emission levels from the emission levels of the Netherlands. This figure clearly shows how after the 1984 excise duty increase, the CO2 emission levels from road transport for the Netherlands declined.*

Based on the key findings, which incorporate Denmark in the sample group and exclude fuel consumption as key predictors, the excise duty increase in 1984 meant that over the period 1984 to 2005, an accumulated reduction of 56.9 million metric tons CO2 emissions has been realised. This means that in an average year during that period, CO2 emissions from transport were reduced by 2.6 million metric ton. To put this into context, the current Dutch emission goals are to have the 2030 emissions levels be 49% of the 1990 levels. This goal translates to a total reduction of 48.7 million metric tons (NOS, 2021). In 1984, the excise duty on gasoline increased from 0.26 to 0.32 euro per litre. This means that an increase in the gasoline price of 6 eurocent could potentially be responsible for 5% of the emission reduction goals set for 2030. However, it is difficult to attribute this decrease solely to the 1984 excise duty increase. As we know, the excise duty price was further increased in 1987 and 1991, which are likely to push the Dutch emission levels further down, resulting in a larger gap between the Netherlands and its synthetic counterpart. Nevertheless, this result also includes countries within the sample group implementing excise duty prices on gasoline in the early 1990's, which could in turn lead to an underestimation of the treatment effect. Unfortunately, it is impossible to accurately quantify both the potential underestimation and overestimation. This scenario adds a level of uncertainty to the overall SCM results.

Furthermore, from SCM results we can deduced an estimated price elasticity of demand for gasoline. Sources within the literature found a short-run elasticity of -0.10 to be reasonable (Gillingham, Jenn, and Azevedo, 2015). Additionally, medium-run elasticity values can range between -0.15 and -0.30 (Gillingham, 2011). The results of the Dutch case study however point towards a elasticity of around -0.90. This means that the analyses illustrates how gasoline is indeed a necessary good, as the elasticity falls between -1 and 0, however only just. These results show how consumers can respond quite a bit to changes in gasoline prices as a result of a policy intervention. However, caution should be applied when comparing the price elasticity of demand, as it can be influenced by a variety of factors[24].

Additionally, the role Denmark plays in the synthetic unit has been debated as it would seem that an unusual spike in Danish emission levels in the years close to the Dutch policy intervention potentially lead to an overestimation of the treatment effect. This notion is validated to some extend by excluding Denmark from the sample group, which gives a less pronounced treatment effect in the early post-treatment years, as shown in figure 22. However, the unusual Danish emission levels are in itself no cause for any bias within the results. Especially since including Denmark leads to a pre-treatment MSPE of 0.0018, while excluding Denmark leads to a value of 0.0034, meaning the reductions produced by the synthetic units which excludes Denmark are less trustworthy than when Denmark is included in the sample group.

Furthermore, key methodological challenges mainly related to the contextual requirements *Availability of a comparison group* and *No anticipation*. The availability of a comparison group requirement details how the units in the sample group should not have enacted any similar policies during the sample period. The sample group utilized in this research was first constructed by Andersson, for his case study relating the Swedish carbon tax (2019). Therefore, Andersson excluded any countries from his sample group which enacted similar policies, according to him. However, Andersson failed to identify an excise duty on fuel as a similar policy. As both figures 10 and 14 show however, several countries increased the excise duty pricing on fuel during the sample group. Thereby violating the contextual requirement, potentially leading to biased results. With regards to the Dutch case study, Denmark, Poland, and Portugal all contribute to the Dutch synthetic version, while also having increased their excise duty in the years after 1984. This could potentially lead to an underestimation of the Dutch treatment effect. Additionally, the no anticipation requirement mentions how the method may be biased when certain elements of the treatment are gradually implemented over time, instead of at once. This is also the case with the Dutch excise duty on gasoline, which was first introduced in 1931. This means that the 1984 policy was not a switch which was turned on, but instead an increase of a treatment already in place. Nevertheless, the 1984 increase was significant when compared to the overall historical development of the excise duty (as shown in

[24] For example, Gillingham's analyses was built on a dataset containing information about California between the years 2002 and 2009, meaning changes in time and place can occur.

Appendix B.) Furthermore, the Placebo-In-Time test illustrated how backdating the intervention did not result in any worrisome results, thereby validation the key findings.

5.2 Excise duty on fuel from a consumer point of view

From a policy point of view, carbon taxes and excise duties which affect fuel prices are designed differently. However, the variety of carbon pricing methods, including a carbon tax such as the one studied by Andersson (2019), and the excise duty on gasoline being studied in this research, are all more or less the same from a consumers point of view, as they result in higher prices. This is important to address because from a consumer point of view, the demand for fuel is inelastic, meaning that a change in the retail price will result in a disproportionally small response in the demand. This is because fuel is a necessary good. Nevertheless, albeit small, changing fuel prices have an effect on demand. However, the extend of this change in demand is not completely the same for each individual consumer, as it is based on several different aspects, including for example the age and fuel economy of a vehicle, personal income, and geographic and demographic variables. Additionally, the elasticity of fuel demand is more elastic in the long-run than in the short-run. Or in other words, changes in demand based on changes in fuel price become more pronounced overtime (Gillingham, 2011). This also relates to the notion that fuel prices tend to fluctuated on a more or less week to week basis (U.S. Energy Information Administration, 2020). However, consumers respond less to price changes as a result of normal market mechanisms, than to policy interventions designed to increase fuel prices. This is because such policy measures are more persistent in nature and therefor inspire more significant changes in consumer behaviour. Additionally, policy interventions are often followed by media attention, which can cause a more public debate, adding fuel to the fire (Davis & Killian, 2010).

The literature review has provided numerous examples of how policy interventions have resulted in pushback and criticism in the public debate. The Swiss rejected a tax on non-renewable energy in 2015, while voters in Washington opposed a carbon tax in 2016 and again in 2018 (Carattini, Kallbekken, & Orlov, 2019). However, in relation to reducing emissions from fuel, the best example of public push back are of course the French yellow vests. A protest movement which was the result of President Macron putting a tax on motor fuels to curb emissions. Ultimately, the proposed tax increase would result in gasoline prices increasing with 2.9 eurocent. This is about half of the Dutch increase in 1984, yet it lead to over a quarter million French to protest President Macron. However, when assessing the yellow vests movement, the increased fuel prices are often said to be a proxy for a more general frustration felt by French working and middle classes, about their presidents disregard for their cost of living (Feargus O'Sullivan, 2018). Therefore, the proposed gasoline tax increase by President Macron in 2018 might not be the best example as to how consumers would normally respond. In comparison, the Dutch variant in 1984 received no real attention from the media[25], while the 1991 Kwartje van Kok received mostly pushback from branch organizations within the road transportation sector. Additionally, the motivation for the Kwartje van Kok was much less noble when compared to Macron's proposition; It was not designed to reduce emissions and save the planet we inhibit, but to earn the government enough money to close their budgetary gap, at the expense of motorist. Nevertheless, the literature has pointed out that public resistance to carbon taxes is not without merit, as it is largely based on their regressive nature. Meaning a heavier burden is placed on consumers with lower incomes. This is very much the case with an excise duty placed on gasoline and diesel, as this policy is specifically designed to be fully born by consumers. Something which is not

[25] Different extensive Google searches on the 1984 excise duty price increase yield no results as to what the media or the public response was.

always the case for carbon taxes, based on tax incidence[26]. Andersson (2019) for example first had to establish whether or not the Swedish carbon tax is indeed passed on to consumers, or if the burden of the Swedish carbon tax is largely carried by corporations. Nevertheless, the Dutch consumers never truly expressed much resistance in the public debate. But this might be unique, as the French have already shown the other side of the spectrum. However, based on extensive Google searches looking for public responses to excise duty increases on fuels, it seems as the French yellow vests are the exception. Meaning that the notion that the movement was largely driven by a much broader discontentment for their leadership most likely has some merit to it. Figure 10 shows how in more recent years, Poland increase their excise duty on gasoline by more than 30 eurocent. However, no articles about public backslash were found online. This of course does not mean that within the public perception, this policy went unnoticed, but it is encouraging[27]. Similarly, the French themselves increased their excise duty on gasoline with 44 eurocent in 1992, which is the largest year on year difference as found by this research. Nevertheless, no news items have been found in relation to this increase.

Finally, the literature has illustrated how the consumer demand for fuel is both inelastic, but also dependent on numerous variables, meaning that individual consumers can respond differently. Notable drivers for the consumer demand for fuel are income, geography, and demographics and even the type of vehicle an individual drives (Gillingham, 2011).

5.3 Excise duty from a policy makers point of view

As exemplified by Lawrence Goulder and Ian Parry, “the toolkit of environmental instruments is extensive, and includes emissions taxes, tradable emissions allowances (“cap-and-trade”), subsidies for emissions reductions, performance standards, mandates for the adoption of specific existing technologies, and subsidies for research toward new, “clean” technologies” (p. 152, 2008). Nevertheless, because of competing criteria along different dimensions, no single best solution exists. Consequently, although carbon pricing is a popular policy choice in the literature (Nordhaus 2008, 2013 and Weitzman 2015, 2016), taxes on inputs or goods associated with emissions are not without flaws. These kinds of taxes, which include taxes on gasoline, electricity, or air travel do not sharply focus on the externalities (Goulder & Parry, 2008). This could however be accomplished by deploying particular requirements for production processes as a policy measure, called technology mandates. A technology mandate could for example incentivize certain production standards that lead to more fuel efficient vehicles. However, in terms of cost effectiveness, research has pointed out how abatement costs[28] are 40 to 95% less under emissions taxes or tradable allowances than under technology mandates (Goulder & Parry, 2008). Within the literature, carbon pricing is often stated to be an economic or cost *efficient* tool (Howard & Sylvan, 2015; High-Level Commission on Carbon Prices. 2017). However, the word efficient is used in relation to carbon pricing to such an extent that it is at the risk of becoming nothing more than a buzzword. Instead, a more appropriate phrase would be that carbon pricing is often *more cost efficient* than other climate mitigation policies. Such as shown by the research of Goulder & Parry (2008). This is especially true because efficiency in itself is hard to quantify, meaning its use in absolute terms should be approached with caution.

[26] Tax incidence relates to the distribution of the burden of a tax which is covered by both buyers and sellers (Investopedia, 2020)

[27] Some Polish articles were found voicing contempt for the excise duty increase. However, nothing points towards a more nationwide form of protest.

[28] Abatement costs are costs incurred when negative environmental externalities are reduced, such as pollution.

Additionally, a combination of different policies is more likely to achieve the required result than a standalone policy. For example, technology policies or mandates are largely complementary to carbon taxes, meaning they perform better when implemented jointly (Baranzini et al., 2017). The additional benefit of carbon taxes however, when compared to a technology mandate, is that carbon taxes succeed in producing revenue for the government. In 2017, the Dutch excise duty on gasoline generated 4.293 million euro for the Dutch government, which amounted to 0.6% of the total GDP (CBS, 2017; 2021). This generated revenue is especially relevant as Stiglitz and Stern note how a combination of policies can also include for example investing in public transportation or relevant R&D design, for which the revenue generated by the excise duty can be used. Additionally the revenue can also be used to foster equitable growth, for example by supporting poorer sections of the population (High-Level Commission on Carbon Prices, 2017). This would mean that a key argument against carbon pricing and fuel taxes, being their regressive nature, would be at least partly mitigated.

Furthermore, despite the focus of experts and the Andersson case study being on carbon taxes, this paper has chosen to focus on the Dutch excise duty. Throughout this thesis, mainly in the literature review, the difference between the two policy measures has been addressed, with the conclusion being that while the reasoning behind their design and subsequent implementation may differ, from a consumer point of view carbon taxes and excise duties on fuel are practically the same. The most important difference however, is that carbon tax prices for specific goods or activities are set in accordance with their carbon content, while an excise duty is simply a tax set by the government to generate revenue. Nevertheless, this makes for an interesting discussion. As noted by Stern and Stiglitz "as carbon-pricing mechanisms take time to develop, countries should begin doing so immediately" (p. 1, High-Level Commission on Carbon Prices. 2017). Utilizing existing excise duties on fuels means that at least countries within the EU have a head start, as they have all implemented a minimum excise duty on gasoline back in 2003 (Tax Foundation, 2019). Additionally, this research has shown how significant an increase in the excise duty price on gasoline can be, on total CO2 emissions. This begs the question what's in a name? Excise duties aren't necessarily regarded as a policy measure within the carbon pricing family. For example, they are hardly mentioned in the High-Level Commission on Carbon Prices (2017). Nevertheless, they are already widely implemented and can have the same effect as carbon taxes. However, the challenge will remain the Pigouvian argument of setting the price at a level which is equal to the marginal external damages. In order to reach the targets set in the Paris Agreement, this equates to US$40–80/tCO2 in 2020 and US$50–100/tCO2 in 2030 (High-Level Commission on Carbon Prices. 2017). Based on CO2 emissions for gasoline which are around 2,932 kilogram per litre (Ecoscore, 2021), this translates to a price of between 0.08 and 0.16 euro per litre for the coming years. Adding this to existing carbon taxes or excise duties on gasoline would be significant, but looking at figure 10, not unlike some of the historical changes in the excise duty development. However, implementing such a change will undoubtedly lead to public push back due to the regressive nature of the policy. However, as the literature also shows, the stage is set for more aggressive adaption as governments and political parties are facing more and more backslash for their unambitious environmental policies (FD, 2021). Furthermore, a well-designed climate mitigation strategy should be based on a combination of policies. A good example of this would be to employ the additional revenue earned from the increased excise duty to mitigate the regressive nature of the tax, while technology mandates can be utilized to incentivize further technological change.

Finally, the context in which carbon pricing policies (or a similar excise duty) are implemented should be taken into account. We know from the literature review and the use of the synthetic control method that several variables drive the level of road transportation and thus by extension the road emission levels. In this case, the key predictors are GDP (or income level), the level of urbanization, and the number of vehicles per capita, with for example a lower level of urbanization contributing to more car use (Neumayer, 2004), and the price elasticity for fuel demand (Cillingham, 2011). Therefore, when judging if the results for the Dutch case study could logically be expected for another country, it is important to consider whether these key predictors are similar. Additionally, the context and the subsequent external validity can be split up into both in time, and in place.

5.3.1 External validity in time

The interventions studied in both the Swedish and Dutch case study were implemented over 25 years ago. At that time, important innovations relating to road transport were the shift from leaded gasoline to unleaded gasoline, and from gasoline to diesel (CBS, 2010). However, 20 years later, entirely new innovation driven trends have emerged, with the rising share of electric vehicles being a good example. When designing a strategic environmental policy, the entire landscape should be taken into account. This landscape has significantly changed over the past three or four decades. For example, in the last ten years the global stock of electric passenger vehicles has risen form 0.02 million to 9.80 million (IEA, 2021). Ultimately this means that the share of fuel combustion vehicles has declined, meaning the inherent relevance of targeting gasoline and diesel prices as a policy measure has changed. Additionally, other trends are in favour of more stringent climate change mitigation policies. The largest public survey on climate change ever carried out, with 1.2 million respondents, shows how the vast majority of people feels that climate change is an emergency (Flynn et al., 2021). This growing sense of urgency could contribute to policy interventions becoming more easily accepted by the general public. Additionally, it makes senses that over time the price elasticity of demand for fuel would change. Currently, fuel is classified as a necessary good. However, due to technological advancements and changing consumer preferences, the dependence on gasoline and fuel for personal transportation decreases. The rising share of electric passenger vehicles is a great example of how a substitution for traditional combustion engine vehicles can decrease the need for diesel and gasoline, thereby increasing the consumer responsiveness to price changes in fuel.

5.3.2 External validity in place

Apart from the differences between different time periods, the differences between geographic regions should also be taken into account when determining if the results produced by this case study are likely to hold for another country or region. For example, the previous paragraph illustrates how the sentiment towards climate change, and the share of electric vehicles has changed over time, and how these can influence the external validity of this research. However, not only have these variables changed over time, differences based on geography currently are also apparent. To illustrate, the share of sales of newly purchased electric vehicles is five times as high in Europe as it is in the United States (IEA, 2021). Additionally, 72% of people in western Europe and North America believe climate change to be an emergency, while only 61% of people living in Sub-Saharan Africa believe the same thing to be true. As discussed, the public perception of climate change can influence the level of public acceptance towards (regressive) climate policy measures, while the share of electric vehicles is linked to the relevance of designing an environmental policy aimed at fuel prices. Additionally, the relevance of a policy measure aiming to reduce emissions from road transport (by targeting fuel prices), is also based on a countries share of road emissions. Addressing road transport emission has inherent value for both Sweden and the Netherlands, as emissions form road transport make up a significant portion of total emissions. However, this might not be the case for other countries.

6. Conclusion

6.1 Answering the sub-questions

The four different sub-questions were developed to help guide the research towards answering the main research question. Eventually, based on the preceding chapters, we are able to do so. Yielding the following results:

What are the key characteristics of the Dutch gasoline excise duties and its historical development?

The Dutch excise duty on gasoline has been introduced as early as 1931, with the original goal of generating additional revenue for the Dutch central government. In the decades following, the price remained relatively the same[29], only being raised by the central government to adjust for inflation. The excise duty was significantly raised in 1984, 1987 and again in 1991. In 2005 real prices, the increases were 0.8, 0.7 and 0.10 euro respectively. However, only the 1991 increase received notable attention in the public and political debate, as its primary goal was to close the gap in the central government's budget, at the expense of motorist. The additional argument for the increase, as given by the minister of Transportation, was that it would restrict car use and thereby result in energy conservation and environmental protection. This argument is in line with the secondary goal of excise duties, being that they are placed on goods the government tries to discourage consumers from using. With other examples of goods placed under excise duty pricing being tobacco and alcohol. Furthermore, after the 1991 increase, which is commonly known as the Kwartje van Kok, the excise price on gasoline remained relatively stable. Nevertheless, the excise duty on gasoline brought in 4.3 billion euro of revenue for the Dutch government in 2017, which is equal to 0.6% of the total Dutch GDP that year.

How does an excise duty on fuel relate to other carbon mitigating policy tools?

In contrast to the carbon tax as studied by Andersson in the Swedish case study, the Dutch excise duty is not primarily, by design, an environmental policy. Nevertheless, from a consumer point of view it can be regarded as similar, as it quite simply raises gasoline prices. Thereby addressing a key argument for carbon taxes, being that they take into account that consumer behaviour is driven more by prices than by environmental concerns. Following this logic, the Dutch excise duty can have a similar effect as a comparable carbon tax on fuel[30]. In addition to the comparison between excise duties and carbon taxes, the relation between the two pricing methods to other emission mitigation policies is important. Regarding this, the literature is quite unanimous; while carbon pricing interventions should be central within an intelligently designed environmental strategy, there is no best in class solution for combatting climate change. Primarily because different evaluation criteria apply. Therefore, a combination of policies is most likely to provide the best overall result. This is especially true because carbon pricing and technology mandates are complementary. Furthermore, the revenue generated by pricing policies can be used to both further promote environmental policies, and to foster equitable growth. For which the latter will also mitigate one of the policies key counter arguments, being that the taxes are regressive in nature .

[29] Unfortunately, the data for the Dutch excise duty development is hard to come by, meaning we only have data going back to 1970.

[30] For the sake of simplicity, carbon pricing and excise duty pricing will from this point on be regarded as the 'same' policy.

What would Dutch road emissions have been without the fuel excise duties?

The method employed to empirically estimate what the emissions from road transport would have been, had the excise duty not been increased in 1984 (and subsequently in 1987 and 1991) is the Synthetic Control Method. By constructing a counterfactual, or in other words a 'synthetic' Netherlands, the SCM is able to provide an overview of the yearly emission levels, from 1984 till 2005, without the 1984 policy intervention. By comparing the difference between the actual Dutch emission levels post-treatment, with those of the synthetic Netherlands the 'treatment effect' can be identified. While the execution of the synthetic control method has not been perfect, based on the (partial) violation of several contextual requirements, it is able to give a good insight. This insight is to a large extend validate by several tests. In conclusion, the method points to how the 1984 policy has resulted in a total emission reduction 56.9 million metric ton, over a period of 21 years. This equates to a yearly average of 2.6 million metric ton CO2.

Can the results from the Dutch excise duty on fuel realistically be generalized for other countries?

As is true for the Swedish case study, the external validity of the results brought forward by this report need to be approached with caution. For example, large differences in gasoline prices in Europe means that a gasoline price increase will have a different relative effect (Andersson, 2019). An increase of for example 5 eurocent, will have a different affect in Moldova where gasoline prices are only € 0.91, as compared to the Netherlands were they are currently twice as high (the highest in Europe) (Tolls.eu, 2021). These price difference are in part due to the difference in excise duty pricing on gasoline already in place. For an overview of the European excise duties on gasoline, see Appendix G.

Additionally, aiming to reduce emissions from road transport is relevant for both Sweden and the Netherlands, as road emissions make up a significant part of both countries total emissions. Ultimately, carbon emission compositions differ for individual countries, meaning that specific policies will automatically differ in relevance and expected effectiveness.

Furthermore, the results produced by the SCM are to a large extend driven by the key predictors. As identified by this research, these are GDP per capita, number of motor vehicles per 1000 people, and level of urbanization. This means that when trying to extrapolate the findings for the Netherlands to other countries, it is important to take the similarity between countries into account, with regard to these key predictors. This also resonates with the literature, which points out how individual consumers can respond differently to fuel price changes, based on income, geography, demographic, and even the type of vehicle an individual drives. Understanding the heterogeneity in consumer responsiveness to fuel price changes, based on the aforementioned variables is important. For example, consumers with vehicles with a higher fuel economy tend to response less, lower levels of urbanization are linked with higher levels of vehicle usage, and the highest elasticity in fuel demand is found within the wealthy and low-income households.

However, apart from the purely quantifiable characteristics of a country, such as GDP per capita, numerous other factors come into play when assessing the external validity. Ultimately, excise duties and carbon taxes are designed to increase consumer prices, meaning that the public opinion and sentiment towards these policy measures and their implementation is important to take into account. Additionally, by aiming to reduce road emission through consumer pricing, new and cleaner transportation trends can be encouraged. This is particularly true when fuel pricing is part of a more holistic environmental strategy, also making use of for example technology mandates.

6.2 Answering the main research question

According to the Joseph Stiglitz and Nicholas Stern, "It is of vital importance to the effectiveness of climate policy, particularly carbon pricing, that future paths and policies be clear and credible. New data will emerge continually and new knowledge be generated, and these facts and lessons learned should be taken into account" (p. 4, High-Level Commission on Carbon Prices, 2017). With this notion in mind, the main aim of this research has been to develop a greater understanding of how a policy measure designed to increase fuel prices can contribute to decreasing CO2 emissions. This goal has materialized in the following main research question:

How effective is an excise duty on gasoline, in reducing CO2 emissions from road transport?

Ultimately, by breaking down this research question in the aforementioned sub-questions, a response can be given. Firstly, from a policy design perspective, the excise duties differ from carbon taxes, as they are in general not specifically designed to combat emissions. Nevertheless, from a consumer point of view they are very similar and are thus able to produce similar results. As the Dutch case study has shown, the 1984 increase in the excise duty on gasoline has contributed to a yearly average reduction of CO2 emissions per capita of around 0.170 metric ton. This is encouraging, as it adds to the results produced by Andersson in the Swedish case study (2019), which also causally linked per capita emission reductions to increased fuel prices as a result of environmental policy. To put the Dutch emission reductions in context, the Dutch ambition currently is to have the 2030 emissions levels be only 49% of the 1990 levels. The analysis performed by the synthetic control method has shown how 5% of this ambitious reduction could be achieved by a policy similar the 1984 excise duty increase.

These findings resonates with the current body of literature available, in which the role of carbon pricing is championed. However, in designing an intelligent environmental policy, several notions should be taken into account. The first being that the key difference between excise duties and carbon taxes remains that following the Pigouvian argument, excise duties are not designed to include the costs of emissions. Nevertheless, all European countries have excise duties in place meaning it could serve as a good platform for future fuel price increases. Especially as experts urge policy makers to take action as soon as possible. The second design implication which should be taken into account is that environmental policies are often complementary and should therefore be implemented as such. Based on national characteristics, fuel pricing is more likely to yield promising results when accompanied by complementing technology mandates. And finally, as in all policy design, a great situational awareness is crucial. This relates to how the promising results from the Swedish and Dutch case study are based on policies addressing road transportation, which are responsible for around 20% of both countries total emissions, making it inherently relevant policies. Furthermore, not only does the road emission share play a role in the external validity of these results, similarities between the key predictors, and other national characteristics, such as the level of current fuel prices, all contribute to whether or not similar results are likely to be found for a different case study.

In conclusion, this research has found that an excise duty on gasoline has proven to be able to historically reduce emissions from road transport, and in combination with the existing literature should prove to be a valuable policy tool for policy makers aiming to reduce domestic road emissions.

6.3 Reflection

As in any research, numerous challenges arose in writing this report. Nevertheless, the goal has always been to address these, and mitigate them as much as possible. Thereby aiming to validate the results to a larger extend. However, the framework of this research gave certain natural restrictions, such as limited time and resources. Furthermore, during this thesis, the research design has proven to be crucial, mainly in relation to the employment of the synthetic control method. The SCM has proven to be invaluable, however at times either the research set-up or the SCM itself proved to be imperfect. Mainly based on the relation between the data input and the contextual requirements. Nevertheless it served as a great tool, which could undoubtably play an important role in any follow up research. In relation to potential follow up research, improving the external validity by performing a new case study could prove to be highly interesting. Especially because both the Dutch and Swedish case study focussed on policy interventions around 20 to 30 years ago, it would be interesting to perform a research looking at a more recent policy intervention. Given that trends in the transportation sector have changed significantly over time.

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Appendix

Appendix A. Data sources used in Carbon Taxes and CO2 Emissions: Sweden as a Case Study (Andersson, 2019)

- **CO2 emissions from transport.** Measured in metric tons per capita. Source: The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.

- **GDP per capita (PPP, 2005 USD)**. Expenditure-side real GDP at chained PPPs, divided by population. Source: Feenstra, Inklaar, and Timmer (2013), ”The Next Generation of the Penn World Table”. Available at: www.ggdc.net/pwt.

- **GDP per capita (2005 SEK)**. Expenditure-side real GDP, divided by population. Source: Statistics Sweden (2015) statistical databases. Available at: statistikdatabasen.scb.se.

- **Motor Vehicles (per 1000 people)**. Source: Dargay, Gately, and Sommer (2007), ”Vehicle Ownership and Income Growth, Worldwide: 1960-2030”.

- **Gasoline and Diesel consumption per capita.** Measured in kg of oil equivalent. Source: The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.

- **Urban Population**. Measured in percentage of total. Source: The World Bank (2015) WDI Database. Available at: data.worldbank.org/indicator.

- **Unemployment rate in Sweden.** Percentage of total labor force. Source: Statistics Sweden (2015), statistical databases. Available at: statistikdatabasen.scb.se.

- **Unemployment rate in OECD countries.** Percentage of total labor force. Source: AMECO (2018) database. Available at: ec.europa.eu/economy finance/ameco/user/serie/SelectSerie.cfm.

- **Gasoline prices and taxes in Sweden.** Measured in 2005 Swedish Kronor. Sources: SPBI (2016), Statistics Sweden (2015), The Swedish Tax Agency (2018). Available at: spbi.se/statistik/priser; statistikdatabasen.scb.se; skatteverket.se.

Appendix B. Year on year change in the real gasoline excise duty price (Bovag, 2019)

The year on year changes of the real excise duty price on gasoline, with 2005 as base year, shows an interesting development. From 1970 to 1983, prices are relatively stable and even decline in most years due to inflation. 1984 sees the first significant increase of 0.08 euro per litre gasoline.

Year	YoY change real excise duty price on gasoline
1970	
1971	0,03
1972	-0,04
1973	0,01
1974	-0,06
1975	-0,05
1976	-0,02
1977	-0,03
1978	-0,02
1979	-0,02
1980	0,01
1981	-0,02
1982	0,00
1983	-0,01
1984	0,08
1985	-0,01
1986	0,00
1987	0,07
1988	0,00
1989	-0,01
1990	0,00
1991	0,10
1992	-0,03
1993	-0,01
1994	0,05
1995	-0,01
1996	0,00
1997	-0,01
1998	0,05
1999	0,00
2000	-0,01
2001	-0,02
2002	0,00
2003	-0,01
2004	0,02
2005	0,00

Table 1. Year on year difference real excise duty price on gasoline, 2005 as base year

Appendix C. Synthetic Control Method experimental set-up

Figure 1 shows a screenshot of the input used for the experimental set-up in Rstudio, using the statistical package Synth. It includes they key predictors, the timespan over which they are aggregated and the used lagged years.

```
dataprep.out <-
  dataprep(foo = carbondata_P,
           predictors = c("GDP_per_capita" ,
                          "vehicles_capita" ,
                          "urban_pop"
           ),
           predictors.op = "mean" ,
           time.predictors.prior = 1975:1983 ,
           special.predictors = list(
             list("CO2_transport_capita" , 1983 , "mean"),
             list("CO2_transport_capita" , 1980 , "mean"),
             list("CO2_transport_capita" , 1970 , "mean"),
             list("gas_cons_capita", 1983 , "mean"),
             list("gas_cons_capita", 1970 , "mean")
           ),
           dependent = "CO2_transport_capita",
           unit.variable = "Countryno",
           unit.names.variable = "country",
           time.variable = "year",
           treatment.identifier = 1,
           controls.identifier = c(2:15),
           time.optimize.ssr = 1960:1983,
           time.plot = 1960:2005
  )
```

Figure 1. SCM input in Rstudio package 'Synth'

Appendix D. Synthetic Control Method results overview

Year	CO2 emissions from Transport (metric ton) Synthetic Netherlands	Gap CO2 emissions from Transport (metric ton)	CO2 emissions from Transport (metric ton) Netherlands
1984	1,604	-0,059	1,545
1985	1,756	-0,242	1,514
1986	1,827	-0,264	1,562
1987	1,830	-0,262	1,568
1988	1,860	-0,232	1,627
1989	1,917	-0,221	1,696
1990	1,844	-0,108	1,736
1991	1,931	-0,208	1,724
1992	1,939	-0,156	1,783
1993	1,966	-0,171	1,794
1994	2,038	-0,223	1,815
1995	2,050	-0,195	1,855
1996	2,085	-0,191	1,894
1997	2,087	-0,179	1,907
1998	2,103	-0,162	1,941
1999	2,113	-0,118	1,996
2000	2,118	-0,106	2,012
2001	2,117	-0,097	2,020
2002	2,123	-0,084	2,039
2003	1,987	-0,123	1,864
2004	2,217	-0,154	2,063
2005	2,224	-0,177	2,047

Table 2. SCM output: CO2 emissions for the Netherlands and Synthetic Netherlands

Appendix E. Overview key predictors development Denmark

	GDP per capita	YoY % change	Urban population	YoY % change	Vehicles per 1000	YoY % change	Gasoline consumption	YoY % change
1960	11049,58349		73,687		126		146,96	
1961	11665,5331	5,57%	74,417	0,99%	143	13,15%	164,37	11,85%
1962	12233,81417	4,87%	75,093	0,91%	162	13,25%	177,29	7,86%
1963	12383,94281	1,23%	75,757	0,88%	176	8,67%	193,19	8,97%
1964	13370,68444	7,97%	76,409	0,86%	192	9,35%	210,92	9,18%
1965	13906,03831	4,00%	77,048	0,84%	208	8,04%	215,59	2,21%
1966	14237,61076	2,38%	77,619	0,74%	223	7,17%	232,21	7,71%
1967	14925,72152	4,83%	78,163	0,70%	237	6,72%	245,90	5,89%
1968	15672,05508	5,00%	78,698	0,68%	251	5,77%	261,67	6,41%
1969	16786,95333	7,11%	79,222	0,67%	264	5,22%	286,19	9,37%
1970	16978,34131	1,14%	79,737	0,65%	271	2,52%	287,50	0,46%
1971	17269,57856	1,72%	80,239	0,63%	277	2,31%	296,79	3,23%
1972	17945,4748	3,91%	80,731	0,61%	284	2,34%	300,30	1,18%
1973	18878,28384	5,20%	81,211	0,59%	295	3,87%	303,87	1,19%
1974	18034,88648	-4,47%	81,683	0,58%	295	0,19%	279,47	-8,03%
1975	17828,41678	-1,14%	82,146	0,57%	305	3,14%	300,80	7,63%
1976	19011,87103	6,64%	82,6	0,55%	317	4,13%	318,57	5,91%
1977	19349,3937	1,78%	82,886	0,35%	326	2,65%	324,46	1,85%
1978	19963,96197	3,18%	83,169	0,34%	332	1,95%	338,15	4,22%
1979	20532,6426	2,85%	83,448	0,34%	334	0,68%	318,95	-5,68%
1980	20150,15302	-1,86%	83,723	0,33%	325	-2,71%	293,77	-7,89%
1981	19282,97415	-4,30%	83,915	0,23%	319	-1,90%	276,48	-5,89%
1982	19506,18538	1,16%	84,025	0,13%	316	-0,83%	270,82	-2,05%
1983	19682,60408	0,90%	84,134	0,13%	322	1,90%	277,85	2,60%
1984	20211,50347	2,69%	84,243	0,13%	334	3,61%	288,56	3,85%
1985	20744,9189	2,64%	84,351	0,13%	349	4,45%	295,87	2,53%
1986	22368,83819	7,83%	84,458	0,13%	360	3,11%	295,48	-0,13%
1987	22569,27853	0,90%	84,565	0,13%	367	2,07%	294,91	-0,19%
1988	22539,36186	-0,13%	84,671	0,13%	370	0,82%	299,64	1,60%
1989	22846,83328	1,36%	84,777	0,13%	370	0,10%	294,78	-1,62%
1990	23328,95392	2,11%	84,843	0,08%	368	-0,60%	300,53	1,95%
1991	23527,28777	0,85%	84,871	0,03%	369	0,29%	318,96	6,13%
1992	24205,26856	2,88%	84,898	0,03%	383	3,77%	334,15	4,76%
1993	23936,94517	-1,11%	84,925	0,03%	375	-2,20%	342,29	2,44%
1994	25330,69089	5,82%	84,952	0,03%	374	-0,20%	353,23	3,20%
1995	26295,50873	3,81%	84,979	0,03%	388	3,64%	355,03	0,51%
1996	27123,31784	3,15%	85,006	0,03%	398	2,58%	356,64	0,45%
1997	28948,95963	6,73%	85,033	0,03%	406	1,98%	364,81	2,29%
1998	30285,19849	4,62%	85,06	0,03%	413	1,81%	370,65	1,60%
1999	30977,62719	2,29%	85,086	0,03%	419	1,52%	367,92	-0,74%
2000	32337,08368	4,39%	85,1	0,02%	418	-0,26%	361,45	-1,76%
2001	32129,6032	-0,64%	85,15	0,06%	427	2,15%	355,30	-1,70%
2002	32652,96635	1,63%	85,25	0,12%	430	0,80%	355,66	0,10%
2003	31182,95554	-4,50%	85,36	0,13%	444	3,10%	355,62	-0,01%
2004	32246,1289	3,41%	85,566	0,24%	457	2,96%	350,45	-1,45%
2005	31887,64901	-1,11%	85,856	0,34%	470	2,90%	338,97	-3,28%

Table 3. Overview of historical development of the Danish key predictors.

Appendix F. Results Synthetic Control Method, Denmark excluded, gasoline consumption excluded

MSPE (LOSS V): 0.0034
Lagged years CO_2 from transport: 1983, 1980, 1970
Lagged years gasoline consumption: 1983, 1970

Weights	Sample country	Weights	Sample country
0.000	Australia	***00.577***	**Japan**
0.002	**Belgium**	***0.065***	**New Zealand**
0.000	Canada	***0.029***	**Poland**
Excluded	Denmark	***0.232***	**Portugal**
0.001	**France**	*0.000*	Spain
0.000	Greece	***0.004***	**Switzerland**
0.000	Iceland	***0.091***	**United States**

Table 4. Country Weights in Synthetic Netherlands, Denmark excluded, gasoline consumption excluded

	Weights	Netherlands	Synthetic NL	OECD mean
GDP per capita	0.001	18765.2	14631.7	17102.6
Vehicles p. 1000	0.029	325.0	312.7	347.8
Urban population	0.002	64.5	68.0	73.8
CO_2 from transport 1983	0.081	1.5	1.6	2.0
CO_2 from transport 1980	0.103	1.6	1.6	2.2
CO_2 from transport 1970	0.472	1.2	1.2	1.7
Gasoline consumption p capita 1983	0.033	250.0	292.4	423.6
Gasoline consumption p capita 1970	0.279	232.4	232.2	352.8

Table 5. CO_2 Emissions from Transport Predictor Means Pre-Treatment, Denmark excluded

Appendix G. Overview of European excise duties on gasoline

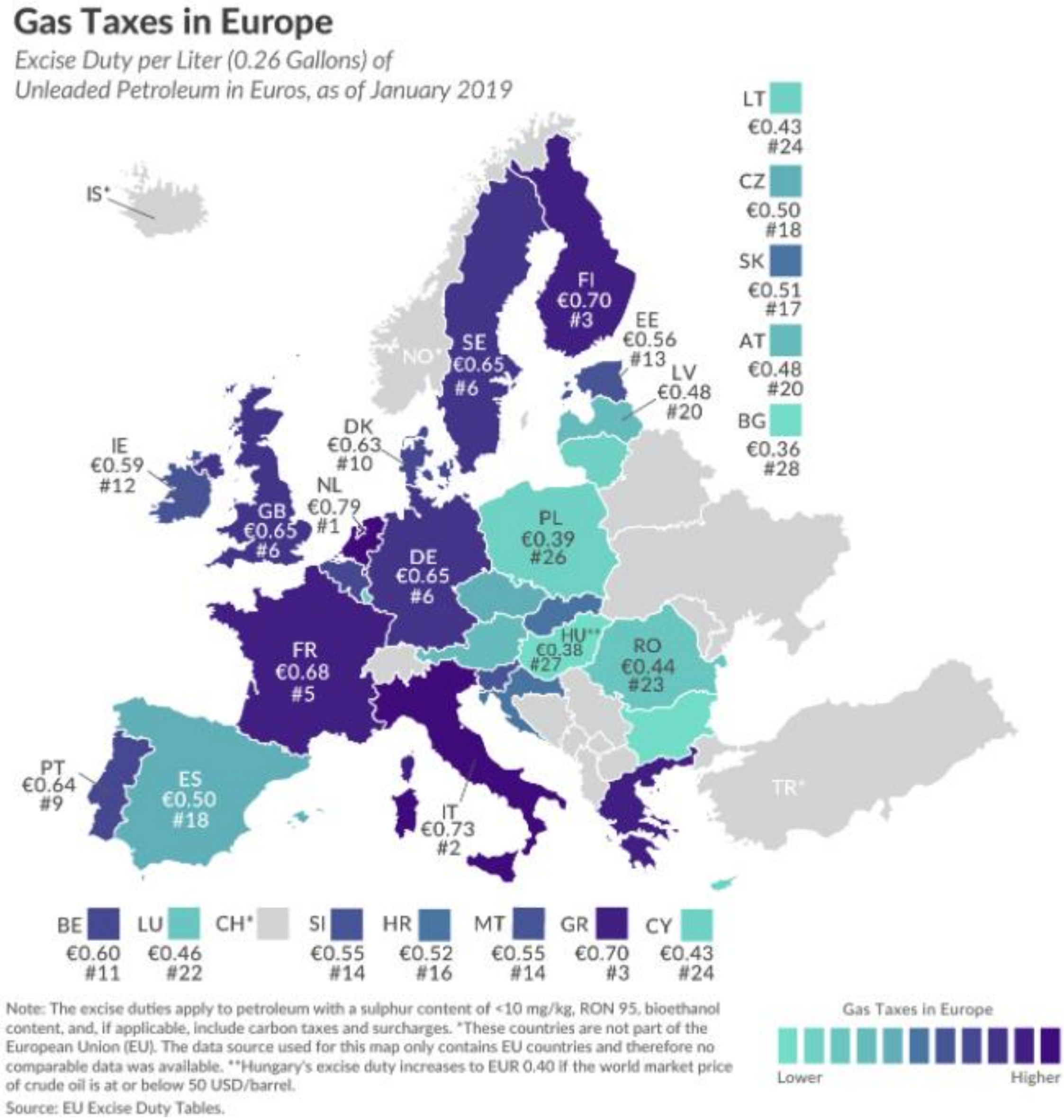

Figure 2. Overview of European excise duties on fuel (Tax foundation, 2019)