# BILAGA 1: WSP'S UNDERLAGSRAPPORT TILL UTVÄRDERING AV SKATTEREDUKTION FÖR RENA OCH HÖGINBLANDADE FLYTANDE BIODRIVMEDEL

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# EXECUTIVE SUMMARY

Biofuels have been exempt from carbon dioxide and energy taxes in Sweden since 1961. Before Sweden's entry into the EU, the exemption was more general, but after joining, the subsidies needed to be tied to specific programs to be approved by the EU. For example, ethanol, the main biofuel at the time, was completely exempt from taxes (except VAT) because its production was classified as a "pilot project." In 2003, Sweden transitioned to a general exemption from excise taxes (carbon dioxide and energy tax) for all ethanol. This policy change needed approval from the European Commission as the tax reduction was considered state aid. Despite the transition to a general tax subsidy being approved by the Commission in 2003, it did not lead to any change in the average tax rate for biofuels sold in Sweden. This was because almost all biofuels sold at the time were domestically produced and already subsidised as part of the pilot projects.

An additional change was made in 2016 to exempt synthetic diesel, hydrotreated vegetable oil (HVO), a change that took effect in 2015. The latest decision to extend the tax exemptions was made on December 14, 2022.

For the tax exemption to be extended, the European Commission must approve Sweden's state aid for biofuels. Following a decision by the Commission on tax reductions for pure and high-blend liquid biofuels, the Swedish authorities were commissioned to evaluate the tax exemptions direct and indirect effects, including its impact on competition, the proportionality of the aid, and the appropriateness of the chosen aid instrument (European Commission, 2017). An evaluation report was submitted on January 8, 2020.

The European Commission indicated that the evaluation needed to be supplemented, particularly to meet the Commission's requirements for appropriate evaluation methods. The previous evaluation did not sufficiently explore the possibilities of using counterfactual methods to estimate the effect of the tax exemption and did not present any alternative methods if counterfactual methods could not be used. Therefore, the purpose of this evaluation is to meet the European Commission's requirements for appropriate methods to evaluate the effects of the Swedish tax exemption.

Two questions have been evaluated:

1. Have the volumes of pure and high-blended liquid biofuels used/sold been affected by the tax reduction? This question aims to determine whether the tax reduction has led to increased use and sales of biofuels.
2. Has the tax exemption had an effect on carbon dioxide emissions from the domestic transport sector?

The evaluation has been conducted using both quantitative quasi-experimental methods and a theory-based approach. Two theories of change were constructed – one for the tax exemption for pure and high-blend ethanol, and one for the tax exemption for HVO and FAME. As for ethanol, the conclusion is that tax exemption was crucial for making the price of E85 competitive compared to petrol and thus enabling a transition from fossil-fueled vehicles to ethanol cars and from petrol to E85. Several factors in the surrounding context contributed, but since people are price-sensitive, these changes would likely not have occurred without a competitive price.

The results from the quantitative analysis consistently show that consumers have been highly price-sensitive when it comes to choosing between E85 and petrol. This result can be expected since both fuels were sold at many petrol stations in Sweden during the period, allowing consumers with flexi-fuel cars to easily substitute between the two fuels.

We use two types of approaches to estimate the effects. In the first, we estimate the direct relationship between sales and prices over time. In the second, we estimate the relationship between the relative sales and price of E85 versus petrol. In both approaches, we control for seasonality and long-term trends. The advantage of the second approach is that the oil price can be used as an instrument for the relative price, which mitigates the problem of reverse causality bias. In the preferred model of the first approach, the cross-price elasticity of petrol exceeds the direct price elasticity of E85. The results from the second approach, which uses the oil price as an instrument for the relative price between E85 and petrol, also show high price sensitivity among consumers. Additionally, the results indicate that the substitution effect between E85 and petrol in particular seems to be a driving factor.

For this evaluation, looking at price sensitivity has an indirect purpose. In a simple model, the tax elasticity will be a fraction of the price elasticity, depending on how much of the tax will be passed on to consumers. However, adjustments to taxation can also have a signaling effect, indicating that a more long term change in prices. This can make the tax elasticity exceed the price elasticity, as it can bring about more structural changes to the fuel market.

Before 2015, pure and high-blend HVO were taxed as fossil diesel. In 2015, HVO became completely exempt from excise taxes, leading to an increase in sales, primarily of pure HVO. The results from the analysis, both theoretical and empirical, strongly suggest that the tax reforms have been a cause of this rapid increase. Before 2015, sales of pure HVO were zero. But from 2015 onwards, there was a steep increase in sales. Since there is no variation in the sales data prior to 2015, due to the effective truncation of the sales data at zero, it is not fruitful to conduct a statistical time series analysis comparing the pre- and post-periods. The striking difference before and after 2015, nonetheless, constitute strong empirical evidence that the tax exemption was necessary for the development of a market for pure HVO.

As a complement, comparisons between countries have also been conducted, where Sweden is compared with a synthetic control group based on other European countries. These comparisons show that Sweden's use of biodiesel increased significantly after the tax reform in 2015 and diverged from comparable countries without similar reforms during the period 2011-2020. The sharp increase in biodiesel sales also coincides with a significant increase in the share of biofuels used in the transport sector, compared to similar European countries. The results suggest that the increase in biodiesel use is the main factor explaining Sweden's relatively large reduction in emissions from the transport sector over the past decade.

Regarding the second evaluation question above, an additional comparison between countries was made using a synthetic control method with emissions from the transport sector as the outcome variable. The results show that Sweden has reduced emissions more per capita than comparable countries since biofuel markets began to emerge in the early 2000s. This effect is particularly pronounced after 2015, further supporting the hypothesis that the tax exemption for biodiesel has been a particularly strong contributing factor in reducing emissions from the transport sector.

# SAMMANFATTNING

Biobränslen har varit undantagna från koldioxid- och energiskatter i Sverige sedan 1961. Före Sveriges inträde i EU var undantaget mer generellt, men efter medlemskapet behövde subventionerna knytas till specifika program för att godkännas av EU. Till exempel var etanol, det huvudsakliga biobränslet vid den tiden, helt undantaget från skatter (förutom moms) eftersom dess produktion klassificerades som "pilotprojekt". År 2003 övergick Sverige till ett generellt undantag från punktskatter (koldioxid- och energiskatt) för all etanol. Åtgärden behövde godkännas av EU-kommissionen eftersom generella skattereduktioner räknas som statligt stöd. Trots att övergången till en generell skattesubvention godkändes av kommissionen 2003, ledde det inte till någon förändring i den genomsnittliga skattesatsen för biobränslen som såldes i Sverige. Detta berodde på att nästan alla biobränslen som såldes vid den tiden var inhemskt producerade och redan subventionerade som en del av pilotprojekten.

En ytterligare ändring gjordes 2015 för att undanta den syntetiska dieseln hydrerad vegetabilisk olja (HVO), en ändring som godkändes av EU-kommissionen 2016. Det senaste beslutet om förlängning av skatteundantagen togs den 14 december 2022.

För att skatteundantaget ska kunna förlängas framöver måste EU-kommissionen godkänna Sveriges statsstöd för biobränslen. Efter ett beslut av kommissionen om skattenedsättningar på rena och höginblandade flytande biobränslen, fick de svenska myndigheterna i uppdrag att bedöma åtgärdens direkta och indirekta effekter, inklusive dess påverkan på konkurrens, stödets proportionalitet och lämpligheten av det valda stödinstrumentet (Europeiska kommissionen, 2017). En utvärderingsrapport lämnades in den 8 januari 2020.

EU-kommissionen angav att utvärderingen behövde kompletteras, särskilt för att uppfylla kommissionens krav på lämpliga utvärderingsmetoder. Den tidigare utvärderingen undersökte inte tillräckligt möjligheterna att använda kontrafaktiska metoder för att uppskatta effekten av skatteundantaget och presenterade inga alternativa metoder om kontrafaktiska metoder inte kunde användas. Syftet med denna utvärdering är därför att uppfylla EU-kommissionens krav på lämpliga metoder för att utvärdera effekterna av det svenska skatteundantaget.

Två frågor har utvärderats:

1. Har volymerna av rena och höginblandade flytande biobränslen som används/säljs påverkats av skattenedsättningen? Denna fråga syftar till att avgöra om skattenedsättningen har lett till en ökad användning och försäljning av biobränslen.
2. Har skatteundantaget haft en effekt på koldioxidutsläppen från den inhemska transportsektorn?

Utvärderingen har genomförts med både kvantitativa kvasiexperimentella metoder och en teoribaserad ansats. Två förändringsteorier konstruerades – en för skattebefrielsen för ren och höginblandad etanol, och en för skattebefrielsen för HVO och FAME. När det gäller etanol är slutsatsen att skattebefrielsen var avgörande för att göra priset på E85 konkurrenskraftigt jämfört med bensin och därmed möjliggöra en övergång från fossildrivna fordon till etanolbilar och från bensin till E85. Flera faktorer i den omgivande kontexten bidrog, men eftersom människor är priskänsliga skulle dessa förändringar sannolikt inte ha inträffat utan ett konkurrenskraftigt pris.

Resultaten från den kvantitativa analysen visar att konsumenter har varit starkt priskänsliga när det gäller valet mellan E85 och bensin. Resultatet är förväntat eftersom båda bränslena såldes på många bensinstationer i Sverige under perioden, vilket gjorde att konsumenter med flexifuel-bilar enkelt kunde växla mellan de två bränslena.

Vi har använt två typer av ansatser för att skatta effekten. I den första skattar vi det direkta sambandet mellan försäljning och priser över tid. I den andra skattar vi sambandet mellan den relativa försäljningen och relativpriset mellan E85 och bensin. I båda ansatserna kontrollerar vi för säsongsvariationer och långsiktiga trender. Fördelen med den andra ansatsen är att oljepriset kan användas som ett instrument för relativpriset, vilket minskar problemet med omvänd kausalitetsbias. I den föredragna modellen i den första ansatsen överstiger korspriselasticiteten för bensin den direkta priselasticiteten för E85. Resultaten från den andra ansatsen, som använder relativa värden samt oljepriset som ett instrument, visar även dem på en hög priskänslighet för konsumenter. Resultaten indikerar dessutom att substitutionseffekten mellan E85 och bensin tycks vara en extra drivande faktor.

Eftersom utvärderingsfrågan gäller effekten av själva skatteundantaget, har priskänsligheten på biobränsle en indirekt funktion. I en enkel modell kommer skatteelasticiteten att vara en bråkdel av priselasticiteten, beroende på hur mycket av skatten som överförs till konsumenterna. Justeringar av beskattningen kan dock också ha ett signalvärde, en indikation på en mer långsiktig förändring av priserna. Detta kan göra att skatteelasticiteten överstiger priselasticiteten, eftersom det kan medföra mer strukturella förändringar på bränslemarknaden.

Före 2015 beskattades ren och höginblandad HVO som fossil diesel. År 2015 blev HVO helt undantaget från punktskatter, vilket ledde till en ökning i försäljningen av främst ren HVO. Resultaten från analysen, både teoretiska och empiriska, tyder starkt på att skattereformerna har varit en orsak till denna snabba ökning. Före 2015 såldes ingen ren HVO. Men från och med 2015 skedde en kraftig ökning i försäljningen. Eftersom det inte finns någon variation i försäljningsdatan före 2015, på grund av att den i praktiken har noll som nedre gräns och därmed är trunkerad, är det inte meningsfullt att genomföra en statistisk tidsserieanalys som jämför perioden före och efter. Det skulle inte tillföra något till den enkla slutsatsen att försäljningen gick från noll före 2015 till en kraftig ökning under de följande åren, vilket i sig utgör ett starkt argument för att reformenen hade en avgörande effekt.

Som komplement har jämförelser mellan länder också genomförts, där Sverige jämförs med en syntetisk kontrollgrupp baserad på andra europeiska länder. Dessa jämförelser visar att Sveriges användning av biodiesel ökade avsevärt efter skattereformen 2015 och avviker från jämförbara länder utan liknande reform under perioden 2011-2020. Den kraftiga ökningen i försäljningen av biodiesel sammanfaller också med en kraftig ökning i andelen biobränslen som används i transportsektorn, jämfört med liknande europeiska länder. Resultaten tyder på att ökningen i användningen av biodiesel är det som främst förklarar Sveriges relativt stora minskning i utsläppen från transportsektorn under de senaste decennierna.

När det gäller utvärderingsfråga två ovan gjordes ytterligare en jämförelse mellan länder med hjälp av en syntetisk kontrollmetod. Resultaten visar att Sverige har minskat utsläppen mer per capita än jämförbara länder sedan biobränslemarknaderna började växa fram i början av 2000-talet. Denna effekt är särskilt uttalad efter 2015, vilket ytterligare talar för hypotesen att skatteundantaget för biodiesel har varit en särskilt starkt bidragande orsak för att minska utsläppen från transportsektorn.

# 1. INTRODUCTION

## 1.1 OVERVIEW OF THE EVALUATION CONTEXT

Biofuels have been exempted from carbon and energy taxes in Sweden in some form since 1961. Before Sweden entered the European union, the exemption had a more general form. Following the Swedish membership, however, the subsidy had to be tied to specific programs to be allowed by the EU. For example, it meant that the main biofuel used at the time – ethanol – was fully exempted from taxes (except VAT) since its production was labeled as “pilot projects”. In 2003 Sweden shifted to a general tax exemption for all biofuels. This policy shift had to be confirmed by the EU commission, since it counts as state aid. Even though the shift to a general subsidy was granted by the commission in 2003, it did not lead to any change in the average tax rate for biofuels sold in Sweden. The reason was that virtually all of biofuels sold at the time was domestically produced and thus already subsidized as part of the pilot projects.

A series of EU directives on renewable energy and biofuel use commit member states to increase the biofuel share of fuels used in the transport sector. Member states have had different policy tools available to achieve biofuel targets, the primary being quotas for fuel suppliers to blend biofuels with petrol and diesel. Excise tax exemptions for the biomass component of low-blended biofuels have been introduced in some member states in order to support blending quotas. Sweden has not adopted blending quotas but introduced a greenhouse gas reduction mandate in 2018, obligating fuel suppliers to reduce greenhouse gas emissions from fuels by a certain percentage every year through the blending of biofuels.

In addition to mandated blending quotas for low-blended fuels, some member states have seen separate markets develop for high-blended and pure biofuels. High-blended biofuels consisting of bioethanol such as E85 and biodiesels such as FAME have been the primary targets of excise tax exemptions and reductions. In 2003, Sweden shifted to a more general tax exemption for biofuels, when ethanol became fully exempted from excise taxes. An amendment was made in 2016 to exempt the synthetic diesel hydrotreated vegetable oil (HVO), applicable from 2015. The latest decision on prolongation of the tax exemptions was taken on 14th December 2022.

For the analysis it is important to highlight the difference between the tax exemption, on the one hand, and its approval as state aid, on the other. The former can exist without the latter, as it did in some form before 2003. The ambition of this report is not to evaluate the isolated effect of the approval. The focus is rather on the tax exemption itself. A reasonable assumption, however, is that the state aid approval, at some point in time, started to become a necessary condition for a continued tax exemption in Sweden. It that case, the approval itself must also have started to affect the average tax level on biofuels at that time. Therefore, a broader approach is motivated where the effects of the granted tax exemption are analyzed in more general sense.

## 1.2 OVERVIEW OF THE ASSIGNMENT: SCOPE, PURPOSE, METHODOLOGY

To secure the extension of state aid from the EU Commission, Sweden has committed to evaluating the effects of the aid. Following a decision by the Commission for tax reductions on pure and high-blended liquid biofuels, the Swedish authorities agreed to assess the measure’s direct and indirect effects, including its impact on competition, the proportionality of the aid, and the appropriateness of the chosen aid instrument (European Commission, 2017). An evaluation report was submitted on January 8, 2020.

The EU Commission indicated that the evaluation needed to be supplemented, particularly to meet the Commission’s requirements for appropriate evaluation methods. The previous evaluation did not adequately

address the applicability of counterfactual methods nor presented any alternative methods if counterfactual methods could not be used.

Sweden therefore submitted a memorandum in 2023 (Swedish Energy Agency, 2023), outlining how the previous evaluation would be supplemented to meet the EU Commission's request for the application of counterfactual or alternative methods. This memorandum describes methodological approaches that can be used to evaluate the Swedish tax exemption for pure and high-blended liquid biofuels.

The main focus is on two evaluation questions that address the effects of the aid, for which quasi-experimental methods could be used in accordance with the EU Commission's guidelines. The memorandum also provides an overview of theory-based evaluation methods that may be relevant if quasi-experimental approaches need to be supplemented.

The purpose of the evaluation is to meet the EU Commission's requirements for using appropriate methods to evaluate the effects of the Swedish tax exemption.

The evaluation will be conducted using counterfactual methods, supplemented by theory-based evaluation methods.

## 1.3 OUTLINE OF THE REPORT

Following this background, the report continues in the following way. Chapter 2 presents the evaluation questions. In Chapter 3, the theory-based evaluation approach is described, and the resulting theory of change for the tax exemption on pure and high-blended ethanol is presented. Next, findings are presented based on evidence from multiple sources. Chapter 4 evaluates the same tax exemption using quasi-experimental methods in relation to evaluation question 1. In Chapter 5, quasi-experimental methods are used to evaluate the tax exemption on HVO and FAME, also in relation to evaluation question 1. Chapter 6 presents an analysis of evaluation question 2, using quasi-experimental methods. Chapter 7 concludes the report.

# 2. EVALUATION QUESTIONS

In 2014, the European Commission published guidelines for evaluating State aid schemes. These guidelines highlight the importance of assessing the direct impact of aid on beneficiaries and its broader effects on policy objectives, competition, and trade.

Previous evaluations have focused on whether the aid contributed to Sweden's long-term goal of a fossil fuel-free vehicle fleet. However, this measure was found to be imprecise because many vehicles can use both fossil and fossil-free fuels. Therefore, the current evaluation focuses more directly on emissions reduction.

The Evaluation Questions are:

1. **"Have the volumes [of pure and high-blended liquid biofuels] used/sold been affected by the tax reduction?"**

This question aims to determine if the tax reduction has incentivized suppliers to increase the use or sale of biofuels. Understanding this helps assess whether the aid is effectively promoting the use of cleaner energy sources.

2. **"Has the tax exemption had an effect on carbon dioxide emissions from the domestic transport sector?"**

This question evaluates the indirect impact of the aid scheme on reducing greenhouse gas emissions. It is crucial for measuring progress towards Sweden's goal of a 70% reduction in emissions from the domestic transport sector by 2030.

These questions are essential for understanding the effectiveness of the aid scheme in achieving its environmental and policy goals. They help ensure that the aid provided is making a significant and positive impact.

# 3. THEORY-BASED EVALUATION: TAX EXEMPTION ON PURE AND HIGH-BLENDED ETHANOL

This chapter describes the methodology underpinning theory-based evaluation approaches as well as its advantages and disadvantages (section 4.1), it outlines the process for developing the theories of change used in the evaluation (section 4.2), presents the theory of change for ethanol (section 4.3) and finally presents findings (section 4.4).

## 3.1 THEORY-BASED EVALUATION APPROACHES

The assignment specifies that if the counterfactual quasi-experimental methods do not yield sufficiently robust evaluation results, they should be complemented with theory-based evaluation approaches. A theory-based approach provides a way to assess the extent to which an intervention has produced or influenced observed results, as well as to examine how the intervention has influenced the observed results.

### *3.1.1 Two core phases – the conceptual and the empirical phase*

Theory-based evaluation approaches are described in the Evalsed sourcebook (Evaluation of Socio-Economic Development) by the EU Commission (2013) as an approach that can be used in evaluations of EU programmes.

*"Theory-based evaluation focuses on this intervention theory; it aims to find and articulate this theory, to test it and to improve it, if necessary. Theory-based evaluation has at its core two vital components. The first is conceptual, the second empirical. Conceptually, theory-based evaluations articulate a policy or programme theory. Empirically, theory-based evaluations seek to test this theory, to investigate whether, why or how policies or programmes cause intended or observed results."* (EU Commission, 2013, p. 52)

During the conceptual phase, a theory of change is developed by the evaluator, that explains how the intervention – in this case the tax exemption and the state support – is expected to produce its results. The program logic or the logic model shows how the intervention is thought to translate into results – outputs, outcomes, and ultimate outcomes (i.e., impact). A theory of change goes beyond such a mechanical logic, and also outlines the mechanisms of change, as well as the assumptions, risks and contextual factors that support or hinder the theory from being manifested as observed outcomes. Theory-based approaches thus also seek to identify and assess any significant influencing factors (contextual factors) that may also play a role in the causal chain and thus affect the contribution claim.

During the empirical phase evaluators examine the causal link between the intervention, its outputs and the observed outcomes and verifies or rejects the expected theory. This is done by collecting empirical evidence both on outputs and outcomes but also each link and assumption, as well as contextual factors. This approach to evaluation is an attempt to understand an intervention's contribution to observed results through

a process interpretation of causation, rather than determining causation through comparison to a counterfactual. The specific steps in a causal chain are tested and when these can be validated by empirical evidence, there is a basis for making causal inference. The empirical evidence can be gathered with different methods.

### 3.1.2 Contribution analysis

Several theory-based approaches have been developed over the years. We have chosen to apply a contribution analysis approach for the present evaluation. The contribution analysis is mentioned in the Evalsed sourcebook (EU Commission, 2013). It is a performance measurement approach developed by the Canadian Auditor General in the 1990s, aiming at establishing the contribution a programme makes to desired outcomes. The contribution analysis offers an approach that seeks to provide plausible evidence that can reduce the uncertainty regarding the difference the intervention is making to observed outcomes. If an evaluator can validate a theory of change with empirical evidence and account for major external influencing factors, then it is reasonable to conclude that the intervention has made a difference. This approach makes it suitable for the present evaluation, where the tax exemption likely is one of several contributing factors affecting the impact, a fact that is highlighted in several of the existing reports and evaluations concerning the tax exemption, e.g. Swedish Energy Agency (2021).

In a contribution analysis, causality is inferred from the following evidence:

- The intervention is based on a reasoned theory of change: the results chain and the underlying assumptions of why the intervention is expected to work are sound, plausible, and agreed to by key players.
- The activities of the intervention were implemented.
- The theory of change is verified by evidence: The chain of expected results occurred, the assumptions held, and the (final) outcomes were observed.
- External factors (context) influencing the intervention were assessed and shown not to have made a significant contribution, or if they did, their relative contribution was recognized.

### 3.1.3 Uses and limitations

Theory-based approaches to evaluation have some advantages compared to other evaluation approaches:

- They offer an alternative: They can often be done where other approaches cannot be used and allow conclusions to be drawn on the cause-effect elements of an intervention.
- They create stakeholder engagement: They allow evaluators and intervention managers to tell a contribution story that makes sense to those involved.
- They open the black box of the intervention. By doing so, they allow evaluators to arrive at findings on why interventions are working or are not working.
- They enhance evaluation efficiency: Theory based approaches can use existing data to a greater extent and help focus new data collection on areas where there are significant gaps.

In the same vein, theory-based approaches also come with some limitations:

- They do not give a simple answer: They do not necessarily provide a quantitative measure of the size of the contribution an intervention is making.

- They constitute a complex undertaking: Developing a theory of change can be difficult because it involves synthesizing a range of views and information sources as well as obtaining the agreement of stakeholders.
- They can be resource demanding: In some situations, developing a theory of change can be time-consuming and/or require significant amounts of data.
- They can lead to misleading conclusions: If the underlying theory of change is flawed or biased, the evaluation results may be misleading.

## 3.2 DEVELOPING AND TESTING THEORIES OF CHANGE

In this evaluation, two theories of change have been developed – one for the tax exemption for ethanol (E85) – see section 4.3 – and one for HVO and FAME – see section 6.1. The decision to develop two theories of change was based on discussions with key informants at the Swedish Energy Agency[1]. The main reason is that the main target groups of the two policy interventions are slightly different – in the case of ethanol it is mainly private motorists and public sector actors while for HVO and FAME it is rather commercial actors and heavy traffic since it replaces diesel. This leads to some differences in the two causal chains, and in the contextual factors that are assumed to influence the outcome of the respective tax exemptions. The difference in timing between the two tax exemptions also matter for the formulation of the theories of change.

The process of developing the theories of change as well as using them to do the contribution analysis has followed a simplified version of the seven steps that are outlined by the Treasury Board of Canada Secretariat (no year) presented below. We have adapted the suggested process slightly in line with their guidance on theory-based evaluations of low-risk interventions. In low-risk interventions, they argue, the combination of risks (e.g., evidence from a prior evaluation suggesting good program performance, no significant questions about program relevance, and other factors e.g., contextual stability) are such that the evaluation approach, scope, design and methods can be calibrated relative to the required confidence level. A “light-touch” theory-driven approach may allow the evaluation team to make causal inferences at a higher level of rigour than other approaches, while still using limited resources.

In the case of the tax exemption, we argue that the process can be simplified since there is ample evidence in previous evaluations suggesting (although not definitely – due to data issues) good program performance, as well as program relevance. Moreover, contextual factors have been well studied in several evaluations or research articles. Finally, the theory-based approach should complement and strengthen the findings from the quasi-experimental method by providing plausible evidence that can reduce the uncertainty regarding the difference the intervention is making to observed outcomes while accounting for the effects of major external influencing factors.

We have adapted the suggested process by

- identifying a few critical assumptions rather than a full set, and no risks
- not collecting new evidence except through key informant interviews.

Step 1: Set out the cause-effect issue to be addressed

Step 2: Develop the theory of change. Contribution analysis needs reasonably straightforward, not overly detailed results chains, especially at the outset.

Step 3: Assess the resulting contribution story. Are there gaps in it? Which links have little evidence, which external factors are not well understood?

[1] Stakeholder workshop, 2024-06-14

- The cause-effect issue to be developed was defined based on the assignment, as well as policy documents.
- The theory of change was developed based on existing literature (Swedish Energy Agency (2023), state support decisions, budget bills, etc etc).
- Key informant interviews were instrumental in defining critical assumptions and context factors. We organised workshops and follow-up interviews with experts at the Swedish Energy Agency[2]. Experts from City of Stockholm[3] and a senior expert at WSP[4] were also interviewed.
- As a consequence of the key informant interviews, the initial Theory of Change (TOC) was adjusted. In the initial TOC, support to Swedish research on ethanol had been included as a supportive contextual factor. Key informant interviews made us realise that the Swedish supply of ethanol is just a small part of the global market and therefore this did not contribute significantly to the availability of E85. Another example was that we assumed that the tax reduction needed to be perceived as permanent in order for private motorists to invest in an FFV. After consultations with experts this assumption was removed since the price difference between an FFV and a petrol car is small, and the FFV can be fuelled with petrol.

Step 4: Gather existing evidence on the theory of change: evidence on activities implemented, on observed results, on assumptions being realised and on relevant external factors.

- The evidence gathered and reported on in sections 4.4.1-4.4.3 is based on a wide set of literature. Both the tax exemption and the contextual factors are well covered in both reports, research and evaluations.

Step 5: Re-assess the contribution story and challenges to it. Which links are strong, and which are weak? How credible is the story overall? Do stakeholders agree with the contribution story? Is it likely that external factors have a noteworthy influence on the results observed? What are the main weaknesses in the story?

Step 6: Seek out additional empirical evidence. This can be gathered using several techniques: quantitative techniques as well as key informant interviews, focus groups and workshops, and case studies.

Step 7: Revise and strengthen the contribution story. The empirical evidence should be used to build a more credible contribution story with strengthened conclusions on the causal links in the theory of change.

- Based on the evidence, we assessed the theory of change in section 4.4.4. Our assessment is that the evidence available is sufficient to assess the contribution story as credible.

## 3.3 THEORY OF CHANGE: PURE AND HIGH-BLENDED ETHANOL/E85

### *3.3.1 The contribution story*

The theory of change in figure 1 depicts how the policy decision to exempt biofuels from tax can be thought to translate into an increased volume of sold E85, and reduced carbon dioxide emissions from the domestic transport sector. This is how we have constructed the theory of change:

The Swedish Government decides to reduce taxes on pure and high-blended ethanol and seeks state aid exemption. The European Commission approves these tax exemption measures under EU state aid rules

[2] [2] Key informant interviews 2024-05-24, 2024-05-30, 2024-06-20 and 2024-09-03; Stakeholder workshop 2024-06-14; Written input 2024-06-12, 2024-07-02.
[3] 2024-05-24
[4] 2024-05-30

(activities 1 and 2). In the next step, it is assumed that producers and importers of ethanol will become aware of the tax reduction and apply for the necessary permissions (A1), and that the relevant body approves the necessary permits (activity 3). Assuming that a significant portion of the tax reduction is passed on to consumers of E85 fuel (A2), the activities result in **the price of E85 becoming competitive compared to petrol** (output 1).

The fact that E85 has a competitive price is expected to lead to several key outcomes, by making certain assumptions.

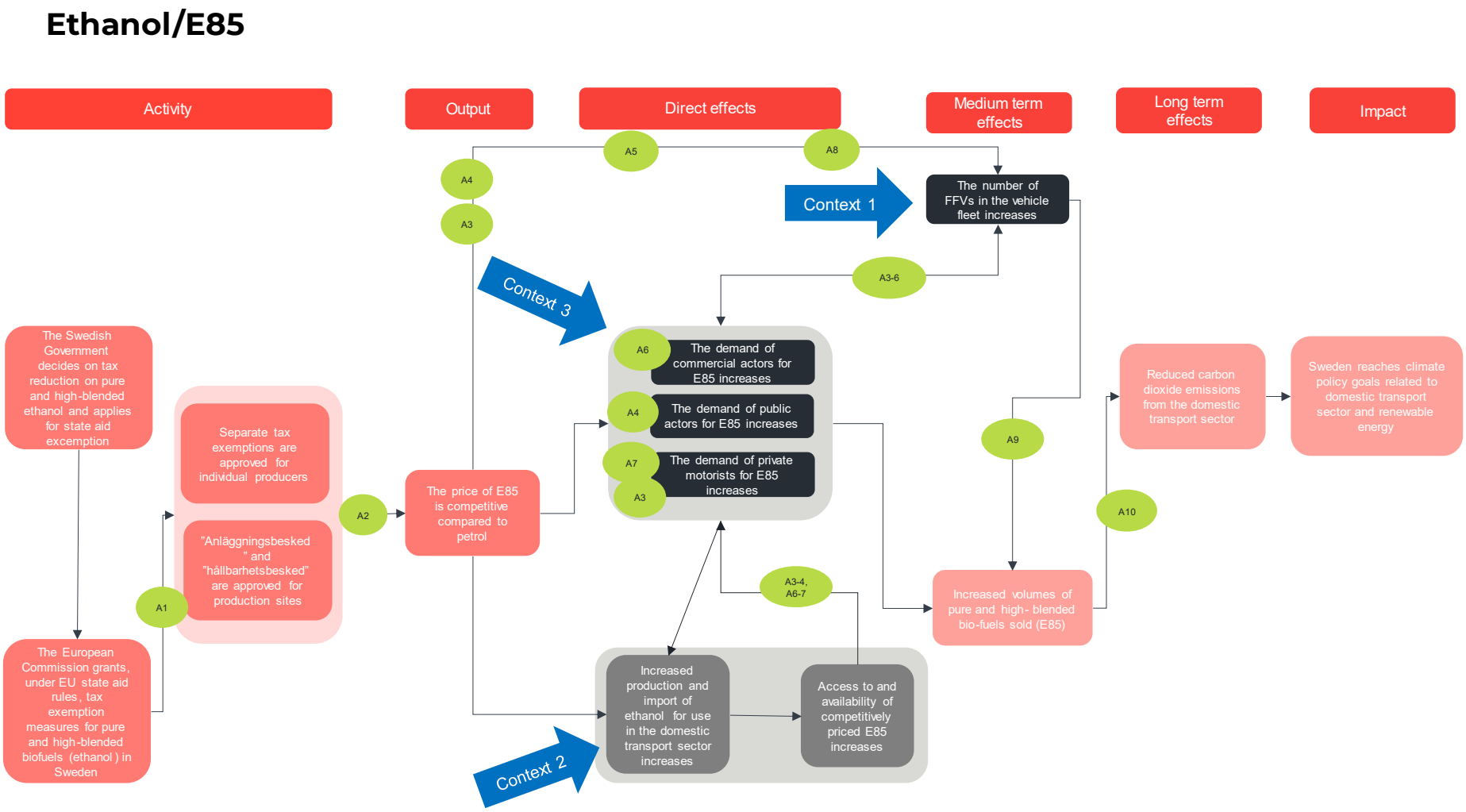
- The first direct effect is **increased demand for E85 among various actors** (direct effect 1). For this to happen, certain assumptions need to hold: Private motorists are assumed to be sensitive to price changes (A3) and have a preference for clean cars and fuels (A7). Public actors are assumed to translate environmental policy into internal demands and policy goals (A4). Commercial actors, such as bus companies and transport firms, will react to the environmental demands in public procurement (A6).
- The second direct effect from the reduced price is an **increase in the domestic production and import of ethanol** (direct effect 2), that will increase availability of competitively priced E85 (direct effect 3). There is an expected feedback effect here, where increased availability of and access to E85 further increases the demand for it, building on the same assumptions as in the previous paragraph. We also expect that the increased demand for E85 (direct effect 1) also affects the domestic production and import of ethanol (direct effect 2).
- E85 cannot be used in regular petrol vehicles. The third effect from lower prices on E85 is thus an **increased demand for FFVs**, that will lead an increased number of FFVs in the vehicle fleet (medium term effect 1). This link builds on the assumptions A3-4, 6-7 – but also a competitive pricing of FFVs (A5) and that producers and importers of FFVs are anticipated to increase their production and import activities (A8). We also expect the increased demand for E85 (direct effect 1) to have an impact on the demand for FFVs as well – and vice versa.

As more FFVs are on the road, **the volumes of pure and high-blended biofuels sold will increase** (medium term effect, evaluation question 1), assuming that FFV owners fuel their vehicles with E85 (A9). The volume sold is also affected by the increased demand from all actors (direct effect 1).

In the long term, this will lead to a **reduction in carbon dioxide emissions from the domestic transport sector** (long term effect, evaluation question 2). For this to materialise, it is crucial that the tax reduction on ethanol does not result in increased mileage (A11). Ultimately, these changes will help Sweden achieve its **climate policy goals related to the domestic transport sector and renewable energy** (impact).

Energimyndigheten

Figure 1: Theory of change - tax exemption for E85/ethanol



### 3.3.2 Contextual factors

As explained in section 4.1.2, contextual factors that are likely to influence the achievement of effects and results – in a positive or negative way – should be identified as part of developing the theory of change. By identifying them and investigating their impact, the story told by the theory of change becomes more realistic and robust.

We have identified three clusters of contextual factors from the literature, guided by the knowledge of key informants[5]:

1. Context 1: Factors affecting the demand for FFVs (medium term effect).
    - Positive: C1. Various public financial incentives like tax rebate for clean cars; C2. Various local policy incentives like reduced parking fees for clean cars (using Stockholm as a case); C5. Factors that promote FFV compared to other clean cars.
    - Negative: C3. Public debate about challenges with FFVs; C4. Second-hand value of FFVs lower than petrol cars; C6. Factors that disfavour FFVs compared to other clean vehicles.
2. Context 2: Factors affecting availability of and access to E85 (direct effect).
    - Positive: C7. Pump law.
    - Negative: C8, Factors that promote the development of or access to other clean fuels, e.g. tax reduction for HVO, development of electric cars, Klimatklivet.
3. Context 3: Factors affecting demand for E85 (direct effect).
    - Positive: C9. The pump law.
    - Negative: C10. Engine problems for FFVs related to the use of ethanol; C11. Public debate about negative aspects of E85; C12. Factors that promote demand for other clean fuels, e.g. tax exemption for HVO.

Most of these context factors have been relatively well studied. Several evaluations and reports concerned with the development of biofuels and FFVs have identified and explored similar contextual factors, for instance Kastensson and Börjesson (2017) and Swedish Energy Agency (2021) covers most of them. For the first set of contextual factors (factors that affect the demand for FFVs), Stockholm is used as a case for local factors, given the availability of evidence on these factors and the efforts that were done by City of Stockholm to promote clean cars.

The contextual factors do not occur simultaneously. Some of them can be traced back to the first decision on state support, in 2003, when policy focus was on facilitating a market transition. Others have a potential impact at later stages, on the more mature market. To map the context factors against the development of ethanol and FFV, we have adapted a model originally produced as part of the BEST project (City of Stockholm, 2009) to depict the intertwined developments of the FFV and E85 markets in Sweden.[6] The timing of the different context factors is depicted in table 1 below. We will get back to what we know about the impact of the contextual factors in section 4.4.3.

[5] Key informant interviews 2024-05-24, 2024-05-30, 2024-06-20 and 2024-09-03; Stakeholder workshop 2024-06-14; Written input 2024-06-12, 2024-07-02.

[6] In its original format, the model refers to the development of clean cars in general, in Stockholm. A key informant (interview 2024-09-03) supported the view that this model also can be used to depict the intimately intertwined developments of FFVs and ethanol nationally in Sweden as well.

Energimyndigheten

Table 1. Timing of contextual factors in relation to staircase model of the development of ethanol and FFV

| | **1999-2000: Beginner** | **2001-2004: Market introduction** | **2005-2006: Developing market** | **2007-2010: Partial market breakthrough** | **2010-2012: Market breakthrough** | **2013- : Market decline** |
|---|---|---|---|---|---|---|
| **C1. Various public financial incentives like tax rebate for clean cars including FFVs** | 1999: Change in assessment values for company cars | | 2006: Carbon dioxide based vehicle tax introduced | 2007-2008: Clean car premium of 10 000 SEK<br>2009: exemption from vehicle tax first five years | | 2012-2015: premium of 40 000 SEK to buyers of electric and hybrid vehicles<br>2017: Bonus-Malus introduced, increase in taxation of FFVs<br>2022: Increased assessment value for FFVs as company cars |
| **C2. Various local policy incentives like reduced parking fees for clean cars (using Stockholm as a case)** | | | Free residential parking in Stockholm for FFVs | FFVs exempted from congestion charges in Stockholm | | |
| **C3, C11. Public debate about challenges with FFVs** | | | | 2009-2010: debate in media about engine problems and sustainability issues | | |
| **C4. Second-hand value of FFVs lower than petrol cars** | | | | Second hand FFVs more available | | |
| **C5, 8, 10, 12. Factors that promote or disfavour FFV or E85 compared to other clean cars / other renewable fuels** | | | | Development of other clean cars take off | | |
| **C7, 9. The pump law** | | | Approved by Swedish parliament in 2005 | | | |

## 3.4 FINDINGS

In this chapter, we present evidence on the different steps in the theory of change, as well as for the assumptions/causal mechanisms and the contextual factors.

Mainly, the chapter relies on existing studies and reports. There are several comprehensive studies and evaluations of good quality that have used different techniques to gather information relevant for the present evaluation. A limited number of interviews with key informants/experts also informs this chapter. The key informant interviews have mainly informed the formulation of the theory of change. In some instances, key informant interviews confirm some observations from the material. This approach has been selected since the evaluation object is quite well researched, not least contextual factors. The five main sources of evidence for the present evaluation are presented in table 2 below.

Table 2 Overview of five reports and evaluations that the present evaluation draws heavily upon

| Name | Year | Author | Purpose, scope and method(s) |
|---|---|---|---|
| **Promoting Clean Cars. Case Study of Stockholm and Sweden** | 2009 | City of Stockholm, BEST Deliverable No 5.12 | Scope: In this report, the work of the multi-year project Clean Vehicles in Stockholm and national policies in Sweden have been used as a case study. The case study followed the developments of clean cars and alternative fuels during the time period 1994-2008 and those measures and incentives that were used to encourage the use of clean cars.<br>Methods: The impact of incentives on clean cars was studied in statistical analyses and qualitative assessments in order to assess how different factors influence the market development of clean vehicles. |
| **Biodrivmedel för bättre klimat. Hur används skattebefrielsen?, RiR 2011:10** | 2011 | Swedish National Audit Office | Scope: The evaluation investigates the impact of the tax exemption on ethanol has on the climate goals. Focus is on the design and management of the tax exemption. It is not a pure impact evaluation due to the confounding contextual factors.<br>Method: The report is based on a literature review of governmental decisions and follow-up reports from the Swedish Energy Agency, a survey of owners of clean cars to investigate which factors that matter for the decision to buy a clean car and the choice of fuel, and interviews with experts in Government Offices and the Swedish Energy Agency. Existing statistical information was compiled, and statistical analysis was made. |
| **Effekter av styrmedel för minskat fossilberoende hos fordonsflottan** | 2012 | WSP (assignment by public enquiry about fossil free vehicle traffic (N 2012-05)) | Scope: The report covers policy instruments aiming at reducing the dependence on fossil fuels in the vehicle fleet.<br>Method: The existing literature was reviewed and summarised with respect to the influence of the respective policy instrument on 1) the vehicle fleet, use of fuels and greenhouse gas emissions, 2) public expenditures and 3) socioeconomic benefits. |
| **Hinder för ökad användning av biobränslen i den svenska fordonsflottan, f3 2017:02** | 2017 | Åsa Kastensson, Luleå tekniska universitet (LTU) Pål Börjesson, Lunds tekniska högskola (LTH) | Scope: The report focuses on the barriers that currently for an increased use of high blend ethanol (especially E85) and ethanol vehicles and by extension other similar vehicle using high biofuel blends.<br>Method: The report is based on a survey including 1200 flex fuel car owners, interviews with stakeholders and analysis of secondary data and scientific literature, reports, decisions, and media reporting. |
| **Utvärdering av skattereduktion för rena och höginblandade flytande biodrivmedel** | 2021 | Swedish Energy Agency, ER 2021:9 | Scope: To evaluate the tax exemption for pure and high-blended liquid biofuels. The evaluation answers evaluation questions regarding direct and indirect effects of the state support, as well as the proportionality and appropriateness of the state support.<br>Method: Literature review and statistical analysis. |

As can be seen from the table above, the reports differ in purpose, data collection methods, in timing and to some extent in scope. WSP assesses that these are all credible and reliable reports. They apply good evaluation techniques and methodology. Some of the reports are meta-studies, that collect evidence from other studies, while others collect and analyse primary data. When we use evidence and findings from the

meta-studies, we refer to the meta-study and not to the underlying reports. Moreover, the five studies above all are rich in diagrams and figures and tables. They are not copied into this evaluation – only referred to. Not least the Swedish Energy Agency's own evaluation of the tax reduction is comprehensive and informative about most aspects of this present evaluation, and it is advisable to read the two reports in parallel.

The rest of this section is structured as follows:

- In section 4.4.1, we account for what the existing literature tells us about whether the different steps in the contribution story have materialised.
- In section 4.4.2, the same process is carried out with regards to the assumptions – do they hold?
- In section 4.4.3, evidence is gathered on what can be said on the contribution of the contextual factors towards increased demand for FFVs, increased availability of and access to E85, as well as increased demand for E85.
- Finally, in section 4.4.4, this evidence is analysed to assess whether the contribution story is realistic, credible and strong.

The strength of this analysis does not lie in gathering and presentation of new evidence – it builds on existing evidence from other reports and studies and complements the existing evidence with a few key informant interviews. The strength rather lies in that it presents this existing evidence as part of a coherent change logic. By doing so, it is possible to assess the evidence as a whole, and consequently assess the realism and strength of the theory of change.

### 3.4.1 Findings: the contribution story

In this section, we account for what the existing literature tells us about whether the different steps in the contribution story have materialised. First, we operationalise the different steps. The motivation for each operationalisation is given in the column labelled Evidence in the table that follows. This section does not attempt to seek explanations for the various observed evidence, developments and trends. In section 4.4.4, an overall analysis of links between the different steps in the contribution story is provided.

Table 3 Evidence for the steps in the contribution story

| | Designation | Operationalisation | Evidence | Verified |
|---|---|---|---|---|
| **Activity 1** | The Swedish Government decides on tax exemption on pure and high-blended ethanol and applies for state aid exemption | Relevant government decisions | We have traced government decisions dating back to 1994/95 that concern tax exemptions on pure and high-blended ethanol. In practice, these government decisions imply that high-blended ethanol has been fully exempt from tax since 1961 (Prop. 1994/95:54, ny lag om skatt på energi, m.m). In the budget bill for 2002 (Prop. 2001/02:1), the government announced a new tax strategy regarding alternative fuels. The government proposed full exemption of pilot projects from tax (both CO2-tax and energy tax), on individual basis, or a general exemption from the CO2-tax supported by article 8.4 in the mineral oil directive. In 2006, a general exemption also from the energy tax was decided. The government has in additional decisions made some minor changes to the degree of the exemption over the period, notably a reduction of the exemption in 2015-2018 - but the decision from 2006 has more or less been maintained.<br><br>Thus, the conclusion is that this activity has taken place throughout the period under evaluation. | Yes |
| **Activity 2** | The European Commission approves, under EU State aid rules, tax exemption measure for biofuels in Sweden | Decisions from the European Commission | There is a continuous series of decisions from the EU Commission on tax exemption measures for biofuels in Sweden since 2003. These can be found in the State Aid register of the Commission. The evaluation of the state support made by the Swedish Energy Agency (2021) concludes that Sweden has had state aid approval similar to the one that exists today since the Energy law was approved in 2003. The evaluation from 2021 also lists relevant state aid decisions in its table 1. | Yes |
| **Activity 3** | Necessary approvals given to individual producers and importers of ethanol | Relevant government decisions | The evaluation by the National Audit Office (2012) includes an overview of separate/individual government decisions granting specific producers tax exemption during the period 2003-2010 (Diagram 3.1-3.3).<br>From 2014 and onwards, to be granted the tax exemptions, producers and importers of ethanol were required to obtain so called sustainability statements (hållbarhetsbesked) as well as production site statements (anläggningsbesked). We have not been given access to statistics on how many such statements have been given. However, given the fact that ethanol has been imported and sold in Sweden, and that the tax exemption has been applied, we assume that the necessary statements have been issued. | Yes |
| **Output 1** | The price of E85 is competitive compared to petrol | Energy adjusted price difference | See figure 19 in Swedish Energy Agency (2021) for the energy adjusted price difference between E85 and petrol during 2005-2019. The figure shows that during most part of the period, the price of E85 has been competitive, given preferences of the consumers for or policy steering towards clean fuels. | Yes |
| **Direct effect 1** | The demand for E85 of a) commercial actors, b) public | Volume high-blended ethanol for | See medium term effect 2 below | See medium |

| | Designation | Operationalisation | Evidence | Verified |
|---|---|---|---|---|
| | actors and c) private motorists increases | E85, ED85 for domestic transport | | effect 2 below |
| **Direct effect 2** | The domestic production and import of ethanol for use in the domestic transport sector increases | Volume high-blended ethanol for E85, ED85 for domestic transport | See medium term effect 2 below | See medium term effect 2 below |
| **Direct effect 3** | The access to and availability of competitively priced E85 increases | Number of petrol stations where E85 is available | Figure A1 in appendix shows the number of public gas stations that offer different renewable fuels. In 2006, when the pump law was approved (see section x), there were 300 stations offering E85. That number increased six-fold up to 2015, when E85 was available at 1846 public gas stations. After peaking in 2015, we are now down to 495 stations offering E85.<br>Up to 2015, the access increased steadily.<br>Up to 2022, it has increased in absolute terms compared to 2006. | Yes |
| **Medium term effect 1** | There is an increasing number of FFVs in the vehicle fleet | Number of newly registered FFVs | Figure A2 in appendix shows the number of FFVs registered annually 2006-2023. Up to 2010, a noticeable part of the newly registered vehicles are FFVs, peaking in 2008 with 59 000 newly registered ones. After 2010, the number becomes smaller and smaller, until 2022 when there is a noticeable increase, albeit at low numbers. | Partly<br>Up to 2010 – yes, after 2010 – no |
| **Medium term effect 2** | The volume of pure and high-blended bio-fuels (E85) sold increases | Volume high-blended ethanol for E85, ED85 for domestic transport | Corresponds to evaluation question 1. Given that there is a world market for ethanol, where Sweden is a small part of global demand, we assume that there is no un-met demand for ethanol in Sweden. Thus we operationalise “volume demanded” with “volume consumed”. Figure A3 in appendix shows that it increases steadily from 1998 up to 2011. In 2012, it starts to decline.<br>The volume used in 2022 is slightly lower than in 2003, when the first state support was granted. For the entire period up to 2021, the demand for E85 was higher than in 2003. | Partly.<br>Up to 2012, yes.<br>Up to 2022 relative to pre-2003, yes |
| **Long term effect 1** | The carbon dioxide emissions from the domestic transport sector reduces | Carbon dioxide equivalents emissions from the domestic transport sector | Corresponds to evaluation question 2. In 2024, the domestic transport sector emitted around a third of the total greenhouse gas emissions from Sweden (Klimatpolitiska rådet, 2024). As can be seen from figure A4 in appendix, the emission of greenhouse gases from the domestic transport sector has decreased steadily since 2010 (first year available). Klimatpolitiska rådet (2024) shows that this decline has not been proportionate to the change in mileage, that has increased during the period. The driving factors behind this decline are an increased share of biofuels as well as increased energy efficiency and electrification of the vehicle fleet. The emissions are targeted to increase in 2024 due to reduction in the reduction duty | Yes |
| **Impact** | Sweden reaches climate policy goals related to domestic transport sector and renewable energy | Reporting on climate goals | In 2017, a climate policy framework was decided by the Swedish parliament. It consists of three parts – a climate act, climate targets, and a climate council. Before that, different high-level goals have existed during the evaluation period. We use the latest one for evaluation purposes but list the three goals that we have found since they have been relevant for the tax exemption policy during the evaluation period.<br>• 2002: The average of Sweden’s emissions of greenhouse gases for the period 2008-2012 should be at least 4 % lower than the emissions in 1990 (Regeringen, 2006).<br>• 2009: In 2020, 50 % renewable energy, 10 % renewable energy in the transport sector, 20 % more efficient energy use, 40 % reduction of climate gases. In 2030, the vehicle fleet ought to be fossil free. (Regeringen, 2009) | Not decisive |

| | Designation | Operationalisation | Evidence | Verified |
|---|---|---|---|---|
| | | | • 2017: The long-term target for Sweden is zero net greenhouse gas emissions by 2045 at the latest. Emissions of greenhouse gases from domestic transport should be reduced by at least 70 % in 2030 compared to 2010. (Regeringen, 2017)<br>Since 2010, the emissions from domestic transport have been reduced by 34 %, which can be compared to the goal of 70 % reduction in 2030 (Klimatpolitiska rådet, 2024).<br>In the report for Sweden on climate policies and measures and on projections (Naturvårdsverket, 2023) projections are also made ahead. According to these projections, the emissions will continue to decrease until 2050, especially the emissions from road transport that are projected to decrease from 14.2 million tonnes in 2021 to 1.3 million tonnes in 2050, mainly due to increased use of biofuels and increased numbers of electric vehicles. The increased use of biofuels is due to the emission reduction obligation. The increase in numbers of electric vehicles and improvement of energy efficiency is due to EU regulations that limits the emissions from new cars, light-duty lorries and heavy-duty vehicles. For 2030, the projection is 5 million tonnes. That would mean that the goal would be achieved. (Naturvårdsverket, 2023) | |

### *3.4.2 Findings: assumptions*

In this section, we account for what the existing literature tells us about whether the assumptions hold, based on existing literature. As in the previous section, their respective importance is not analysed but rather verify if they can be said to exist.

Table 4. Evidence for assumptions

| | Assumption | Evidence | Verified |
|---|---|---|---|
| **A1** | Producers and importers of ethanol become aware of the tax reduction and apply for relevant permissions | If the tax exemption should have any effects on the supply of E85, producers and importers of ethanol need to become aware of the tax exemption.<br>We can ascertain that producers and importers of ethanol applied for relevant permissions, and thus claim that there was awareness among them about the tax exemption.<br>Supporting facts are that news paper articles report about views from the industry on the tax exemption, and on ethanol production and distribution. Hedeler et al. (2023) for instance reports that between 2003 and 2021, there were 423 full length articles in the Swedish leading newspaper Dagens Nyheter on the matter of ethanol as fuel for transport “that comment on how, for instance, industry representatives, politicians, and civil servants argue about the future of biofuel policy in the country” (p 6).<br>(See also Activity 3) | Yes |
| **A2** | A sufficient part of the tax reduction is transferred to consumers of E85 | If the tax exemption should lead to an increase in the consumption of ethanol (E85), it needs to be translated to the consumer as reduced prices. As noted under Output 1, the energy adjusted price difference between E85 and petrol was small during the evaluation period. Thus, a sufficient part of the tax reduction was transferred to consumers. | Yes |
| **A3** | Private motorists are price sensitive | This is a crucial assumption for the theory of change to hold. If the reduced price (that results from the tax exemption) should lead to an increased demand among private motorists for E85, they need to display price sensitivity – the demand for E85 needs to be characterised by price elasticity.<br>There is strong evidence that private motorists are price sensitive with regards to E85, as shown in chapter 5 of this report.<br>But also, other research on the Swedish context confirms this finding. Kastensson and Börjesson (2017) find that actors in the ethanol industry hold the view that price matters for the demand. Findings from the survey of 1200 owners of FFVs show that when choosing fuel, | Yes |

| | Assumption | Evidence | Verified |
|---|---|---|---|
| | | 60 % of the respondents state that the price the most important factor, and in order to select E85 the energy-adjusted price should be the same as or lower than the corresponding price for petrol. There is also evidence that the fuel price affects the demand for FFVs.<br>In the report by City of Stockholm (2009), statistical analysis is used to estimate the effect of incentives on the adoption of clean cars in general, in Stockholm. The statistical analysis shows that the exemption from congestion charges for alternatively fuelled cars, the relative price of the alternative fuel (E85), free parking and the 10,000 SEK subsidy have had significant impacts on adoption of clean cars. The most important incentives are those affecting the running costs of using cars: congestion charges and the fuel price. The number of gas stations offering alternative fuels, free residential parking and the availability of alternative fuel models were not significant variables in their analysis.<br>Liu and Greene (2014) estimate the sensitivity of aggregate E85 demand to E85 and petrol prices is estimated using data from Minnesota, North Dakota, and Iowa. It indicates that the market price elasticity of E85 choice is around -6 and -7. The relatively high price elasticity found in this study indicates that the price difference between E85 and petrol is a critical factor in consumers' choice of E85.<br>We have also found a number of studies that nuance the issue of price elasticity with regards to E85 or fuel in general. Findings in Andersson (2019) suggest that Swedish consumers respond more strongly to changes to the carbon tax rate than equivalent market-driven petrol price changes. The estimated carbon tax elasticity of demand for petrol is three times larger than the price elasticity.<br>Comparing the Brazilian and Swedish experience, the analysis of Pacini and Silveira (2010) suggests that the consumer might prefer more constant price advantages (e.g., in Brazil), while reacting negatively to very volatile markets (e.g., in Sweden). Thus, price stability might play an important role in determining the long-term success of biofuel markets. Sterner (2007) cites several reports and concludes that the price elasticity for petrol is quite high but only in the long run: in the short run it may be quite inelastic which has important implications for policy makers. | |
| **A4** | Environmental ambitions of public actors are converted to internal standards / policy goals | We assume that public actors like municipalities translate environmental policies into internal policies, that affect their procurement of vehicles and fuel. Otherwise, in the absence of economic benefits, public actors would not switch to FFVs and ethanol given the need to prove value for money.<br>In the report by WSP (2012), some examples are given where rules and regulations were adjusted to support green procurement of vehicles in the public sector.<br>• In January 2005 a law came into force, regulating the purchase and leasing of Sweden's public authorities and agencies regarding clean cars. It stated that at least half of the vehicles purchased during one year should be clean cars. This was strengthened in January 2006 to at least 75 % and one year later this was reinforced to at least 85 %.<br>• In 2009 the law was replaced by a law, sometimes referred to as the clean car act, stating that all vehicles that are procured or leased should be clean cars. Subsequently, clean cars increased in the fleet of public actors. When the report was produced, the share of clean cars was higher among public sector actors compared to commercial actors and private motorists.<br>The so-called clean car act was subsequently replaced by a new act in 2020 (SFS 2020:486). The cars that an authority purchases or leases has to be a clean car. | Yes |
| **A5** | The purchase price of FFVs is competitive relative to other cars | To become an interesting alternative, the total cost of owning and running an FFV needs to be competitive compared to traditional cars. The purchase price forms a significant part of this total cost.<br>In 2009 (City of Stockholm, 2009) the alternatively fuelled vehicles available on the Swedish market had a purchase price premium of about 30 percent for hybrid cars, ten percent for biogas cars, and five percent for an ethanol FFV. The price difference was thus small. | Yes |
| **A6** | Environmental ambition of public actors is converted into demands in transport-related public procurement that affect commercial actors (bus | This assumption matters for the theory of change since we assume that commercial actors act on commercial signals and in the absence of economic benefits from buying FFVs and using E85, other stimulus is needed for them to shift behaviour.<br>Again, we refer to the literature review by WSP (2012) for examples of early existence of such requirements.<br>• In 2010, the public procurement act was revised so that public authorities should include environmental and social concerns in public procurement, if the nature of the procurement allows for this. This is still part of the procurement act.<br>• The trade association Swedish Association for Public Transport (nowadays Svensk Kollektivtrafik), transport principals as well as municipalities and counties decided on and revised environmental requirements on several occasions during the period | Yes |

| | Assumption | Evidence | Verified |
|---|---|---|---|
| | companies, transport firms, firm vehicles), and commercial actors apply environmental concerns. | 2001-2010. The environmental programs contained goals relating to the emissions of greenhouse gases by the public transport, and use of renewable fuels. Between 2001 and 2010, the share of buses that run on gas and ethanol increased from 5 to 14 %. During the same time, the share in trucks was substantially smaller.<br>In 2018, the environmental program of Svensk Kollektivtrafik was updated, and the new version has a higher focus on reduced emissions of carbon dioxide and other emissions that affect the climate (Partnersamverkan för en förbättrad kollektivtrafik, 2018). | |
| **A7** | Private motorists have a preference for clean cars and fuels | Above, we have investigated the assumptions about price sensitivity of private motorists. Now we add an assumption about environmental preferences among the same category. This is important for the theory of change to hold, if the economic benefits of owning and running a clean car are small or non-existent.<br>A study in Stockholm, cited by City of Stockholm (2009) conducted deep interviews with owners of alternatively fuelled vehicles and owners of conventional vehicles and found that alternative fuel vehicle ownership was not significantly different from conventional vehicle ownership. Both groups report that their primary reason for owning a vehicle is either family size or the need for a car to travel to their summer house. However, while alternatively fuelled vehicle owners reported environmental performance as the most important purchase factor, conventional vehicle owners reported cost as paramount when choosing a vehicle.<br>In their survey of owners of FFVs, the National Audit Office (2012) finds that the desire to reduce the climate impact is an important factor affecting the choice of an ethanol or gas vehicle. This is the most commonly cited reason – more frequent however among owners of gas-fuelled cars than FFVs. | Yes |
| **A8** | Producers/importers of FFVs increase the production/import – the supply matches the demand. | This assumption simply states that the assumed increased demand for FFVs is matched by an increased supply. Otherwise, there will be no increase in the number of FFVs in the vehicle fleet, and thus no increased demand for E85.<br>In 2009-2012, more than 10 car manufacturers produced FFVs. In 2016, this had gone down to only one car manufacturer (Kastensson and Börjesson, 2017). | Yes up to 2012 |
| **A9** | Owners of FFVs fuel with E85 | This is described thoroughly in the evaluation by the Swedish Energy Agency (2021). They report that FFV owners to an increasing extent have filled with petrol instead of E85, even when the E85 price was advantageous. The degree to which FFV owners refuelled E85 was 45 percent during 2018, which represents an increase compared to 25 % in 2017. Data from earlier years from the National Audit Office (2012) show that the degree was as high as 90 % in 2008 and 2007 and reduced to 60 % in 2009. | Partly |
| **A10** | The tax reduction does not lead to increased mileage | See chapter 6 for an empirical assessment of this question. Since Sweden has reduced its emissions from the transport sector more than comparable EU-countries, this indicates that the tax exemption has not lead to a substantial increase in mileage that outweighs the positive substitution effect from fossil fuel to bio fuel. | |

### *3.4.3 Findings: contextual factors*

In this section, evidence is gathered and presented on what can be said on the contribution of the contextual factors towards increased demand for FFVs, increased availability of and access to E85, as well as increased demand for E85.

Table 5 Evidence for the contextual factors affecting demand for FFVs

| | Designation | Assumed direction of influence | Technique neutral | Evidence | Verified |
|---|---|---|---|---|---|
| **C1** | Various public financial incentives like tax rebate for clean cars | Positive | Mainly yes | A number of financial incentives towards consumers were introduced and adjusted continuously from 1999 and onwards, to facilitate the introduction of clean cars on the car market.<br>• One such was the change in the standard assessment values for company car taxation in 1999. Before the change, clean vehicle drivers received a disadvantageously high tax, since the assessment value was based on purchasing price. In 1999 company car tax on clean vehicles was set equivalent to a comparable conventional car. This meant that Renault Clio Electrique received the same tax value as a conventional Renault Clio. Before the change, the electric car was taxed about three times as high as the conventional car. (City of Stockholm, 2009). In July 2022, this was changed so that electric hybrid vehicles and FFVs were excluded from the reduced standard assessment (Finansdepartementet, 2021).<br>• In 2006 a carbon-dioxide based vehicle tax was introduced on new cars (Swedish Energy Agency, 2021)<br>• In 2007, a clean car premium of 10 000 SEK was introduced for new cars. This was replaced in 2009 by an exemption from vehicle tax during the first five years, that was also applied to fuel efficient petrol and diesel cars. (Swedish Energy Agency, 2021). Between 2012 and 2015, buyers of electric cars and electric hybrid cars received a premium of 40 000 SEK. These incentives were replaced with the so-called bonus-malus system in 2018 that means that buyers of new vehicles with low emissions of carbon dioxide receive a premium and vehicles with higher carbon dioxide emissions are taxed higher during the first three years.<br><br>The reports and studies that we base the evaluation on gives a somewhat contradictory picture of the effect of these incentives on the demand for FFVs.<br>• Swedish Energy Agency (2021) puts forward that the increase in FFVs during 2006-2010 likely is an effect of several policy initiatives taken together, among them these financial incentives. The reduction in number of new FFVs registered following 2008 is explained by the reduced economic benefits of the incentives at that time.<br>• The survey by Kastensson and Börjesson (2017) shows that 60 % of the respondents stated that the clean car premium 2007-08 had not had any effect on their choice of an FFV. This could likely be explained by that they had bought their FFV second hand. However, the reduced vehicle taxation was considered important for 40 % of the owners of FFVs. More respondents state that the reduced vehicle taxation has mattered for their choice of an FFV.<br>• Based on statistical analysis, City of Stockholm (2009) concludes that the exemption from congestion charges for alternatively fuelled cars, the relative price of the alternative fuel (E85), free parking and the 10,000 SEK subsidy have had significant impacts on adoption of clean cars. The most important incentives are those affecting the running costs of using cars: congestion charges and the fuel price. The number of gas stations offering alternative fuels, free residential parking and the availability of alternative fuel models were not significant variables in their analysis.<br>• Lindfors and Roxland (2009), using similar but more detailed data, also find that the premium has had a positive impact on the market shares of green cars in general, and that the impact differs depending on fuel type. Gas cars have experienced the largest impact of the rebate, followed by low emission petrol and diesel cars. The effect on ethanol cars was considerably smaller. Their results indicate that the large increase in the market share of ethanol cars would have taken place even without the rebate. | Yes, but limited impact |

| | Designation | Assumed direction of influence | Technique neutral | Evidence | Verified |
|---|---|---|---|---|---|
| | | | | • The survey done by the National Audit Office (2012) gives a different result, showing that the clean car premium of 2007-2008 and the reduced vehicle taxation has been an important factor for around a third of those that have purchased an FFV.<br>• Sprei (2017) investigates the effects during 2002-2011 and finds that changes in the rebate structure in later years is a significant factor for the decline. | |
| **C2** | Various local policy incentives like reduced parking fees for clean cars (using Stockholm as a case) | Positive | Yes | During the early market phase, the City of Stockholm introduced a number of local measures to enhance the introduction of clean cars in the city. In 2005, Stockholm introduced free residential parking for clean vehicles and free commercial vehicle parking permits for clean vehicles. In 2007-2008, clean cars were exempted from congestion taxes until 2012. No exemptions were however granted for clean cars bought January 2009 or later. (City of Stockholm, 2009)<br><br>Again, the impact that we see in different studies differ.<br>• Kastensson and Börjesson (2017) note little impact on the choice of buying an FFV – again with the caveat that many of the FFV owners that responded to the survey had bought their FFV as a used car, when these incentives were no longer applied.<br>• Statistical analysis by City of Stockholm (2009) shows that the exemption from congestion charges for alternatively fuelled cars, free parking and the 10,000 SEK subsidy have had significant impacts on adoption of clean cars. The most important incentives are those affecting the running costs of using cars: congestion charges and the fuel price. The number of gas stations offering alternative fuels, free residential parking and the availability of alternative fuel models were not significant variables in their analyses.<br>• The National Audit Office (2012) cites the report by City of Stockholm, and notes that the exemption from congestion charges is the single intervention that has had the largest impact on choice of a clean car<br>• Sprei (2017) finds it hard to establish effects of local incentives such as parking subsidies and exemption from the congestion charging in Stockholm. | Yes, but limited impact |
| **C3** | Public debate about challenges with FFVs | Negative | FFV specific | During 2009 and 2010 a number of FFVs experienced engine problems. These are described in Kastensson and Börjesson (2017). The cause for these problems were never fully clarified – fuel producers blamed the car producers, and vice versa. Those that were affected – estimates point at 2000 cars out of 250 000 FFVs – had to pay for the required, quite costly, repairs themselves. The engine problems relate to factors in the fuel, but also so-called teething problems in the vehicles themselves.<br><br>We have so far found no evidence on the impact on demand for FFVs | No evidence found |
| **C4** | Second-hand value of FFVs lower than petrol cars | Negative | FFV specific | Kastensson and Börjesson describe how the second-hand value of FFVs reduces more quickly than for other cars They argue that this might have affected the willingness to buy an FFV, although presenting no evidence. | No, but reasonable to assume |
| **C5** | Factors that promote FFV compared to | Positive | FFV specific | As other clean cars developed, alternatives became available for consumers with a preference for environmentally friendly vehicles. The demand for FFVs in relation to the demand for other clean cars should be positively affected by for instance the positive price difference compared to gas-fuelled vehicles. This context factor did not apply during the first stages of market introduction of FFVs, rather towards the partial market breakthrough stage. We do not explore this | Not explored |

| | Designation | Assumed direction of influence | Technique neutral | Evidence | Verified |
|---|---|---|---|---|---|
| | other clean cars | | | context factor further since it simply means that we assume that consumers are price sensitive in their choice of clean car.<br><br>The pump law (see C7) promoted availability of E85 compared to other renewable fuels. City of Stockholm (2009) however estimates that the number of gas stations offering alternative fuels were not significant variables in their analyses on the adoption of clean cars in Stockholm. | |
| **C6** | Factors that disfavour FFVs compared to other clean vehicles | Negative | FFV specific | Similar to C5, there are also factors that affect the choice between different types of clean cars – but in the favour of other types of clean cars. This includes for instance public support to the introduction of electric cars, like the "supermiljöbilspremie" in 2012-2015. Again, similar to the reasoning under C5 we do not explore the potential impact of this context factor further.<br><br>Findings in Sprei (2017) show that fuel-efficient diesels entering the market has been a significant factor for the decline in sales. | Not explored |

Table 6 Evidence for the contextual factors affecting availability of and access to E85

| | Designation | Assumed direction of influence | Fuel neutral | Evidence | Verified |
|---|---|---|---|---|---|
| **C7** | "Pump law" | Positive | Yes | Late 2005, the Swedish parliament voted a law obliging fuel stations to make renewable fuels available (Swedish Energy Agency, 2021). It required gas stations selling more than 1000 cubic meters of petrol or diesel to supply at least one alternative fuel. The purpose of the decision was to reduce CO2-emissions by improving access to renewable fuels, not least considering that access had been assessed to be one of the largest obstacles to increased use of renewable fuels (Trafikutskottet, 2009). As of 1 January 2015, the legal requirements were loosened so that gas stations selling more than 1,500 m3 of petrol or diesel must supply at least one kind of renewable fuel (Naturvårdsverket, 2023).<br><br>As can be seen in figure 4, refuelling infrastructure supplying E85 initially grew rapidly since the introduction of the renewable fuel obligation in 2006: from 305 in 2006 to around 1800 in 2016. Trafikutskottet (2009) however notes that they cannot conclude that the law has caused this development. They further note that the pump law was intended to be technique neutral – not promoting the use of a specific renewable fuel – but that in practice it was to a large extent pumps for E85 that were installed at the pump stations that were affected by the law. According to City of Stockholm (2009), the initial dominance of ethanol as the preferred option taken by fuel providers to fulfil the national requirement was explained by installation costs. Installation of an ethanol pump requires an investment of approximately 350,000-400,000 SEK, while a biogas pump costs ten times that amount. Further, Trafikutskottet (2009) observes that at that time there were large geographic differences in access to renewable fuels – between different parts of Sweden and between urban and rural areas. | Yes, but weak evidence |
| **C8** | Factors that promote the development | Negative | No | Like we described for demand for FFVs and demand for E85, where we identified factors that affected the choice between alternative fuels or clean cars, we also observe factors that affect the development of or access to other renewable fuels. One such was the possibility for gas stations could apply for subsidies for installing biogas stations (up | Limited evidence |

| | Designation | Assumed direction of influence | Fuel neutral | Evidence | Verified |
|---|---|---|---|---|---|
| | of or access to other clean fuels, | | | to thirty percent of the additional cost), although the assessment in 2009 was that so far, this had not affected ethanol's position as the most-widely available alternative fuel on the Swedish market (City of Stockholm, 2009). The initiative "Klimatklivet" (the climate step), introduced in 2015, contains support to local and regional investments that reduce emissions of carbon dioxide and other gases that affect the climate. Under it, it is possible to apply for support to establish gas stations that supply renewable fuels.<br><br>Evidence for the impact this has had on access to and availability of E85 is limited. Up to 2019, according to Swedish Energy Agency (2021), 35 stations for HVO and 6 stations for ED95 had received support within the program. According to information from a key informant[7], the policy initiative "Klimatklivet" in 2015 made fuel station owners switch away from E85 pumps to other types of renewable fuels, notably HVO. | |

Table 7 Evidence for the contextual factors affecting demand for E85

| | Designation | Assumed direction of influence | Fuel neutral | Evidence | Verified |
|---|---|---|---|---|---|
| **C9** | The pump law | Positive | Yes in theory, in practice E85-specific | See C7 for a description of the pump law and its consequences for the number of gas stations making E85 available.<br><br>Evidence from the US context (Liu and Greene, 2014) shows that access to E85 is critical to increase the demand for it. They estimate that when the availability of E85 exceeds 15 % of the availability of petrol, the negative impact of fuel availability on the consumption of it becomes effectively zero. Thus, in their study, access and availability matters for the demand. One factor that increased the availability of E85 in Sweden was the so-called pump law, that was decided in 2005.<br><br>The Swedish Energy Agency states that the increase in use of high-blended ethanol from 2005 is likely connected to the introduction of the pump law (Swedish Energy Agency, 2021). | Yes, but limited evidence |
| **C10** | Engine problems for FFVs related to the use of ethanol | Negative | E85-specific | During 2009 and 2010 a number of FFVs experienced engine problems. These are described in Kastensson and Börjesson (2017). The cause for these problems were never fully clarified – fuel producers blamed the car producers, and vice versa. Those that were affected – estimates point at 2000 cars out of 250 000 FFVs – had to pay for the required, quite costly, repairs themselves. The engine problems relate to factors in the fuel, but also so-called teething problems in the vehicles themselves. On several occasions, garages have recommended their clients to use petrol instead of E85 in their FFVs. Kastensson and Börjesson (2017) report that media articles show that more garages – one article reports that this applies to 9 garages out of 10 – recommend their customers to fuel with petrol instead of E85.<br><br>Survey evidence (Kastensson and Börjesson, 2017) shows that engine problems indeed had a negative effect on the demand for E85. Engine problems is a factor affecting choice of fuel – both caused by the fear of FFV owners but also that 15% of the respondents actually experienced engine problems. | Yes |

[7] Interview 2024-06-20

| | Designation | Assumed direction of influence | Fuel neutral | Evidence | Verified |
|---|---|---|---|---|---|
| | | | | • Around 35 % of the respondents feared that ethanol might damage the engine. Those respondents also showed less propensity to fuel with E85.<br>• 25% of the respondents in the survey have received recommendations from their garage to switch from E85 to petrol. Those respondents were also less likely to fuel with E85.<br>Other studies confirm this view, although not backed by the same type of evidence. One such example is Miljöbarometern (2024), that claims that the reduced usage of E85 after 2009 and 2010 was due to the engine problems. | |
| **C11** | Public debate about negative aspects of E85 | Negative | E85-specific | Doubts about ethanol being sustainable were raised following articles in Sweden's largest newspaper, starting Dec 14, 2007 (City of Stockholm, 2009) The reputation of ethanol as a fuel was affected by an intense debate around using arable land to grow fuels rather than food. Also, other issues connected to the sustainability of ethanol was discussed intensely during the same period, for instance working conditions at sugar plantations in Brazil and that the climate benefits of ethanol compared t fossil fuels was smaller or non-existent. This led the EU to formulate sustainability criteria for biofuels. (Miljöbarometern, 2024) The media debate peaks in 2008, with a minor revival in 2010. Instead of discussing different types of ethanol, all types were regarded as equal in the debate. (Kastensson and Börjesson, 2017)<br><br>The survey done by Kastensson and Börjesson (2017) shows that nearly 50% of the respondents do not believe that ethanol competes with food production. There is however an insecurity, and those that are concerned by the competition are less likely to fuel with E85. | Yes, to some extent |
| **C12** | Factors that promote demand for other clean fuels, e.g. tax exemption for HVO | Negative | Fuel neutral | In the same way as described under C5, C6 and C8, factors that promote the demand for other renewable fuels likely have a negative impact on the demand for E85 among motorists that have an environmental preference. | Not explored |

### 3.4.4 Conclusions: the theory of change is credible although the context changes

This section tests the theory of change[8]. It starts by assessing the links[9] in the theory of change, and if contextual factors are likely to have influenced the results. It then goes on to assessing the overall credibility of the theory of change and concludes by discussing any weak links. Please refer to the theory of change in figure 1 for ease of reading.

**1. Which links are strong in the theory of change, which are weak? Which contextual factors are likely to have had an influence on the observed results?**

The theory of change starts with the Swedish Government deciding to reduce taxes on pure and high-blended ethanol and seek state aid exemption (activity 1). The European Commission then approves these tax exemption measures under EU state aid rules (activity 2). In the next step, it is assumed that producers and importers of ethanol will become aware of the tax reduction and apply for the necessary permissions (A1), and that the relevant body approves the necessary permits (activity 3).

- *WSP's assessment:*
  - *Activities 1-3 all took place.*
  - *Assumption 1 holds.*

Assuming that a significant portion of the tax reduction is passed on to consumers of E85 fuel (A2), the activities are expected to result in **the price of E85 becoming competitive compared to petrol (output 1)**.

*Assessing the links*

- *The price has been relatively competitive over the period, with some fluctuations.*
- *WSP's assessment:*
  - *Output 1 has materialized.*
  - *Assumption 2 holds.*
  - *The link from activities 1-3 to achieving a competitive price of E85 is strong.*

That E85 has a competitive price is expected to lead to several key outcomes, but certain assumptions are required. The first expected outcome is **increased demand for E85 among various actors (direct effect 1)**. For this to happen, certain assumptions need to hold: Private motorists are assumed to be sensitive to price changes (A3) and have a preference for clean cars and fuels (A7). Public actors are assumed to translate environmental policy into internal demands and policy goals (A4). Commercial actors, such as bus companies and transport firms, will react to the environmental demands in public procurement (A6).

*Assessing the links*

- *The use of high-blended ethanol in domestic transport exhibits a bell-shaped pattern. From quite low steady levels in the late 1990s and early 2000s, it starts to increase in 2006, jumps in 2008 and is back on the increasing trend up to 2011 where it stays until 2012. After 2012, it starts to decrease down towards 2003 levels. There are thus two periods – up to 2011-2012, and from 2013 and onwards.*

[8] Following the steps proposed by Treasury Board of Canada Secretariat (2024).
[9] A link is assessed as strong a) if the activities have taken place, or the results have materialised, and b) if the underlying assumptions hold.

- *A number of assumptions were made for the competitive price (output 1) to contribute to increased demand for (or consumption of) E85.*
    - *Since E85 to a large extent was consumed by private motorists, the most critical assumption is that private consumers are price sensitive (A3). This assumption is backed by solid evidence both from the literature and from the econometric analysis of WSP in chapter 5.*
    - *Evidence is backing the assumption that private motorists have environmental preferences (A7).*
    - *Evidence is also backing the two assumptions that public actors translate environmental policy into internal guidelines and requirements (A4) and into environmental demands in procurements (A6).*
- *WSP's assessment:*
    - *Direct effect 1 has materialized during the entire period. The effect is increasing up to 2012, and from 2013 and onwards decreasing.*
    - *Assumptions 3, 4, 6 and 7 hold.*
    - *The link from the competitive price of E85 to an increased demand for E85 is strong up to 2012, and weaker during the remainder of the period.*

*Assessing the influence from the contextual factors*

- *We have explored the potential impact on the demand for E85 from the pump law (C7), engine problems for FFVs related to E85 (C10), and the debate in media questioning the sustainability of ethanol (C11). There is strong evidence that the increased access to E85 caused by the increase in number of gas stations offering E85 has positively influenced demand for E85. There is evidence of negative influence on the demand of E85 from the engine problems reported during 2009 and 2010, and evidence on some negative influence from the media debate about sustainability challenges of ethanol (C11).*
- *WSP's assessment:*
    - *Two contextual factors are likely to have had significant influence on the increased demand for E85: the positive influence from the increased number of gas stations offering E85 (C7) and the negative influence after 2009 from the engine problems (C10). There was likely some negative influence from the media debate questioning the sustainability of ethanol (C11).*

The second expected direct effect from the reduced price of E85 is **an increase in the domestic production and import of ethanol (direct effect 2)**, that will increase **availability of competitively priced E85 (direct effect 3)**. We also expect that the production and import of ethanol is affected by the increased demand for E85 (direct effect 1) affects. Finally, a feedback effect from the increased availability of and access to E85 on **the demand for E85 (direct effect 1)** is foreseen, building on the assumptions A3-4, and A6-7.

*Assessing the links*

- *Domestic production and import of ethanol was operationalised by the consumption of it. This means that the same bell-shaped pattern is observed as for direct effect 1.*
- *No specific assumptions have been identified for the link between output 1 and direct effect 2. However, the theory of change assumes normal market behaviour, i.e. that producers and importers respond to the increased demand. For the feedback effect from direct effect 3 to direct effect 1, assumptions A3-4, A6-7 are made. They are described above.*
- *WSP's assessment:*

- *Direct effects 2 and 3 have materialized. Direct effect 2 is larger during the period 2003-2012, and smaller from 2013 and onwards. Direct effect 3 is larger up to 2015, and decreases after that.*
- *Assumptions 3, 4, 6 and 7 hold.*
- *All three links – from the competitive price to increased domestic production and import of ethanol; from the increased demand for E85 to the increased import and production of ethanol; and from the access to and availability of E85 to the increased demand for E85 – are strong up to 2012, and weaker after 2012.*

*Assessing the influence from the contextual factors*

- *There is some evidence that the pump law (C7) was important to increase consumer access to E85. We did not identify contextual factors influencing the production of ethanol, since Sweden is one small buyer on the world market.*
- *WSP's assessment:*
  - *Contextual factor C7, the pump law, has likely had an influence on the access and availability of E85.*

E85 cannot be used in regular petrol vehicles. The third expected effect from lower price of E85 is therefore **an increased number of FFVs in the vehicle fleet (medium term effect 1)**. This link builds on the assumptions A3-4 and A6-7, but also a competitive pricing of FFVs (A5) and that producers and importers of FFVs increase their production and import activities (A8). We also expect the increased demand for E85 (direct effect 1) to have an impact on the number of FFVs in the vehicle fleet – and vice versa.

*Assessing the links*

- *Initially and up to 2010, there is an increase in number of newly registered FFVs, but after 2010 the number is reduced substantially. The decrease in FFVs in the vehicle fleet precedes the decline in the demand for E85.*
- *A number of assumptions were identified*
  - *Assumptions A3-4, A6-7 are described above.*
  - *Regarding pricing of FFVs, we noted that the price difference towards petrol cars (A5) was not substantial.*
  - *While the number of car manufacturers producing FFVs increased up to 2012, it then decreased (A8).*
- *WSP's assessment:*
  - *Medium term effect 1 has materialised during the period 2003-2010, but not during the period from 2011 and onwards.*
  - *Assumptions A3-7 hold. Assumption A8 holds up to 2012.*
  - *The link from the competitive price of E85 to an increased number of FFVs in the vehicle fleet is strong up to 2010, and weak during the remainder of the period.*
  - *The feedback link from an increasing number of FFVs in the vehicle fleet to the demand for E85 is stronger than the other way around.*

*Assessing the influence from the contextual factors*

- *We have mainly explored the potential influence on the demand for FFVs of financial incentives to buyers of FFVs and other clean cars (C1), local initiatives in the city of Stockholm (C2), and public debate about engine problems of FFVs (C3).*
  - *We find mixed evidence on the influence that financial incentives like the clean car premium of 10 000 SEK have the decision to buy an FFV (C1). Some studies find that it has had a*

*significant effect, at least for some of the buyers, others find that the impact is small. The financial incentives differ over time. One study reports that the changed incentive structure is a significant factor for the decline in FFVs.*

- *Turning to local policy initiatives in Stockholm (C2), again we find mixed evidence. One study finds that the exemption from congestion charges as well as the free parking has been an important factor for buying an FFV, while another doesn't find a significant effect.*
- *Regarding the public debate about engine problems with FFVs (C3), we found no evidence in the material of its influence on the number of FFVs in the vehicle fleet. (C3 is discussed in further detail in relation to its impact on the demand for E85.)*

- *WSP's assessment:*
  - *Contextual factors, especially the financial incentives (C1), are likely to have influenced the increase in FFVs in the vehicle fleet, but not decisively.*

As more FFVs are on the road, the **volumes of pure and high-blended biofuels sold is expected to increase (medium term effect, evaluation question 1)**, assuming that FFV owners fuel their vehicles with E85 (A9). The volume sold (medium term effect) is also affected by the increased demand for E85 from all actors (direct effect 1).

*Assessing the links*

- *The development of volumes sold is described under Direct effect 1. The increase in volume sold depends on an increased demand for E85, as well as an increased number of FFVs in the vehicle fleet. Neither of these effects materialise consistently during the evaluation period.*
- *Looking at assumption 9, the evidence indicates that the degree to which FFV owners refuelled with E85 was quite high initially decreased, at least in 2016-2017 from which we have data.*
- *WSP's assessment:*
  - *The medium term effect materialised during the period 2003-2012, but not during the period from 2013 and onwards.*
  - *Assumption 9 holds initially, but not over the entire period.*
  - *The link from an increased number of FFVs to increased volumes of pure and high-blended ethanol sold is weak.*
  - *The link from an increased demand for E85 to increased volumes of pure and high-blended ethanol sold is strong.*

In the long term, the increased volumes of pure and high-blended ethanol sold will lead to **a reduction in carbon dioxide emissions from the domestic transport sector (long term effect, evaluation question 2)**. For this to materialise, the tax exemption on ethanol must not result in increased mileage (A10). Ultimately, these changes will help Sweden achieve its **climate policy goals related to the domestic transport sector and renewable energy (impact)**.

*Assessing the links*

- *We observe that carbon dioxide emissions from the domestic transport sector have reduced over the period. Regarding the impact, Sweden's reporting shows that progress is being made.*
- *We have not explored assumption 10.*
- *WSP's assessment:*
  - *The long term effect materialises.*
  - *Progress is being made towards the impact.*

- *The link between increased volumes of pure and high-blended ethanol sold and reduced carbon dioxide emissions from the domestic transport sector is strong.*

**2. How credible is the story told by the theory of change, overall?**

The overall story that we see, based on the evidence presented in sections 4.4.1-4.4.3 and analysed above, is that the tax exemption has reduced the price for E85 to a competitive level, which has contributed to progress on Sweden's climate policy goals.

The competitive price contributed to that private motorists with environmental preferences switched from petrol cars to FFVs to an increasing extent, and also fuelled with E85. The decision to buy an FFV was motivated by environmental concerns, and partly by financial incentives directly linked to the purchase of the FFV. Also, the increasing availability of petrol stations providing E85 contributed. Had the price of E85 not been competitive compared to the price of petrol, it is not likely that private motorists would have switched to FFVs to this extent. This assessment is based on the strong evidence from multiple sources on the price sensitivity of customers in the choice between petrol and E85.

For public actors, the transition to FFVs and E85 was spurred by public policy goals that translated into internal guidelines and regulations. For commercial actors, the transition was initiated by environmental demands in public procurement. The reduced price of E85 likely played a less important role for the decision of these actors to acquire an FFV than for private motorists. Costs are not as decisive for decisions that are governed by regulations guidelines and procurement requirements.

Up to 2012, the demand for E85 grew. The increase in FFVs in the vehicle fleet and the increased availability of E85 in petrol stations contributed. Again, given the strong evidence from several sources on price sensitivity of consumers, the increased demand for E85 would most likely not have happened without the tax exemption on ethanol.

After 2010, fewer and fewer new FFVs entered the vehicle fleet. This was driven by contextual factors: media reports on engine problems in FFVs reduced the willingness to invest in such a vehicle, and reduced financial incentives linked to the purchase of an FFV did not help. The gradual decline in the number of FFVs in the vehicle fleet contributed to the decrease in the demand for E85 after 2012. Two contextual factors also contributed: reports on engine problems for FFVs and to some extent the public debate on sustainability challenges for ethanol. There is no evidence that suggests that the effect from tax exemption (the relatively competitive price of E85 compared to petrol) was weaker during the period of decline.

The switch from petrol to E85 contributed to reducing the carbon dioxide emissions from the domestic transport sector, which in turn contributed to progress on Sweden's climate policy goals.

Overall, we assess the story told to be credible.

**3. Are there weaknesses in the story?**

The main weakness in the story, that we have not been able to find evidence for, relates to assumption A10 – that the reduced price for E85 does not lead to increased mileage. However, the mileage probably needs to increase substantially if it should off-set the positive effect on carbon dioxide emissions from the transition from petrol to E85. The empirical analysis in chapter 6 shows no evidence of such an off-setting effect, however.

# 4. QUANTITATIVE ANALYSIS OF THE TAX EXEMPTION ON ETHANOL

## 4.1 BACKGROUND

Biofuels have been exempted from carbon and energy taxes in Sweden in some form since 1961. Prior to Sweden's accession to the European Union, this exemption was applied more broadly. However, after Sweden joined the EU in 1995, the subsidy needed to be tied to specific programs to comply with EU regulations. For instance, ethanol—the primary biofuel at the time—was fully tax-exempted (excluding VAT) because its production was classified as part of “pilot projects”.

In 2003, Sweden transitioned to a general tax exemption for all biofuels. This policy shift required approval from the European Commission, as it constituted state aid. While the Commission granted approval, this change did not significantly alter the average tax rate for biofuels sold in Sweden. This was because most biofuels at the time were domestically produced and already subsidized under the pilot projects.

For ethanol, there is thus no clear exogenous tax reform available for empirical analysis. Instead, the effect of the tax exemption is estimated indirectly by analyzing the relationship between the price of ethanol and its close substitute, petrol, and their respective sales. Assuming a full pass-through of the tax to prices, the tax elasticity of sales can be interpreted as equivalent to the price elasticity.

During the early 2000s, ethanol—particularly the high-blended E85—became a leading biofuel in Sweden. By 2005, it was available at 206 petrol stations. Its distribution expanded significantly after the introduction of the 2006 "pump law," which required larger petrol stations to offer at least one high-blended biofuel. At its peak in the 2010s, over 1,500 stations sold E85, though this number has since declined to approximately 1,000 as HVO100 gained prominence as an alternative.

The availability of flexi-fuel cars, capable of running on both E85 and petrol, has been a critical factor in shaping consumer behavior. These vehicles enable drivers to choose between fuels based on preferences and relative prices, allowing direct substitution. This price-driven substitution mechanism is hypothesized to be the primary driver influencing E85 sales.

However, other mechanisms may also play a role. For example, higher E85 prices might prompt drivers to reduce driving altogether or switch to other vehicles. The econometric design in this study aims to isolate the causal effect of price changes on fuel consumption without disentangling these specific mechanisms.

Petrol prices have fluctuated widely over time, influenced by factors such as:

1. Seasonal variation in oil prices, with higher demand in summer.
2. Seasonal variation in petrol prices, where a cheaper type of petrol can be used during the winter months.
3. Stochastic shocks to oil prices, such as the 2008 financial crisis.

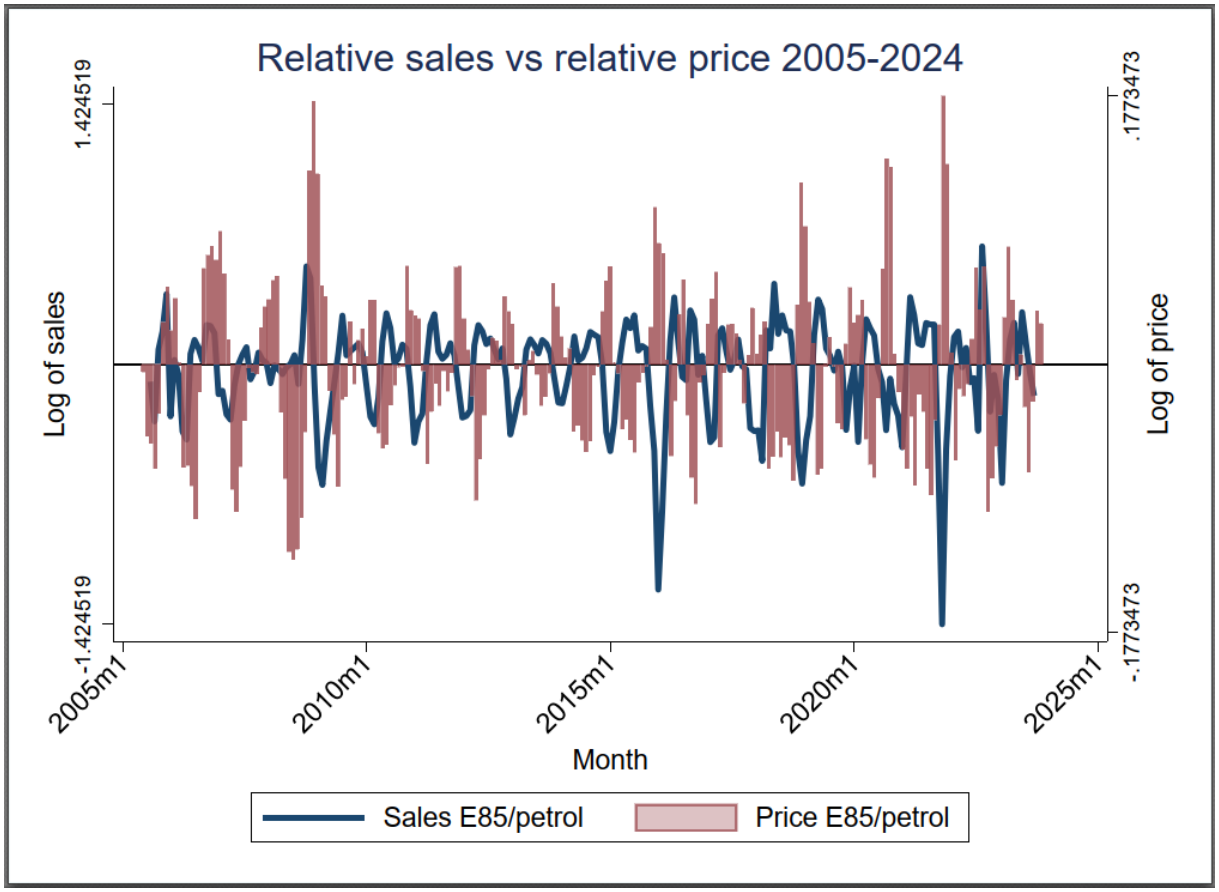
E85 prices are generally more stable but tend to move in the same direction as petrol due to two factors: the 15% petrol content in E85 and the increased production costs for ethanol crops during periods of high oil prices. Before 2010, E85 prices occasionally moved in the opposite direction of petrol, likely due to limited competition in the ethanol market, enabling suppliers to charge higher prices to "loyal" consumers with inelastic demand. Post-2010, increased competition has resulted in seasonal E85 price variations aligning more closely with petrol.

The relative price of E85 compared to petrol varies significantly over time, primarily driven by fluctuations in petrol prices. The analysis uses the prices of E85, petrol, and their relative price as independent variables.

The relationship between relative sales and relative price is illustrated below. Specifically, for each variable, we plot the logarithm of the ratio, adjusted to remove yearly average fluctuations by subtracting the moving average. The two variables are specified in equation 4) and 5) respectively in the chapter named *Empirical model* below. This specification implies that the curves represent the percentage deviations of relative sales and relative prices from their respective yearly averages.

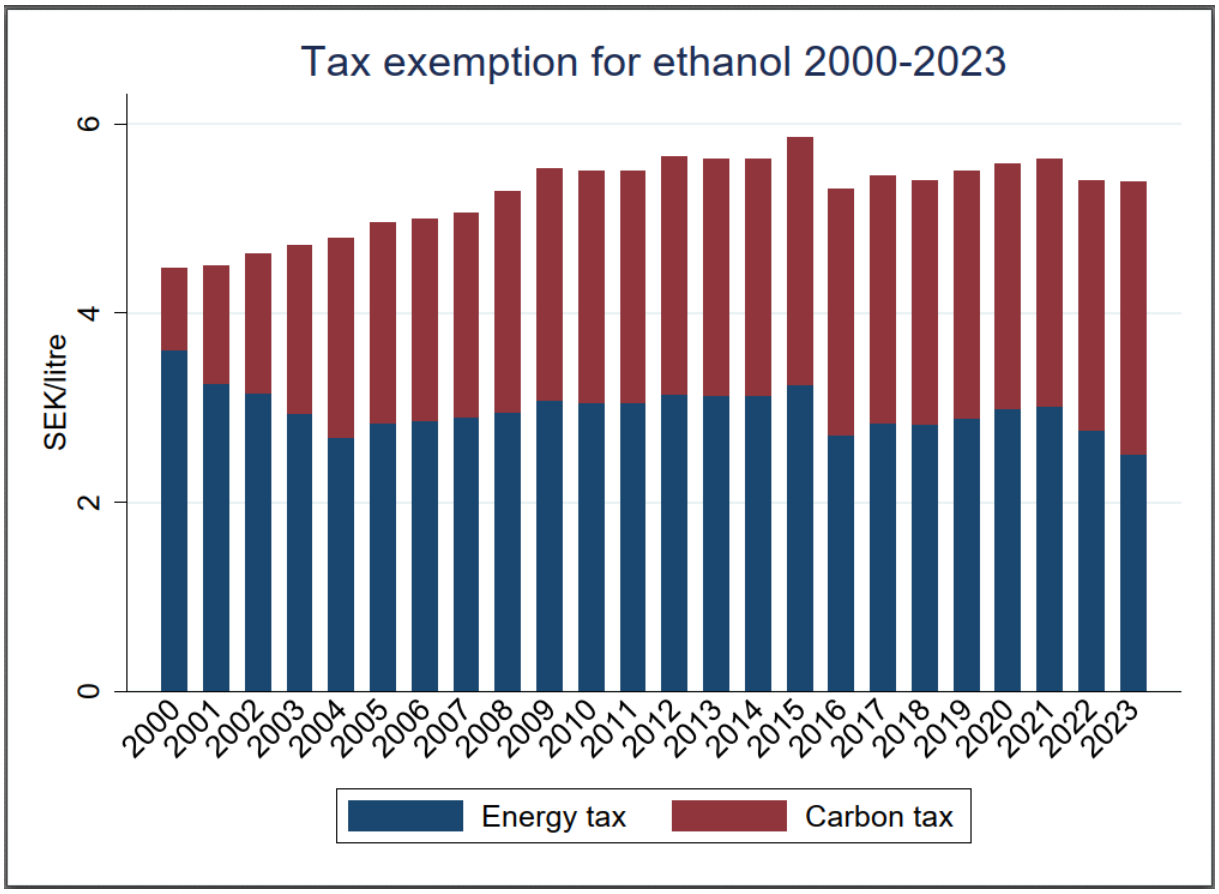
The plot reveals a clear seasonal variation in relative prices, with higher relative E85 prices in winter. Conversely, the blue line, representing relative sales, moves in the opposite direction, indicating strong consumer responsiveness to price incentives. This hypothesis will be tested in the following analysis.

Figure 2: Relative sales vs relative price. Monthly variations adjusted for yearly trends.




The excise tax for fuel includes carbon and energy tax as well as an additional 25% VAT. Ethanol has been virtually exempted from excise taxes since its introduction on the fuel market until 2016, when the reduction was reduced to 73% of the energy tax component Since ethanol has been used mainly as a substitute for petrol, the size of the tax exemption for ethanol was equivalent to the size of the excise tax for petrol until 2016, after which only 73% of the energy tax content could be deducted (the exemption from carbon tax was still 100%). Over the time period of interest, the excise tax has been relatively stable without any large changes from year to year. It is stable because the purpose of the tax policy is to make the price of ethanol compensating for its higher production cost. This is also the reason for the reduced deduction in 2016, that was a correction in relation to previous years where the full tax exemption led to an overcompensation.

Figure 3: The expected size of the tax exemption for ethanol between 2000-2023.




## 4.2 EMPIRICAL MODEL

To analyse the relationship between fuel prices and E85 sales, two methodological approaches are employed:

1. **Time-Series Analysis**

   In the first approach, the logarithm of E85 sales is regressed on the logarithms of the prices of E85 and petrol, respectively.

2. **Relative Price Substitution Model**

   The second approach examines consumers' incentives to substitute between E85 and petrol based on their relative prices. This model uses the world oil price as an instrumental variable for the relative price, mitigating concerns about reverse causality. Since fluctuations in the relative price are largely driven by changes in petrol prices, the oil price serves as a strong instrument. In this approach, the logarithm of the ratio of E85 to petrol sales is the dependent variable, while the logarithm of the ratio of their prices (E85/petrol) is the independent variable.

Both approaches address non-stationarity in the time series due to market trends by applying an 11-month moving average to filter the data. [10]

## 4.3 SEASONAL VARIATIONS AND CONTROLS

Fuel prices and sales are subject to seasonal fluctuations. For example:

- Car traffic increases in the summer, potentially altering the relative sales of E85 if the fuel blend (ethanol vs. petrol) differs seasonally.
- In winter, a perception that ethanol performs poorly may prompt consumers to switch to petrol.[11]

To account for these seasonal effects, monthly dummy variables are included in the regression. The model compares data across equivalent calendar months, measuring deviations in prices and sales from their yearly averages. This approach controls for spurious relationships between seasonal sales variations and seasonal price fluctuations. However, it may introduce some downward bias by removing average seasonal price effects.

Economic activity, measured by GDP, could introduce omitted variable bias, as it correlates with both petrol prices and fuel consumption. However, GDP is unlikely to affect short-term monthly variations, and the availability of only quarterly GDP data limits its usability in this analysis

## 4.4 ADDRESSING ENDOGENEITY

Endogeneity due to reverse causality—where higher demand for E85 raises its price—poses a significant econometric concern. The second approach mitigates this by using the world oil price as an instrument for the relative price of E85 and petrol. This instrument is valid because:

- Swedish fuel demand has a negligible impact on global oil prices.
- Global oil prices strongly correlate with petrol prices, making them a robust and strong instrument.

However, the instrumental variable (IV) approach cannot fully eliminate omitted variable bias. Global oil prices are influenced by the international business cycle, which also affects fuel prices and demand. While GDP might be a useful control in this context, its quarterly frequency and potential to introduce bias limit its inclusion in the IV model.

**Approach 1: The simple time series analysis**

In the simple time series analysis, the following equations are estimated:

1) $Log(sales\ E85)_t = \alpha + \beta Log(price\ E85)_t + \delta Log(sales\ petrol)_t + \epsilon$

2) $Log(sales\ E85)_t = \alpha + \beta Log(price\ E85)_t + \delta Log(sales\ petrol)_t + \sum_{i=2}^{12} \theta_i\ (month)_{it} + \epsilon$

3) $filtered\ sales\ E85_t = \alpha + \beta(filtered\ price\ E85)_t + \delta(filtered\ sales\ petrol)_t + \sum_{i=2}^{12} \theta_i\ (month)_{it} + \epsilon$

Where the filtered variables are defined as:

[10] Since we want to include the present observation in the moving average, a 12-month period would have been asymmetrical with either one more lag or one more lead included in the average.
[11] Consumers were even instructed by car manufacturers to switch to petrol during the winter in the early 2000's.

4) $filtered\ sales\ E85_t = \log(sales\ E85)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(sales\ E85)\right)_{t+i}$

5) $filtered\ price\ E85_t = \log(price\ E85)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(price\ E85)\right)_{t+i}$

6) $filtered\ sales\ petrol_t = \log(sales\ petrol)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(sales\ petrol)\right)_{t+i}$

The specification in 4) thus makes $filtered\ sales\ E85$ equal to the percentage change in $sales\ E85$ relative to its moving 11-month moving average, and equivalently for the other filtered variables in 5) and 6).

**Approach 2: relative prices vs relative sales and IV**

For the second approach where the ratios of E85 and its substitute petrol are used, the following equation is estimated:

7) $filtered\ sales\ E85/petrol_t = \alpha + \beta(filtered\ price\ E85/petrol)_t + + \sum_{i=2}^{12}\theta_i\,(month)_i + \epsilon$

The filtered ratios are defined as in equation 4) to 6):

8) $filtered\ sales\ E85/petrol\ _t = \log(sales\ E85/petrol)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(sales\ E85/petrol)\right)_{t+i}$

9) $filtered\ price\ E85/petrol\ _t = \log(price\ E85/petrol)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(price\ E85/petrol)\right)_{t+i}$

The IV-approach is estimated using two-stage least squares, with the following specification where 9) is the first stage equation and 10) is the second:

10) $(filtered\ \widehat{price}\ E85/petrol)_t = \varphi + \gamma(filtered\ oil\ price)_t + \sum_{i=2}^{12}\delta_i\,(month)_{it}$

11) $(filtered\ sales\ E85/petrol)_t = \alpha + \beta(filtered\ \widehat{price}\ E85/petrol)_t + \sum_{i=2}^{12}\theta_i\,(month)_{it} + \epsilon$

The filtered oil price is defined as before:

12) $filtered\ oil\ price_t = \log(oil\ price)_t - \log\left(\frac{1}{11}\sum_{i=-5}^{5}(oil\ price)\right)_{t+i}$

In time series analysis, autocorrelation in the error terms is another concern. To account for this, Newey-West standard errors are used, allowing for autocorrelation over a six-month lag period.

## 4.5 DATA

This analysis utilizes monthly data on sales and prices for E85 and petrol, sourced from Drivkraft Sverige, with Statistics Sweden providing the original data. The dataset covers the period from January 2005 to June 2024, comprising a total of 252 monthly observations.

Although the focus is on E85, the sales data also include ED95—a related ethanol-based fuel. The distinction lies in their primary use cases: E85 substitutes petrol, whereas ED95 replaces diesel. However, this discrepancy is not expected to cause significant measurement errors for two reasons. First, ED95 constitutes only a small fraction of total sales. Second, both E85 and ED95 are ethanol-oil blends, and their sales are influenced similarly by price fluctuations, tax changes, and raw material costs. That said, ED95's higher ethanol content (95% vs. 85% for E85) could make it slightly more sensitive to price changes in oil or ethanol.

For simplicity, all references to "E85" in this report will include aggregated sales data for both E85 and ED95.

Oil price data were also extracted from Drivkraft Sverige, with the World Bank as the source.

## 4.6 DIFFERENCES TO THE 2021 EVALUATION

This analysis builds upon the Swedish Energy Agency's 2021 evaluation but incorporates two significant methodological advancements:

1. Use of Monthly Data

   The previous report relied solely on yearly data due to the unavailability of monthly figures. The inclusion of monthly data in this study enhances precision by:

   - Increasing the number of observations.
   - Enabling the investigation of short-term fluctuations and their impact.

2. Focus on Relative Use and Instrumental Variables

   Unlike the 2021 evaluation, this analysis emphasizes the relative use of E85 versus petrol. By employing the oil price as an instrumental variable for the relative price of E85 to petrol, this approach mitigates the issue of reverse causality. This strategy avoids the challenge of identifying a sufficiently strong and exogenous instrument for ethanol prices.

## 4.7 RESULTS

**Approach 1: The simple time series analysis**

The results of the simple time series analysis are presented in Table 1, where the dependent variable is the logarithm of E85 sales. Independent variables include the logarithm of the price of E85 and petrol, allowing the coefficients to be interpreted as elasticities.

In Model (1), corresponding to Equation (1), the coefficient for the price of E85 is -5.100, meaning a 1% increase in the price of E85 results in a 5.10% decrease in its sales. This demonstrates strong price sensitivity among E85 consumers. Conversely, the coefficient for the price of petrol is 4.150, suggesting a 1% increase in petrol prices leads to a 4.15% increase in E85 sales. This finding reflects a significant substitution effect as consumers switch to E85 when petrol prices rise. Both coefficients are statistically significant at the 1% level.

Model (2), corresponding to Equation (2), incorporates monthly dummies to account for seasonal factors such as driving patterns and fuel efficiency concerns. The inclusion of these controls slightly reduces the magnitude of the elasticities. The coefficient for the price of E85 decreases to -4.67, while the coefficient for petrol decreases to 3.58. Despite the reduction, the results confirm substantial price sensitivity.

In Model (3), which uses filtered price series as specified in Equations (3) and (4), short-term deviations are isolated by subtracting the yearly moving average from the logarithm of the respective time series. The coefficient for the filtered price of E85 is -1.619, indicating that a 1% increase in the short-term price of E85 leads to a 1.62% reduction in its sales. Similarly, the petrol cross-price elasticity is 2.52, showing that even short-term price fluctuations significantly affect consumer behavior. Due to the moving average construction, the first and last five observations are dropped in this model.

| Table 8 – Simple time series analysis | | | |
|---|---|---|---|
| Dependent variable: log(sales of E85) in (1) and (2). Filtered log(sales of E85) in (3) | | | |
| VARIABLES | (1) | (2) | (3) |
| Log(price of E85) | -5.100*** | -4.666*** | |
| | (0.817) | (0.953) | |
| Log(price of petrol) | 4.150*** | 3.578** | |
| | (1.250) | (1.438) | |
| Log(price of E85), filtered | | | -1.627*** |
| | | | (0.437) |
| Log(price of petrol), filtered | | | 2.528*** |
| | | | (0.548) |
| Constant | 2.779 | 2.865 | -0.431*** |
| | (2.402) | (2.510) | (0.061) |
| Monthly dummies | No | Yes | Yes |
| Observations | 232 | 232 | 222 |

Newey West standard errors (lag 6) in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Approach 2: relative prices vs. relative sales and IV**

The results for this approach are presented in Table 2, where the dependent variable is the filtered ratio of E85 sales to petrol sales, and the explanatory variable is the filtered price ratio of E85 to petrol. Two model specifications are used: an OLS model (Equation (5)) and an instrumental variables (IV) model (Equations (6) and (7)).

In the OLS model (Column 1), a 1% increase in the relative price of E85 is associated with a 2.09% decrease in the relative sales of E85. The coefficient is statistically significant at the 1% level, indicating that consumers are responsive to changes in the price ratio of E85 to petrol.

In the IV model (Column 2), the elasticity increases in magnitude. The coefficient for the relative price of E85 rises to -3.617 and remains statistically significant at the 1% level. This suggests that addressing endogeneity—by using oil price variations as an instrument for the relative price—amplifies the estimated impact of price changes on sales. The larger IV estimate reflects the dominant influence of petrol prices on the relative pricing dynamic.

Table 9: Relative prices vs. relative sales and IV

| Dependent variable: Filtered sales E85/petrol | | |
|---|---|---|
| VARIABLES | (OLS) | (IV) |
| Filtered price E85/petrol | -2.086*** | -3.617*** |
| | (0.396) | (0.712) |
| Constant | -0.277*** | -0.225*** |
| | (0.055) | (0.048) |
| Monthly dummies | Yes | Yes |
| Observations | 222 | 222 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

**Conclusions**

The analysis consistently demonstrates strong price sensitivity for E85, particularly in response to petrol prices. In the preferred specification of the first approach (Model 3), which accounts for seasonality and short-term deviations, the cross-price elasticity of petrol exceeds the direct price elasticity of E85. This finding aligns with the expectation that consumers can substitute petrol for E85 with relatively low friction. The point estimate for the cross-price elasticity in this model is around 2.52.

The second approach further emphasizes the role of petrol prices, with the IV estimates in Table 2 suggesting that cross-price effects are a primary driver of consumer behavior. The larger elasticity in the IV model compared to the OLS model highlights the importance of addressing reversed causality when analyzing price effects.

The results are very much in line with previous studies on fuel-switching behaviour, that also find large price elasticities for E85 as well as large cross-price elasticities for petrol within the same vicinity. Liu & Greene (2014) uses data for Minnesota, North Dakota and Iowa and finds short-run price elasticities between -2 and -4.5 for the relative price of E85 compared to petrol. The 2SLS estimates are also larger, as in our results. Andersson (2012), using the same Minnesota data from a previous period, finds own-price elasticities of negative 3.2–3.8 and a petrol-price elasticity of 2.3–3.2.

The results have important implications for tax policy and market dynamics. The strong price sensitivity suggests that fuel distributors may bear a larger share of tax burdens since there are indications that they exhibit price setting behaviour, specifically when it comes to relative pricing between fuels. However, the degree to which tax exemptions are passed on to consumers remains an open question. Previous studies, such as Andersson (2019)[12] that studies Sweden's carbon tax, have found that tax elasticity can exceed price elasticity, with taxes being fully passed on to consumers.

Overall, the findings underline the importance of considering both direct and cross-price elasticities when designing policies to promote biofuel adoption. By leveraging insights into consumer behaviour and pricing dynamics, policymakers can craft more effective incentives to encourage the transition to renewable fuels.

[12] Andersson, Julius J. 2019. "Carbon Taxes and $CO_2$ Emissions: Sweden as a Case Study." *American Economic Journal: Economic Policy*, 11 (4): 1–30

# 5. EVALUATING THE TAX EXEMPTION ON HVO AND FAME

## 5.1 THEORY OF CHANGE: HVO AND FAME

The theory of change in figure 3 below depicts how the policy decision to exempt biofuels from tax can be thought to translate into an increased volume of sold HVO and FAME, and reduced carbon dioxide emissions from the domestic transport sector. It was developed following steps 1 and 2 in section 4.2.

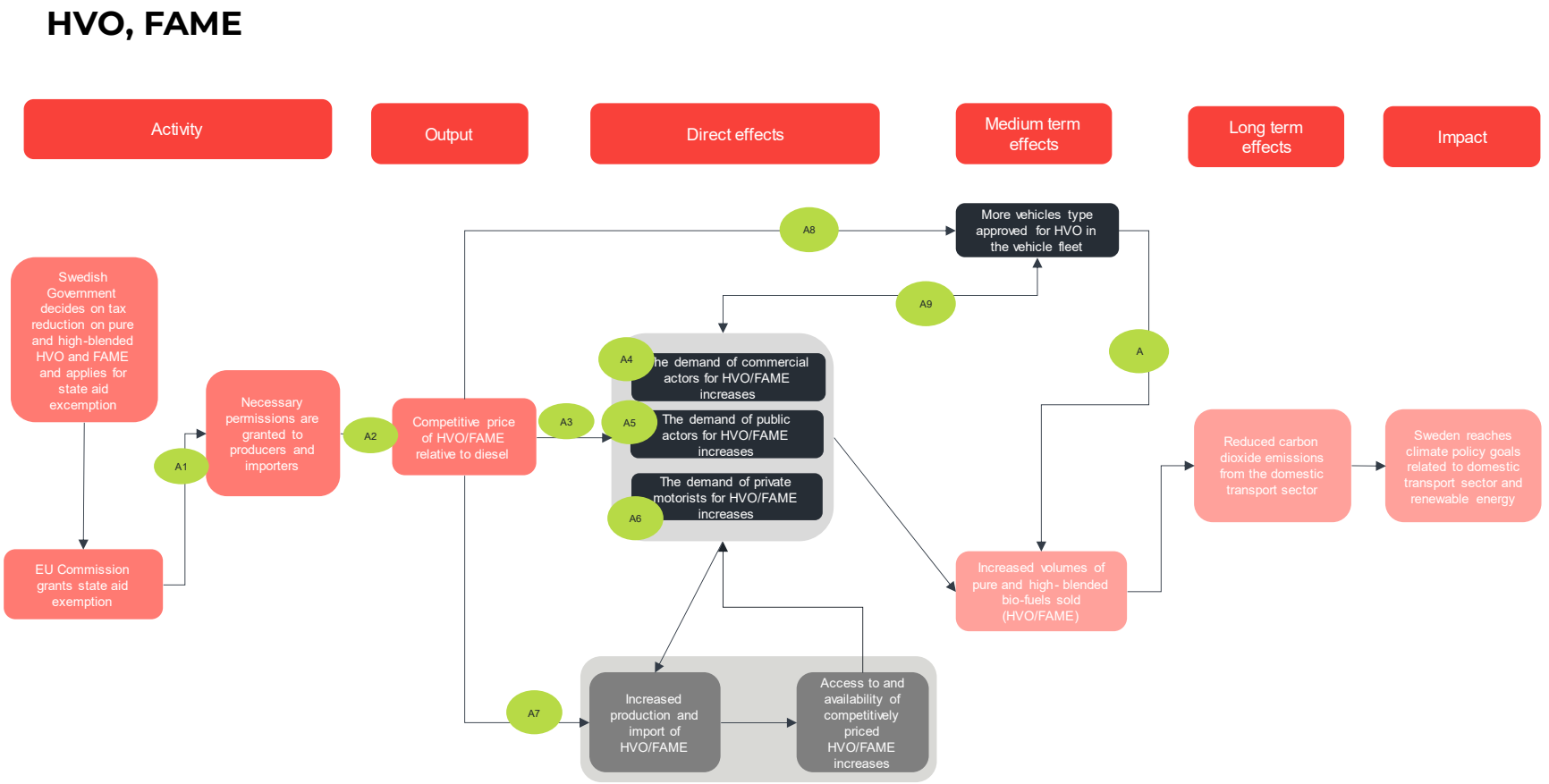
The Theory of Change for HVO and FAME outlines a comprehensive pathway to reduce carbon dioxide emissions from Sweden's domestic transport sector. It begins with the Swedish Government deciding on a tax reduction for pure and high-blended HVO and FAME and applying for a state aid exemption (activities). Once the EU Commission grants this exemption, producers and importers of HVO and FAME become aware of the tax reduction (A1) and apply for the necessary permissions (activities). These permissions are then granted, and if the tax reduction is transferred to consumers (A2), **HVO and FAME become competitively priced relative to diesel (output)**.

This competitive pricing is crucial as it leads to an **increase in demand for HVO and FAME among commercial, public, and private actors (direct effect 1)**, assuming price sensitivity (A3). To affect commercial actors, such as bus companies and transport firms, the environmental ambitions of public actors need to be converted into demands in transport-related public procurement (A4). Public actors themselves convert their environmental ambitions into internal demands or policy goals (A5), while private motorists show a preference for clean cars and fuels (A6).

As demand increases, producers of HVO and FAME perceive the tax exemption as permanent and invest in production capacity (A7). This investment leads to **increased production and import of HVO and FAME**, ensuring that **these fuels are available at competitive prices** (direct effect 2). In the medium term, **more vehicles in the fleet become type-approved for HVO** (A8), and the **production and import of these type-approved vehicles increase** (medium term effect 2). Owners of these vehicles then fuel with HVO (A9), further **increasing the volume of HVO and FAME sold** (medium term effect, evaluation question 1).

Ultimately, these steps lead to a **long-term reduction in carbon dioxide emissions from the domestic transport sector** (long term effect, evaluation question 2). This reduction helps **Sweden achieve its climate policy goals related to the domestic transport sector and renewable energy** (impact).

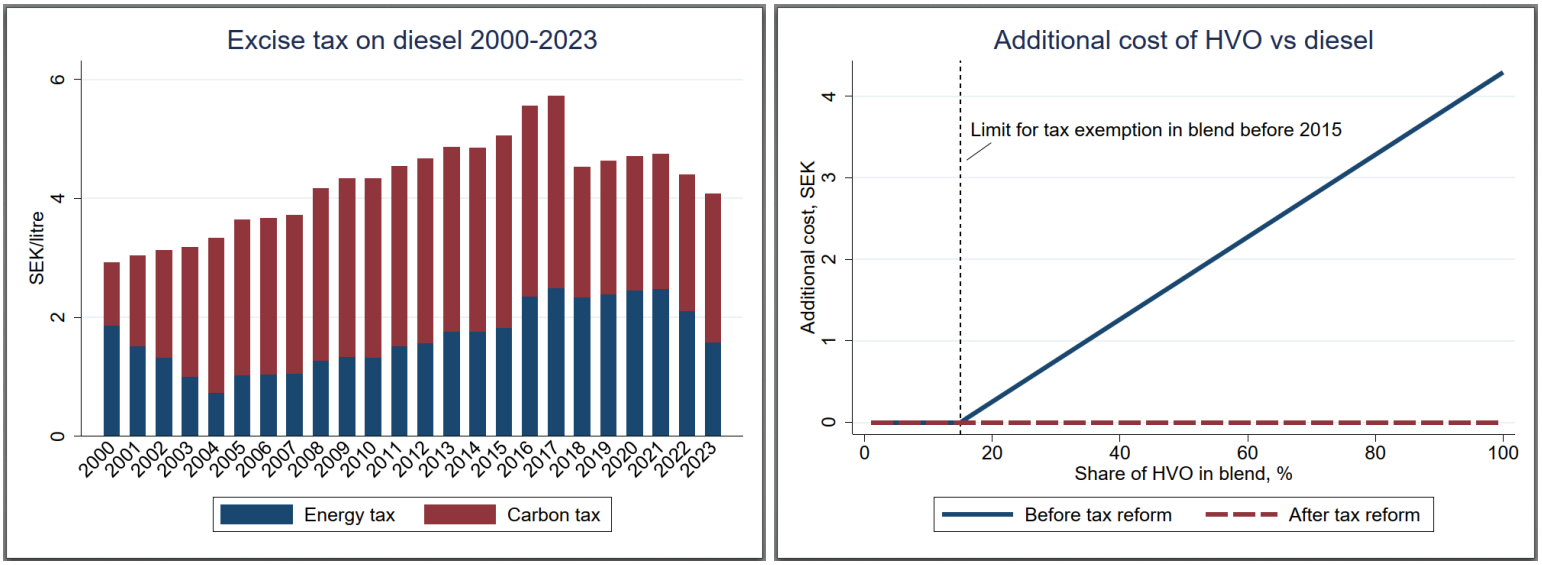
Figure 4: Theory of change: Tax exemption HVO and FAME



## 5.2 QUANTITATIVE ANALYSIS OF THE TAX EXEMPTION ON HVO AND FAME

The market for Hydrotreated Vegetable Oil (HVO) in Sweden began to develop around 2010. Initially, HVO was used exclusively as a low-blend additive to diesel fuel and was not sold in pure or high-blend forms. This restriction was largely a consequence of tax policies that allowed only up to 15% of the diesel blend to be exempted from taxes. Any portion of HVO exceeding this threshold was taxed as fossil diesel, limiting the expansion of high-blend or pure HVO.

Figure 5: The excise tax on diesel (left panel) and the expected additional cost of HVO vs diesel as a function of the blend (right panel)




A pivotal policy change in 2015 altered this landscape. The Swedish government restructured its tax regulations, exempting the entire HVO portion of any diesel blend from carbon and energy taxes. This reform catalyzed the emergence of the market for pure HVO (HVO100), which experienced rapid growth in sales. Since this change, the HVO component in any diesel blend has been fully exempted from excise taxes. The tax exemption aimed to even out the difference in production cost between fossil diesel and HVO, making HVO a competitive alternative to fossil diesel. If this policy has been successful or not is a more open question, however, since a complete tax exemption will even out the difference only if the additional production cost of HVO is exactly equal to the size of the excise tax. The size of the tax reduction for biofuels is consequently always under scrutiny from the EU. In the case of FAME in 2016, for example, the tax exemption was reduced to adjust previous over compensation. The marginal cost of increasing the share of HVO in diesel, as depicted in the right panel of the graphs above, is derived from the premise that the tax exemption for HVO is equal to the difference in production cost.

Before 2015, for blends with an HVO component exceeding 15%, the excess portion was taxed as fossil diesel. This created significant additional costs for blends with more than 15% HVO, approximately equivalent to the excise tax on diesel multiplied by the excess share of HVO in the blend. The impact of this is illustrated in the right panel of the graphs, showing the cost of HVO-blended diesel as a function of HVO's share. After 2015, blending more than 15% HVO incurred no additional costs, as the tax exemption neutralized the difference in production costs. Consequently, the marginal cost of increasing HVO content has been effectively zero since the reform.

In 2016, the tax reduction for pure HVO (HVO100) was 5.37 SEK, which is 29% of its estimated price.[13] Since we do not have access to price data for HVO100 for this year, we can only use the price of diesel as a proxy. The price of HVO100 will be equal to the diesel price (including tax) if the additional production cost of HVO100 is exactly equal to the tax. The additional production cost, by assumption, matched the additional excise tax of 5.37 SEK that would have applied to HVO100 in 2016 without the tax reform. This substantial tax reform underscores the transformative nature of the 2015 policy change.

## 5.3 EMPIRICAL MODEL

The 2015 tax reform provides a natural experiment to assess the impact of the HVO tax exemption on sales. We apply two complementary approachesFor Sweden, monthly data on HVO sales from 2011 to 2024, covering both pure and low-blend forms, were analysed. While this high-frequency data and the tax reform offer exogenous variation, identifying a robust empirical strategy with Swedish data alone proved challenging. A simple time-series analysis demonstrates that pure HVO sales increased significantly post-2015. However, isolating the reform's effect on aggregated biodiesel usage, including FAME (Fatty Acid Methyl Esters), is difficult due to indirect effects on multiple fuel types and the absence of a clear control group in a difference-in-difference approach.

To address these challenges, a cross-country comparison was conducted using Eurostat data (2011-2022) on biodiesel volumes, distinguishing between blended and pure forms. A synthetic control model was applied, comparing Sweden to a weighted average of untreated countries after 2015. Weights were calculated to minimize differences between Sweden and the control group in the pre-treatment period. The analysis examined three outcomes: pure biodiesel sales, total biodiesel sales, and biofuels' share of total transport-sector fuel consumption.

However, the lack of detailed yearly data before 2015 limited the robustness of the synthetic control group's pre-treatment fit. Nonetheless, Sweden's post-2015 biodiesel usage starkly contrasts with other European countries, ensuring the robustness of the estimated treatment effect despite variations in the control group. Challenges also arose from defining "treated" countries and identifying countries with consistent tax policies. Ideally, treated countries would have had no pre-2015 exemptions, while untreated countries would have maintained stable policies throughout the period. However, Sweden's pre-existing FAME exemptions and the limited transparency of other countries' biofuel policies complicated this classification. [14]

To address these issues, an iterative approach was used to refine the donor pool of untreated countries. Countries with policy shifts during 2010-2018 were excluded, and weights recalculated until a stable, untreated subset was achieved. The analysis focuses on the period before Sweden's 2018 reduction mandate, which shifted incentives and marked a new biofuel policy era.

## 5.4 DATA

In the first approach above, when the development for blended and pure HVO are analysed, monthly data on HVO100 sales are used, sourced from SCB and compiled by Drivkraft Sverige. The data covers the period from 2010 to 2024. However, due to the reduction mandate's impact starting in 2018, which led to increased

[13] The tax exemption includes 85% of the energy and carbon tax for diesel plus VAT of 25%.
[14] In order to obtain a robust estimation of the counterfactual Sweden, the weights are calculated based on several variables in addition to the outcome variable. These variables are GDP per capita, the urbanization rate, the number of passenger cars per capita and the diesel price. These variables are selected in for the purpose of making the synthetic Sweden structurally similar to Sweden. The estimation method calculates to which degree these structural variables should be included in calculating the weights of each donor country. The aim is to find the set of weighted predictors that minimizes the difference between Sweden and its synthetic counterpart with respect to the outcome variable and these predictors.

use of HVO in blended diesel, the analysis will focus on the years prior to 2018 to maintain a clean comparison of pure HVO sales.

A challenge in the analysis of pure HVO is determining the starting point for the data, as HVO100 sales were effectively zero prior to 2015. A reasonable starting point is 2010, when HVO was first used in low-blended biodiesel. One could argue that the sales of pure HVO, had it been fully exempted from taxes, would have started a bit later than usage of HVO for blending. However, this does not significantly impact the analysis, provided one accepts the assumption that there could have been a viable market for pure HVO a few years before 2015, if it had not faced fiscal disadvantages.

For the cross-country comparison, yearly data from Eurostat is used from the dataset *Final energy consumption in road transport by type of fuel,* which covers the period 2011-2022. The share of biofuel use in the transport sector comes from the SHARES data set from Eurostat. Data on emissions per capita from the transport sector is collected from Our World in Data and sourced from Climate Watch. Data on the other predictors are collected from the World Bank.

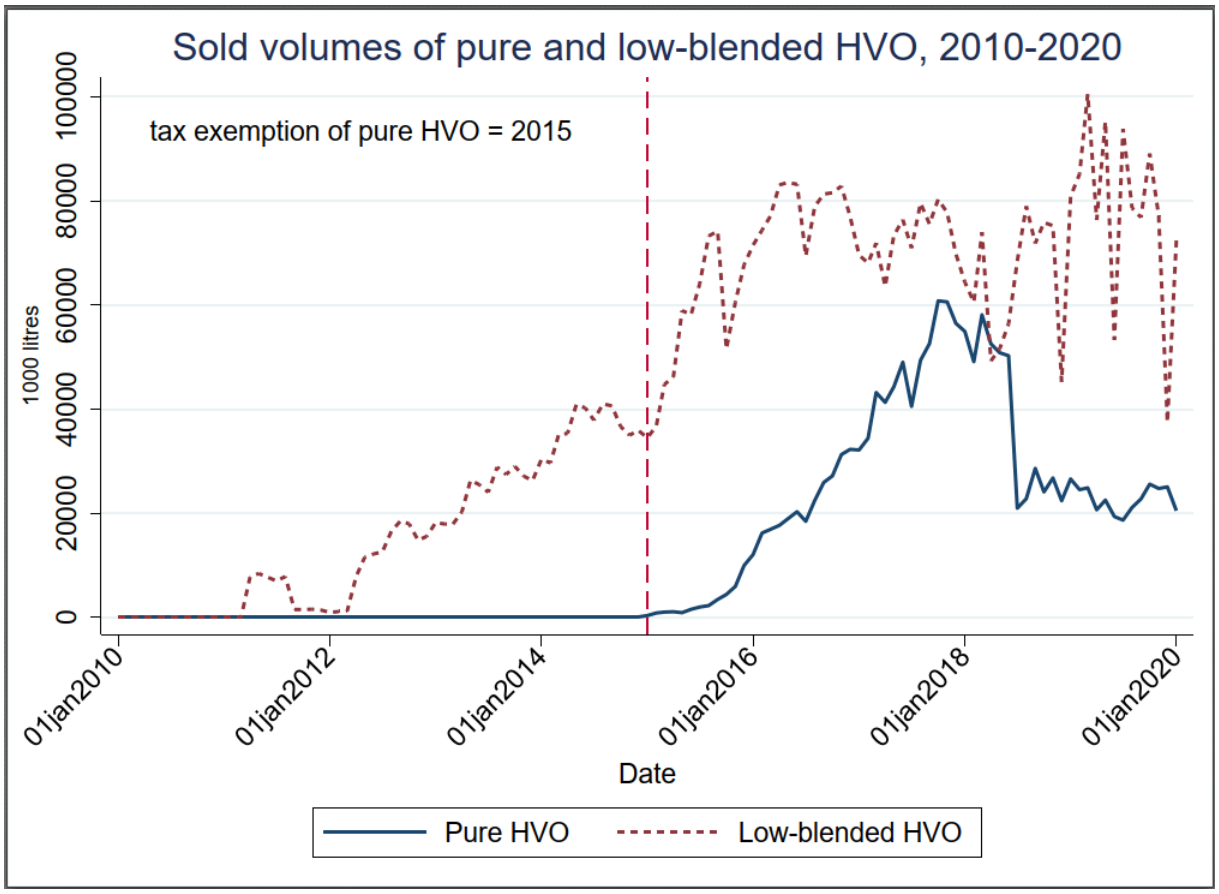
## 5.5 RESULTS

**Results from the analysis on monthly data in Sweden**

Graphical analysis (see below) tracks pure HVO and low-blended HVO sales (2010-2022). The introduction of low-blended HVO marks the market's inception, with sales of pure HVO beginning post-2015 due to the tax reform. While causal inference from Swedish data alone is challenging, the stark increase in pure HVO sales after 2015 strongly indicates the reform's impact. A simple time-series regression on post-treatment sales reveals significant effects, though the lack of pre-treatment variation complicates elasticity calculations. Alternative designs, such as Regression Discontinuity in Time (RDiT), were unsuitable due to the gradual post-reform sales increase.

Using other fuels as a control group is problematic. Many were indirectly affected by the reform, and pure HVO's pre-2015 sales trend (zero) lacks parallelism with other fuels. Despite these challenges, the sales trajectory of pure HVO before and after 2015 provides compelling evidence that the tax reform drove its growth, even if quantifying this effect statistically is difficult.

Figure 6: Sold volumes of pure and low-blended HVO




**Results from the cross-country comparison**

Comparing Sweden to other European countries highlights its exceptional biodiesel use, particularly after 2015. Sweden's biodiesel market's growth, driven by HVO, distinguishes it from other nations. Key factors include FAME and HVO's popularity as diesel alternatives, a temporary FAME tax subsidy in 2014, and the 2015 HVO tax exemption.

Sweden's biofuel share in transport-sector energy consumption diverged positively from the synthetic control group after 2015. This deviation reflects the country's biodiesel market development, with Sweden accounting for a significant portion of Europe's HVO consumption. While pre-2015 trends show some divergence, these are partly explained by favorable conditions for FAME and HVO adoption in Sweden. The synthetic Sweden (87% Austria, 13% Finland) mirrors this pre-trend but diverges markedly post-2015.

Sweden's total biodiesel use similarly outpaces the synthetic control (Finland 76%, Bulgaria 17%, France 7%) post-2015. For pure biodiesel, Sweden's growth is unmatched, with a sharp divergence from Austria (51%) and Croatia (49%) post-2015, reinforcing the tax reform's role in driving pure HVO sales. Importantly, no evidence suggests that the tax exemption for pure HVO negatively impacted other biodiesels (e.g., FAME or blended HVO).

The results from the synthetic control models are presented in more detail in Appendix 1.

Figure 7: The share of renewables in transport in Sweden versus synthetic Sweden between 2004-2021

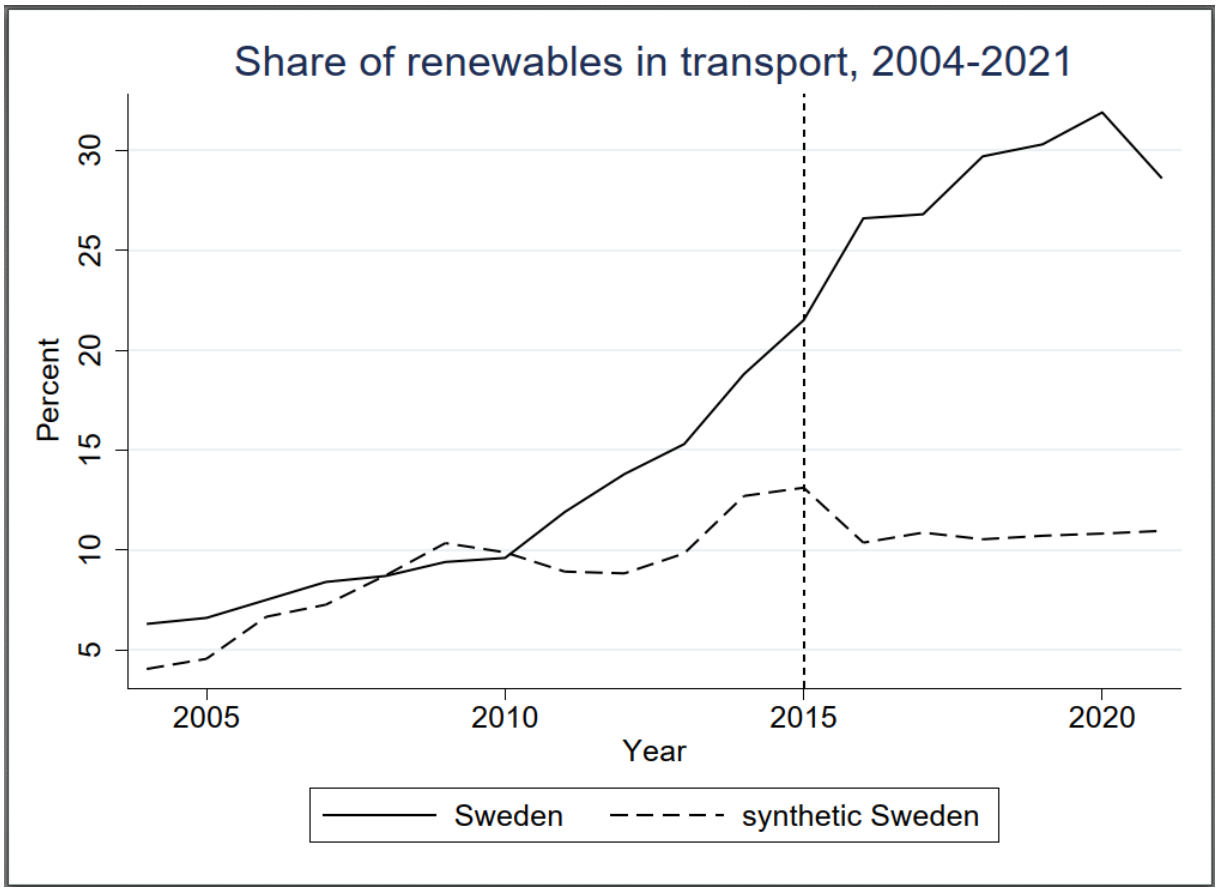


Figure 8: Total sold volumes (million litres) of biodiesel in Sweden vs synthetic Sweden

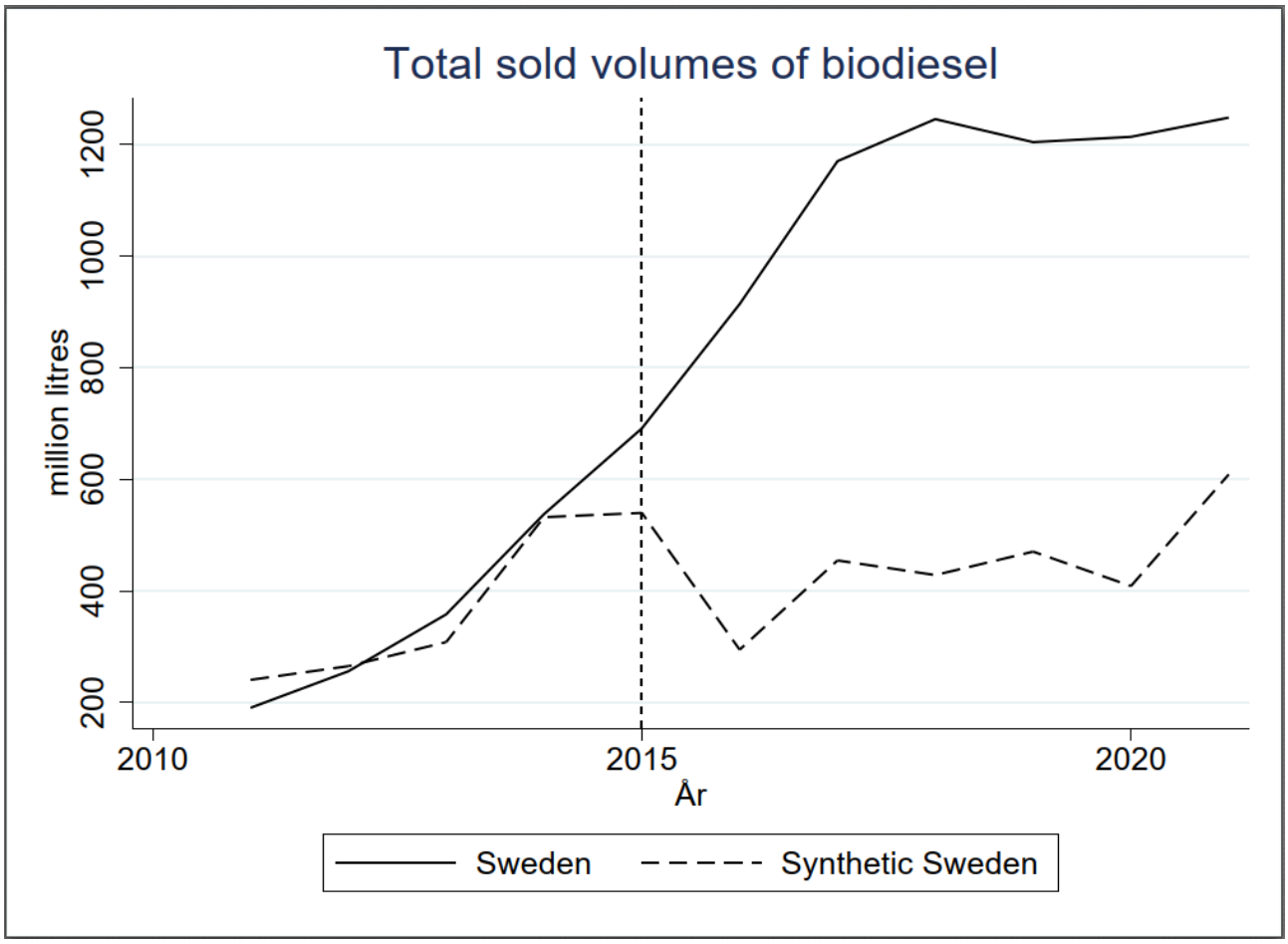
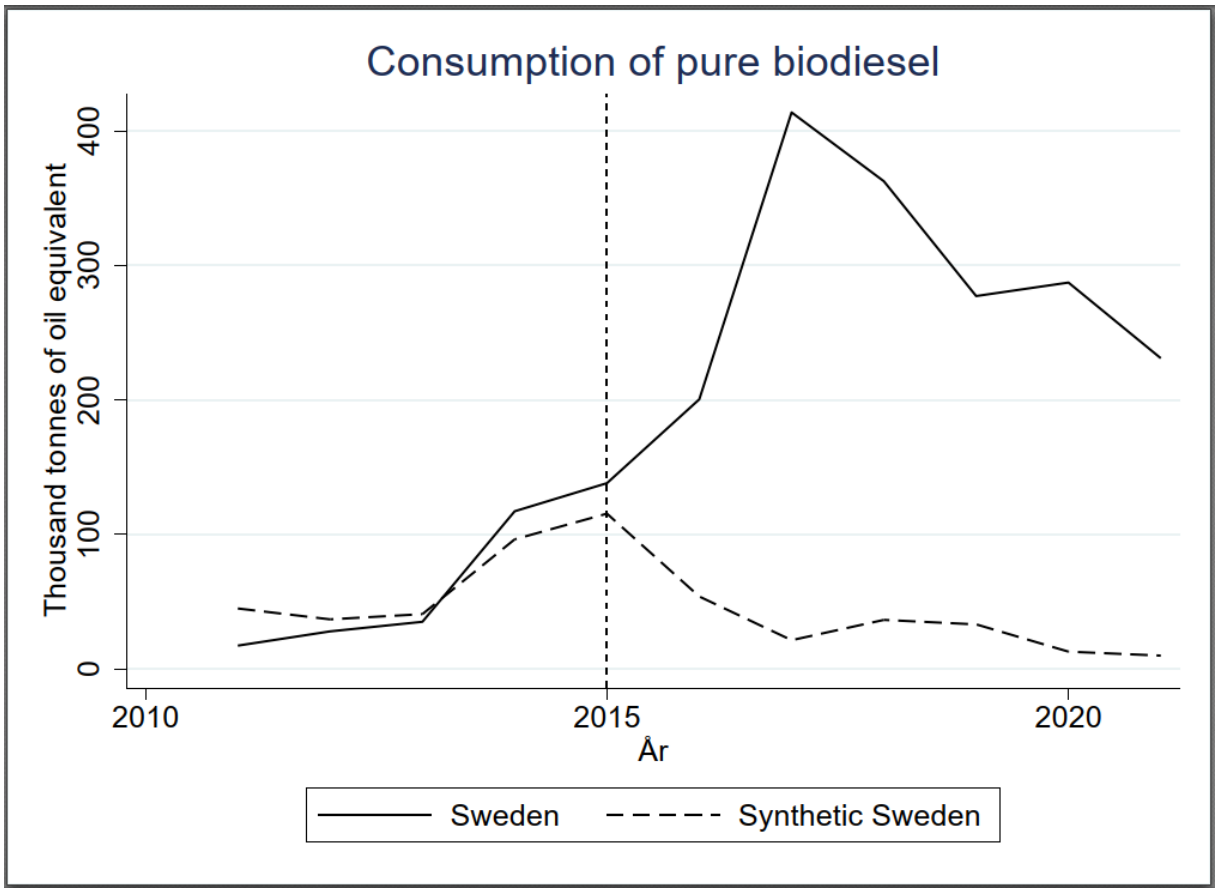


Figure 9: Consumption of pure biodiesel in Sweden vs synthetic Sweden



# 6. THE EFFECT OF THE TAX EXEMPTION ON EMISSIONS

The tax reduction's impact on emissions operates through two channels. First, increasing biofuel's share of transport fuel reduces emissions, assuming constant transport output (intensive margin). Second, lower fuel prices from tax reductions could increase total fuel consumption (extensive margin), potentially offsetting emission reductions. Thus, the net effect on emissions is ambiguous.

To empirically asses this effect, we conduct a cross-country comparisons of transport-sector greenhouse gas emissions, using synthetic control models with treatment years of 2003 (ethanol's emergence) and 2015 (pure HVO exemption). Sweden's emissions decline from 2004 is unmatched, ensuring robustness to donor group variations. When 2015 is the treatment year, Sweden's emissions trajectory diverges significantly from Finland (the sole donor country), confirming the tax reform's effectiveness in reducing emissions.

Overall, the results show no evidence that increased biofuel use led to higher total fuel consumption offsetting emission reductions. The conclusion is thus that Sweden's tax reductions on biofuels, particularly HVO, have contributed to substantial emission decreases in the transport sector.

The results from the synthetic control models are presented in more detail in Appendix 1.

Figure 10: Emissions from transport in Sweden vs synthetic Sweden under the assumption that a major shift in tax policy directed at biofuels took place in 2003. Country weight: Denmark 10%; Finland 80%; Luxembourg 1%; Norway 3%; Slovenia 4%.

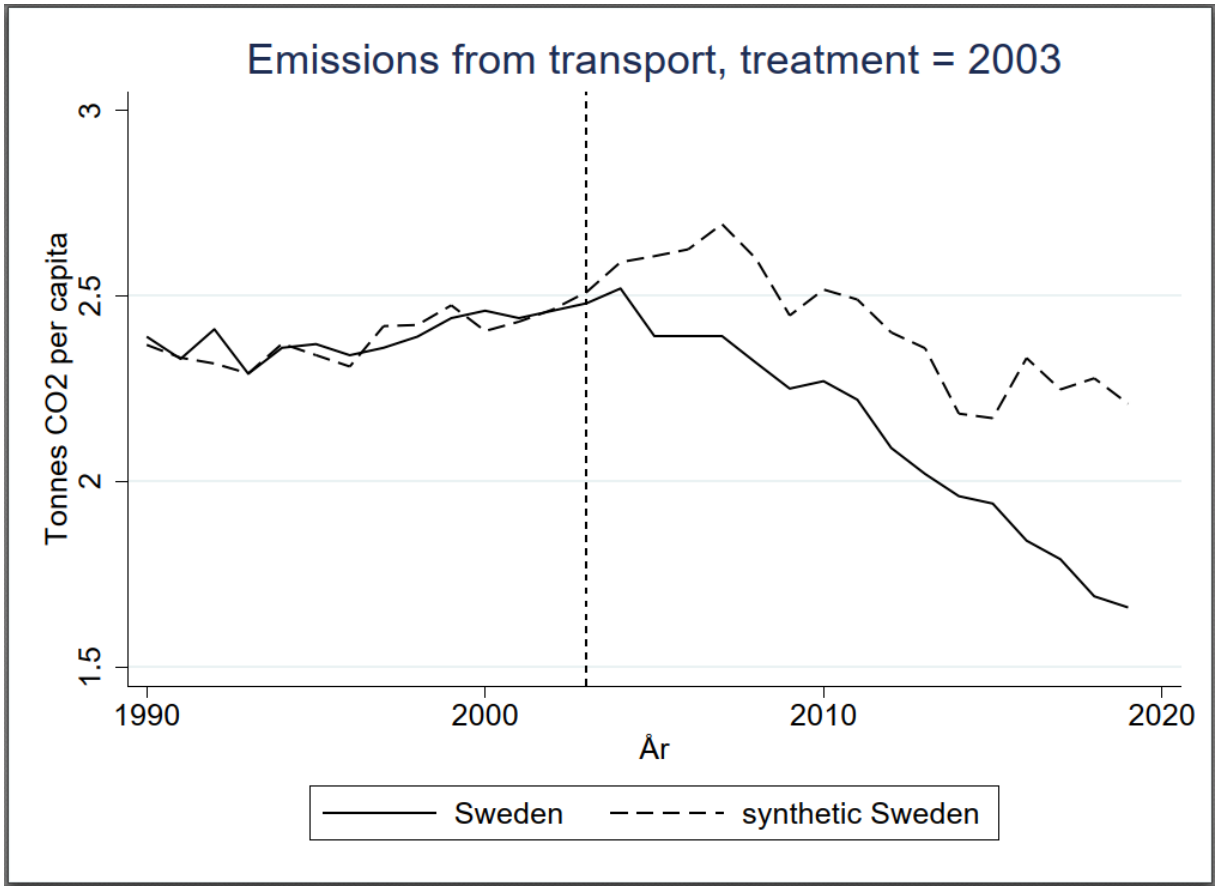
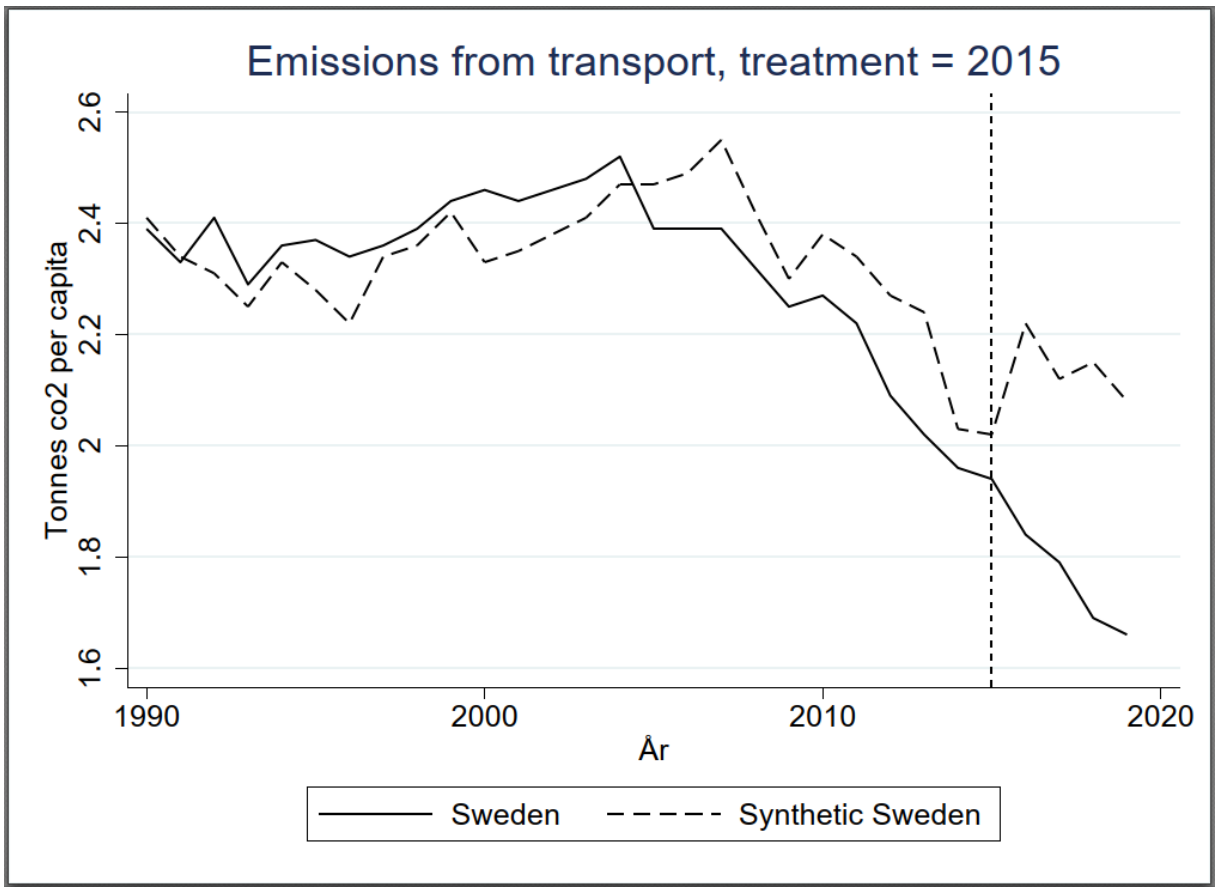


Figure 11: Emissions from transport in Sweden vs synthetic Sweden, with the tax exemption on pure and high-blended HVO as treatment. Country weight: Finland 100%.




# 7. CONCLUSIONS

The aim of this report has been to investigate further into the effects of the Swedish tax exemption on biofuels. In particular, the aim has been to test several new approaches, both empirical and theoretical ones. Overall, the analysis has been successful in finding new appropriate ways to test the hypothesis that the tax exemption has led to an increase in sales of biofuels. When it comes to quasi experimental methods, this success is in part due to access to monthly data on sales and prices.

The analysis has also been successful in building a credible empirical case that the tax exemption has led to reduced greenhouse gas emissions from the transport sector. One of the main objectives of the report was to find ways to compare the development in similar countries using longer times series. Since the data on biofuel use only dated back to around 2010, using emissions as the dependent variable provides the analysis with a long enough pre-treatment period to estimate a counterfactual scenario of the development in Sweden without tax exemptions on biofuels.

## 7.1 RESEARCH QUESTION 1: HAVE THE VOLUMES [OF PURE AND HIGH-BLENDED LIQUID BIOFUELS] USED/SOLD BEEN AFFECTED BY THE TAX REDUCTION?

Both the empirical and the theoretical approach provide evidence that the tax reduction indeed has had the desired effect to increase the sales of biofuels. Both approaches look separately at ethanol and HVO.

Based on the overall assessment of the theory based evaluation, the conclusion is that the tax exemption has contributed to the increase in volumes sold. Contextual factors contributed to the transition from petrol cars to FFVs, and to the resulting transition from petrol to E85 – but they would not have been sufficient on their own. The price sensitivity made the reduced price necessary for the switch to occur.

For ethanol, the significant cross-price effect of petrol on E85 sales, as well as the significant negative effect on sales of an increase in the relative price of E85, highlights the ease of substitution between ethanol and petrol. All estimated models from the time series analysis indicate a significant price effect on sales in the expected direction. Both approaches show that E85 sales are particularly sensitive to changes in petrol prices. When looking at relative sales in relation to the relative price of E85 versus petrol, the estimated elasticity is relatively large – minus 3.5 in the preferred model with an IV approach. This is expected, however, since petrol is a close substitute. The results suggest that petrol prices are the main driver of consumer behavior.

For HVO, the tax reform in 2015 has been analyzed from two different perspectives. The analysis of monthly data in Sweden shows a clear increase in sales of pure HVO after 2015. Before the reform, when high blended HVO was taxed as fossil diesel, sales were zero. The magnitude of the post-treatment period estimate depends on the chosen period length, however, making it somewhat arbitrary to assess. In a cross-country comparison, Sweden diverges substantially from comparable countries after 2015. Several models where a synthetic control group is constructed show equally clearly that the use of biodiesel has increased in a way that is likely influenced by the tax reform.

## 7.2 HAS THE TAX EXEMPTION HAD AN EFFECT ON CARBON DIOXIDE EMISSIONS FROM THE DOMESTIC TRANSPORT SECTOR?

The tax reduction on biofuels can lead to a decrease in emissions from the transport sector through mainly two different channels:

1) By affecting the *share* of fossil fuel used in transport. Holding the output of the transport sector constant, a higher ratio of biofuels to fossil fuel will reduce emissions. To borrow a concept from the labour economic literature, this can be thought as the *intensive margin* response.
2) By affecting the *total output* of the transport sector, for example, total miles driven. A tax reduction on fuel, all else equal, is likely to increase the total demand for fuel since it reduces the price. This could be thought of as the *extensive margin* response.

Given that effect 1) and 2) is likely to go in different directions, it is *a priori* unclear if a tax reduction on biofuels will reduce or increase total emissions from the transport sector. An empirical analysis comparing emissions in Sweden to comparable countries, however, shows that emissions per capita has gone down at a faster rate in Sweden compared to comparable countries. Again, a synthetic control approach has been used, where a synthetic Sweden based on a weighted average of comparable countries, has been constructed to function as a control group. The results show no indication that the tax reductions on biofuels have led to an increase in total consumption that is large enough to offset the effect from an increased share of biofuels. The conclusion is thus that the tax exemption also has led to decreased carbon emissions from the transport sector.

# REFERENCES

**Literature**


Soren T. Anderson (2012). The demand for ethanol as a gasoline substitute. Journal of Environmental Economics and Management. Volume 63, Issue 2. Pages 151-168. https://doi.org/10.1016/j.jeem.2011.08.002

Andersson, Julius (2019). Carbon Taxes and CO2 Emissions: Sweden as a Case Study. American Economic Journal: Economic Policy 2019, 11(4): 1–30. https://doi.org/10.1257/pol.20170144

City of Stockholm, 2009. Promoting Clean Cars - Case Study of Stockholm and Sweden. BEST (BioEthanol for Sustainable Transport) Deliverable No 5.12

Energimyndigheten, 2021. Utvärdering av skattereduktion för rena och höginblandade flytande biodrivmedel, ER 2021:9

European Commission, 2013. EVALSED - The resource for the evaluation of Socio-Economic Development: Sourcebook - Method and techniques.

European Commission (2017). Statligt stöd SA.48069 (2017/N) – Sverige: Skattelättnader för rena och höginblandade flytande biodrivmedel. https://ec.europa.eu/competition/state_aid/cases/270233/270233_1935809_111_2.pdf

Finansdepartementet, 2021 Ändrad nedsättning av förmånsvärdet för miljöanpassade bilar, Fi2021/03348. andrad-nedsattning-av-formansvardet-for-miljoanpassade-bilar.pdf (regeringen.se)

Hedeler, B,. Hellsmark, H., and Söderholm, P. 2023. Policy mixes and policy feedback: Implications for green industrial growth in the Swedish biofuels industry, Renewable and Sustainable Energy Reviews, Volume 173, https://doi.org/10.1016/j.rser.2022.113098

Kastensson, Å. & Börjesson, P. (2017) Hinder för ökad användning av höginblandade biodrivmedel i den svenska fordonsflottan. Rapport nr 2017:02, f3 Svenskt kunskapscentrum för förnybara transportbränslen, Sverige. Tillgänglig på www.f3centre.se.

Lindfors, A. och Roxland, M. (2009), An analysis of the Swedish green car rebate (2009), Promoting Clean Cars – Case Study of Stockholm and Sweden

Liu, C., & Greene, D. L. (2014). Consumer Choice of E85 Denatured Ethanol Fuel Blend: Price Sensitivity and Cost of Limited Fuel Availability. Transportation Research Record, 2454(1), 20-27. https://doi.org/10.3141/2454-03

Miljöbarometern, 2024. Använd mängd etanol. Web-page (accessed 2024-10-03) https://2030.miljobarometern.se/nationella-indikatorer/branslet/anvand-mangd-alternativa-drivmedel-av-olika-typ-b2c/etanol/

Naturvårdsverket, 2023. Report for Sweden on climate policies and measures and on projections. https://www.naturvardsverket.se/4acd41/contentassets/caf14fb0008a41d29b9d51228f874fcb/report-for-sweden-march-2023.pdf

Pacini, H., & Silveira , S. (2010) Ethanol or gasoline? Consumer choice in the face of different fuel pricing systems in Brazil and Sweden, Biofuels, 1:5, 685-695, https://doi.org/10.4155/bfs.10.49

Partnersamverkan för en förbättrad kollektivtrafik, 2018. Branschgemensamt miljöprogram. branschgemensamt_miljoprogram_20180705.pdf (svenskkollektivtrafik.se)

Regeringen 2006. Nationell klimatpolitik i global samverkan. Prop. 2005/06:172, https://www.regeringen.se/contentassets/2ed3aeae6a8f4b5497dff7098bab6255/nationell-klimatpolitik-i-global-samverkan-prop.200506172

Regeringen, 2009 En sammanhållen klimat- och energipolitik – Klimat. Prop. 2008/09:162. https://www.regeringen.se/contentassets/cf41d449d2a047049d7a34f0e23539ee/en-sammanhallen-klimat--och-energipolitik---klimat-prop.-200809162

Regeringen 2017. Regeringens proposition 2016/17:146 Ett klimatpolitiskt ramverk för Sverige. Microsoft Word - Prop 2016_17_146 Ett klimatpolitiskt ramverk för Sverige (regeringen.se)

SFS 2020:486. Förordning (2020:486) om miljö- och trafiksäkerhetskrav för myndigheters bilar

Sprei, F. (2017). Discontinued diffusion of alternative-fueled vehicles—The case of flex-fuel vehicles in Sweden. *International Journal of Sustainable Transportation*, *12*(1), 19–28. https://doi.org/10.1080/15568318.2017.1323983

Sterner, T. (2007) Fuel taxes: An important instrument for climate policy, Energy Policy 35 (2007) 3194–3202, https://doi.org/10.1016/j.enpol.2006.10.025.

Swedish Energy Agency. (2023), Supplement to the plan for the evaluation of the state aid for pure and high-blended liquid biofuels (SA.102347)

Trafikutskottet, 2009. Pumplagen. Uppföljning av lagen om skyldighet att tillhandahålla förnybara drivmedel. Sammanfattning av uppföljningsrapport 2009/10: RFR7. Sveriges Riksdag

Treasury Board of Canada Secretariat (no year), Theory-Based Approaches to Evaluation: Concepts and Practices, https://www.canada.ca/en/treasury-board-secretariat/services/audit-evaluation/evaluation-government-canada/theory-based-approaches-evaluation-concepts-practices.html (accessed 2024-09-30)

WSP, 2012. Effekter av styrmedel för minskat fossilberoende hos fordonsflottan

**Other sources**

***Key informant interviews***

Noak Westerholm, Programme manager, Swedish Energy Agency, 2024-06-20, 2024-09-03

Per-Erik Österlund, fuel expert, City of Stockholm, 2024-05-24

Sirje Pädam, energy expert, WSP, 2024-05-30

David Fornborg, Programme manager, Swedish Energy Agency, 2024-10-17

***Stakeholder workshop 2024-06-14***

Angelina Björklund, Programme manager, Swedish Energy Agency

John Rasulov, Programme manager, Swedish Energy Agency

***Written input***

Helena Leander, Programme manager, Swedish Energy Agency, 2024-06-12, 2024-07-02

# APPENDICES

## APPENDIX 1 – PREDICTOR BALANCE AND COUNTRY WEIGHTS FOR SYNTHETIC CONTROL ANALYSIS

**Share of renewables in transport, predictor balance**

| | Treated | Synthetic |
|---|---|---|
| shares 2006 | 7.5 | 6.655 |
| shares 2008 | 8.7 | 8.729 |
| shares 2010 | 9.6 | 9.881 |
| shares 2012 | 13.8 | 8.83 |
| shares 2014 | 18.8 | 12.703 |
| popurb_share | 85.03627 | 61.26424 |
| tCO2percapita | 2.256364 | 2.749127 |
| diesel_price | 1.688333 | 1.473667 |
| BNP_percap_PPP | 47441.95 | 51052.13 |

**Share of renewables in transport Country weights**

| Country | Weight |
|---|---|
| Austria | 0.87 |
| Finland | 0.13 |

**Total biodiesel, Predictor Balance**

| | Treated | Synthetic |
|---|---|---|
| tot_bio 2011 | 190.606 | 240.6651 |
| tot_bio 2012 | 256.013 | 265.177 |
| tot_bio 2013 | 358.068 | 308.3073 |
| tot_bio 2014 | 537.606 | 532.1326 |
| popurb_share | 85.775 | 82.47303 |
| cars_per1000 | 466.25 | 535.14 |
| tCO2percapita | 2.0725 | 2.017275 |
| diesel_price | 1.99 | 1.80802 |
| BNP_percap_PPP | 48742.36 | 41093.57 |

**Total biodiesel, country weights**

| Country | Weight |
|---|---|
| Bulgaria | 0.166 |
| Finland | 0.758 |
| France | 0.076 |

**Pure biodiesel, predictor Balance**

| | Treated | Synthetic |
|---|---|---|
| pure_bio 2011 | 17.255 | 44.88602 |
| pure_bio 2012 | 27.85 | 36.80197 |
| pure_bio 2013 | 34.985 | 40.68756 |
| pure_bio 2014 | 117.161 | 96.28642 |
| popurb_share | 85.775 | 56.46763 |
| cars_per1000 | 466.25 | 446.864 |
| tCO2percapita | 2.0725 | 2.0462 |
| diesel_price | 1.99 | 1.66292 |
| BNP_percap_PPP | 48742.36 | 39026.1 |

**Country Weights**

| Country | Weight |
|---|---|
| Austria | 0.512 |
| Croatia | 0.488 |

**Emissions from transport (treatment=2003), predictor Balance**

| | Treated | Synthetic |
|---|---|---|
| co2 1990 | 2.39 | 2.367815 |
| co2 1993 | 2.29 | 2.290964 |
| co2 1996 | 2.34 | 2.309516 |
| co2 1999 | 2.44 | 2.474544 |
| co2 2002 | 2.46 | 2.4632 |
| popurb_share | 83.74846 | 79.9372 |
| cars_per1000 | 425.3077 | 383.8946 |
| diesel_price | 0.9025 | 0.8252875 |
| BNP_percap_PPP | 36175.82 | 36019.09 |

**Emissions from transport (treatment=2003), country weights**

| Country | Weight |
|---|---|
| Denmark | 0.107 |
| Finland | 0.807 |
| Luxembourg | 0.01 |
| Norway | 0.029 |
| Slovenia | 0.047 |

**Emissions from transport (treatment=2015), predictor Balance**

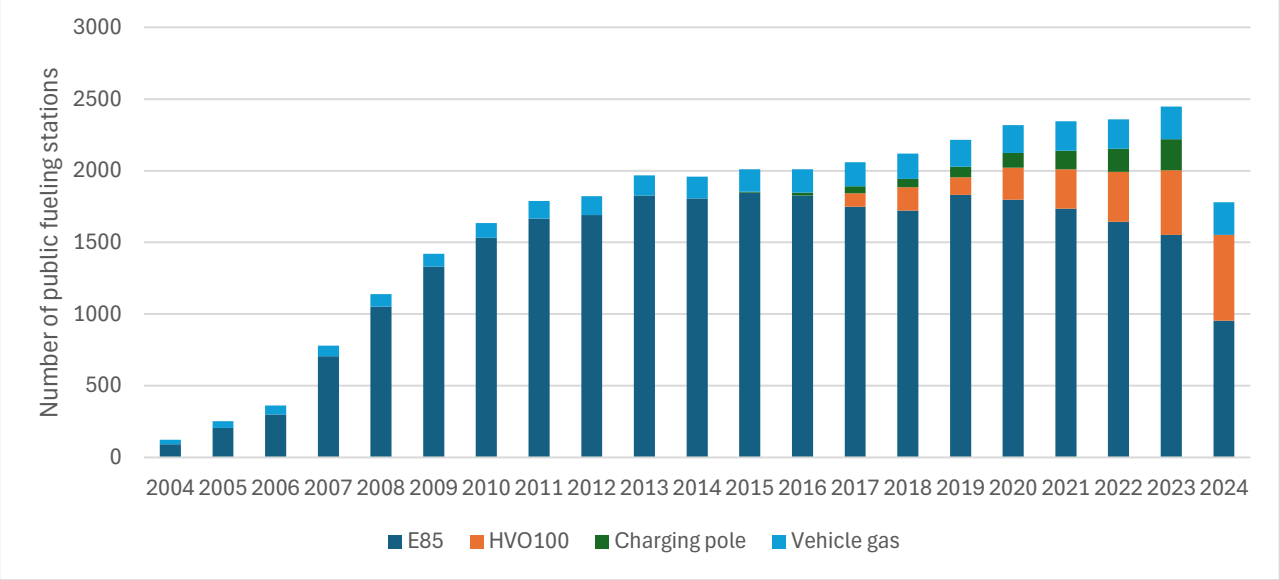
| | Treated | Synthetic |
|---|---|---|
| co2 1994 | 2.36 | 2.33 |
| co2 1999 | 2.44 | 2.42 |
| co2 2004 | 2.52 | 2.47 |
| co2 2009 | 2.25 | 2.3 |
| co2 2014 | 1.96 | 2.03 |
| popurb_share | 84.333 | 82.37064 |
| cars_per1000 | 442.8 | 447.64 |
| diesel_price | 1.374 | 1.247 |
| BNP_percap_PPP | 41393.02 | 39843.39 |

**Emissions from transport (treatment=2015), country weights**

| Country | Weight |
|---|---|
| Finland | 1 |

# APPENDIX 2 - FIGURES

Figure A1 . Number of public gas stations with renewable fuels in Sweden 2004-2024. Source: Drivkraftsverige.se




Note: No data for charging poles 2024.

Figure A2. Number of newly registered vehicles, 2006-2023. Source: Trafikanalys (2024)

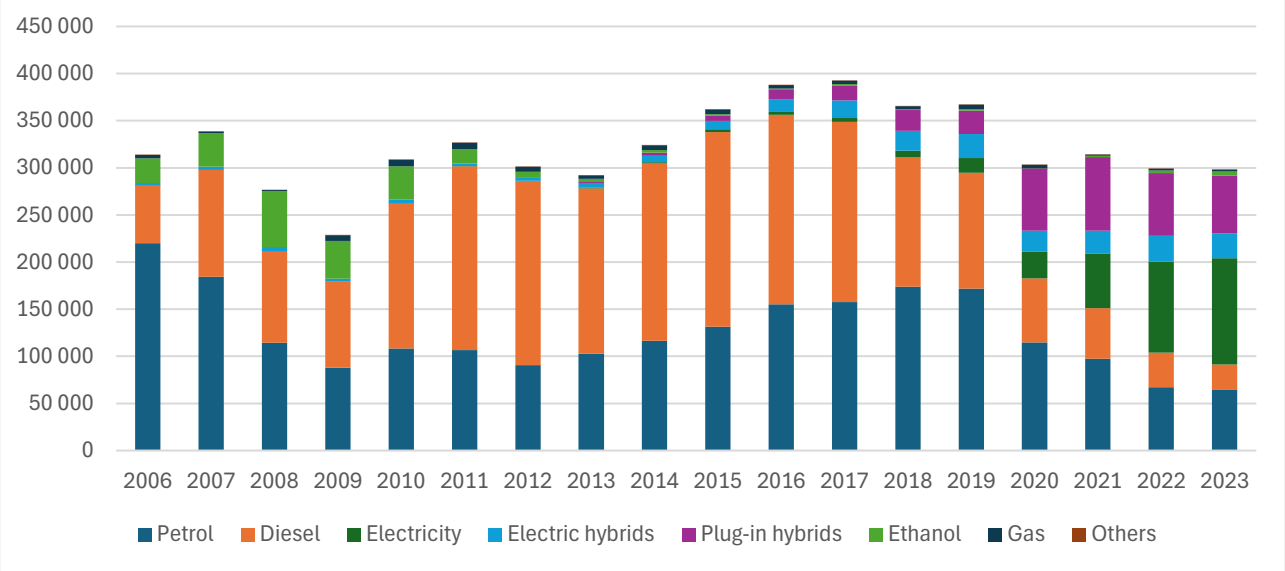


Figure A3. Domestic transport sector, emission of greenhouse gases 2010-2023. Source: www.naturvardsverket.se

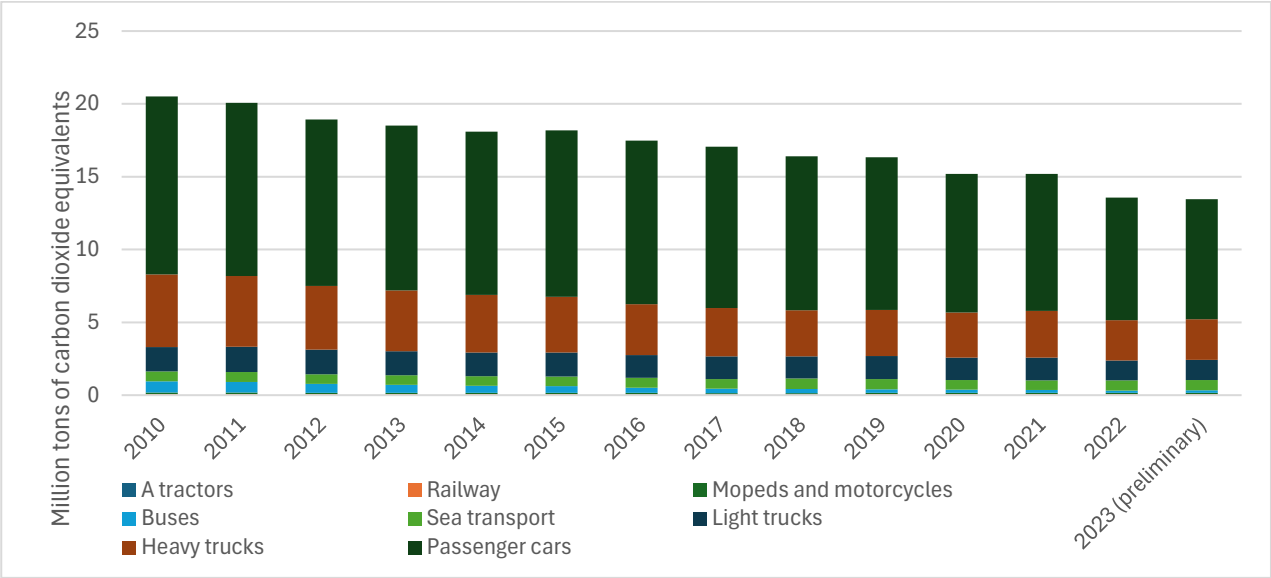
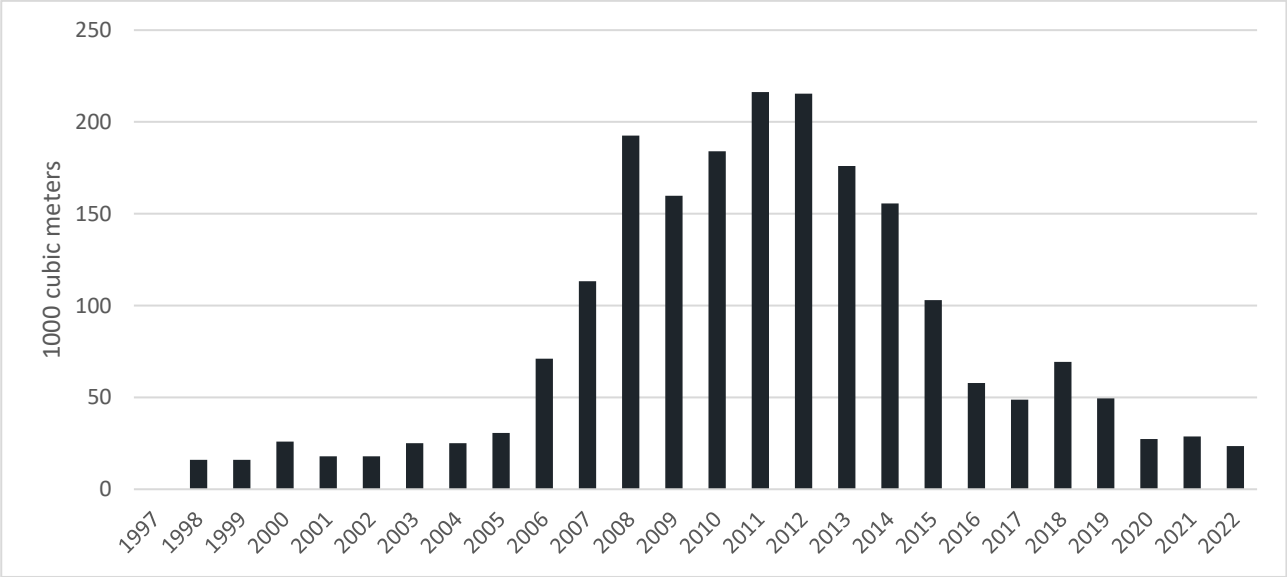



Figure A4. Use of high-blended ethanol in domestic transports, 1000 cubic meters, 1997-2022. Source: www.energimyndigheten.se



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