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Dieseltangeling the Swedish Reduktionsplikt

A welfare analysis of the Swedish emissions reduction mandate for diesel

Pontus Larsson (42865) and Jakob Oberhammer (42839)

Abstract. This paper provides a welfare-economic evaluation of the Swedish Reduktionsplikt for diesel during 2018–2024, connecting mandate-induced price increases to demand responses, emissions reductions, net welfare and abatement cost. A difference-in-differences design with Denmark as counterfactual identifies the causal effect on Swedish diesel prices without taxes. Combined with an estimate of the price elasticity of diesel demand, this yields the emissions reductions from the price channel. Adding emissions reduction from increased biofuel blending (technical substitution) gives a full abatement cost. The results reveal sharp variation in abatement cost over time. In the early mandate years the price premium was close to zero while technical substitution generated large emissions reductions, making the policy welfare-positive. From 2021 onward, rising biofuel prices pushed the premium to 2.05 SEK per litre and consumer surplus losses came to dominate the climate benefit. Over the full mandate phase, estimated emissions reductions of 14 Mt CO_2e imply an abatement cost of 1,574 SEK per tonne, slightly above the Swedish carbon-tax benchmark. The central finding is that reduction mandates are not inherently costly, but that welfare costs arise when compliance depends on expensive biofuel inputs.

Keywords: Climate Policy; Fuel Blending; Welfare Effects; Diesel; Biofuels

JEL Classification: C23; D61; H23; Q54; Q58

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Discussants: Soumya Sanskruti Sahoo
Examiner: Sampreet Singh Goraya

Acknowledgment and AI-Declaration

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AI has been used as support for phrasing, language refinement, and improving clarity in selected passages. It has also been used as a coding assistant, for example to help structure code, debug errors, and interpret programming-related issues. In addition, we have used AI as a learning tool; to clarify concepts and discuss methodological choices. Finally, AI has been used as a search and navigation instrument.

All substantive decisions, empirical work, interpretations, and final text remain our own responsibility. We have reviewed, verified, and edited all AI-assisted material before including it in the thesis. All errors are our own.

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1. Introduction

The 2015 Paris Agreement marked a turning point in international climate policy, committing parties to limiting global warming to below 2°C and pursuing efforts to limit the increase to 1.5°C (UNFCCC, 2015). For advanced economies, meeting these commitments required not only broad decarbonisation strategies but credible near-term policies in sectors where emissions had proved difficult to reduce. Sweden positioned itself as an early mover. In 2017, the Riksdag adopted one of the most ambitious national climate frameworks in the world, committing to net-zero greenhouse gas emissions by 2045 and establishing sector-specific interim targets to anchor the transition (Regeringen, 2017). The transport sector presented a particular challenge. Road transport accounted for approximately 90 percent of domestic transport emissions and around one third of Sweden's total greenhouse gas emissions, yet remained heavily dependent on fossil fuels and faced slow fleet turnover (Naturvårdsverket, 2019). Sweden therefore adopted a sector-specific target of reducing domestic transport emissions by at least 70 percent by 2030 relative to 2010 levels (Regeringen, 2017). A target of this ambition could not be met through electrification alone within the available timeframe; it also required instruments that lowered emissions from the existing stock of internal-combustion vehicles (Klimatpolitiska rådet, 2024).

It was against this backdrop that Sweden introduced the *Reduktionsplikt* in July 2018[1]. The policy requires fuel suppliers to achieve a specified annual reduction in the average lifecycle greenhouse-gas intensity of the gasoline and diesel they place on the market, primarily through the blending of renewable biofuels into conventional fossil fuels (Sveriges riksdag, 2017). Ideally, the mandate reduces emissions through technical substitution, by making each litre less carbon-intensive without substantially raising prices. However, if compliance costs increase and are passed on to consumers, the policy also creates an unwanted price channel. A government-induced price increase without corresponding tax revenue. The mandate was tightened progressively, reaching a diesel reduction requirement of 30.5 percent in 2022, before being rolled back to the EU minimum of 6 percent in January 2024 following a sharp rise in fuel prices during the 2022–2023 European energy crisis (Regeringen, 2023b). From July 2025, a redesigned mandate has been phased back in.

The Reduktionsplikt did, in fact, not operate without economic consequences. This risk was recognised already in the 2019 control-station process. Energimyndigheten and the subsequent government proposition noted that higher reduction levels would increase blending costs, since biofuels already were — or risked becoming — more expensive than fossil fuels, and that these costs were expected to be passed on to customers (Energimyndigheten, 2019; Regeringen, 2021). As the diesel mandate increased toward 30.5 percent and coincided with the European energy crisis of 2021–2022, fuel prices rose sharply and the policy became a central topic of political debate. Critics argued that the mandate had made diesel unaffordable for households and haulage firms, and the government ultimately cited high fuel prices as a primary motivation for the 2024 rollback (Regeringen, 2023a). The price effects of the policy have attracted academic and institutional attention. Konjunkturinstitutet (2023b) and C. Andersson and Thorell (2024) study the pass-through of mandate-induced costs to pump prices using Sweden–Denmark comparisons, while Sajtos (2025) examines the price effect of the 2025 policy change. Scenario analyses have also been used to assess the feasibility of reaching Sweden's 2030 transport target

[1]"Reduktionsplikt" directly translates to "reduction duty".

under alternative mandate trajectories (Klimatpolitiska rådet, 2024).

Yet the policy debate has proceeded largely without a welfare-economic assessment of whether the Reduktionsplikt was worth its costs. Price increases are a transfer, not a social loss in themselves. What matters for economic efficiency is whether the climate benefits generated by the mandate exceeded the total surplus foregone by consumers and producers. This question is distinct from asking how large the price increase was, and it has not been addressed in the existing literature. With the Reduktionsplikt currently under revision and new reduction levels in force from July 2025, the question of whether the instrument is economically and environmentally justified is directly policy-relevant.

This paper fills that gap. Our analysis combines causal estimates of the mandate's price effect with estimates of the emissions reductions achieved by two distinct channels. A *technical substitution channel*, through which biofuel blending reduces the greenhouse gas intensity of each litre sold, and a *price channel*, through which higher fuel costs reduce the quantity of diesel consumed. From a welfare perspective, the key distinction is that the latter works by reducing diesel consumption while also creating surplus losses for consumers and producers. In practice, the sharp increase in HVO prices appears to have made this second mechanism increasingly important, raising compliance costs, affecting demand, and thereby increasing the welfare cost of the policy. Combining these channels, we can estimate the total surplus cost borne by consumers and producers, and divide by total emissions reductions to arrive at an abatement cost. Comparing this against the Swedish carbon tax rate and the social cost of carbon, we assess whether the welfare cost of the policy was commensurate with the climate benefit it delivered. Our findings are also relevant for predicting the implications of the redesigned mandate now being phased back in. Specifically, this paper aims to:

1. estimate, in monetary terms, what the Reduktionsplikt cost Swedish society during the high-mandate years from 2018 to 2024;

2. estimate the emissions reductions from both the price channel and the technical substitution channel; and

3. combine (1) and (2) into an abatement cost estimate that can be benchmarked against various valuations of carbon emissions.

Our empirical strategy reflects the constraints imposed by the policy environment. A direct estimate of the mandate's effect on fuel consumption is not feasible. The Bonus-Malus vehicle taxation system was introduced simultaneously in 2018 (Statens offentliga utredningar, 2016), and fuel tax changes in 2022 confound any consumption-based comparison. Bonus-Malus is a particularly clear confounder because it directly affects diesel consumption by incentivising electric vehicle purchases and discouraging high-emitting vehicles, making it difficult to isolate the demand effect of the Reduktionsplikt from observed consumption alone. Consumption is also more likely to be affected by other country-specific shocks, such as differences in Swedish and Danish Covid-19 strategies, whereas diesel prices without tax[2] are assumed to be more plausibly exogenous to Swedish fuel demand. We therefore identify the mandate's price effect using a difference-in-differences design with Denmark as the control unit, exploiting six discrete changes in the mandated reduction level over 2018–2024, and work with diesel prices wot to

[2]For the remainder of the paper, referred to as diesel prices wot.

avoid confounding by the distinct and evolving tax structures in the two countries. We focus exclusively on diesel, where the mandate was far more ambitious, reaching 30.5 percent as opposed to 7.8 percent for gasoline. This is partly because EU fuel-quality rules severely limit high biofuel blending in conventional gasoline vehicles, whereas HVO can be used as a drop-in diesel substitute at much higher blend levels (European Commission, 2026). This makes diesel the more relevant fuel for evaluating the effects of high-blend biofuel mandates.

Our findings reveal a policy whose welfare cost varied sharply over its mandate trajectory. The reduction mandate was not costly in itself. When HVO prices were stable, the policy operated mainly through the technical substitution channel and generated emissions reductions without a measurable price effect. In the early phase (2018–2020), the estimated price premium was indistinguishable from zero, while the technical substitution channel generated substantial climate benefits. The policy was unambiguously welfare-positive in this period. The policy became costly only later, when the high Swedish blending requirement coincided with sharply rising biofuel prices during the European energy crisis, creating an unintended price channel. From the 26 percent mandate level onward, the price premium rose steeply, reaching an estimated 2.05 SEK per litre at the 30.5 percent mandate and coinciding with the European energy crisis. As diesel demand is highly inelastic (see tables 4.2 & 5.2), the consumer surplus loss came to dominate the climate benefit, with the welfare turning point in the second half of 2021. Over the full mandate phase from H2 2018 to H2 2023, total emissions reductions are estimated at 14 Mt CO_2e, of which around 94 percent are attributed to the technical substitution channel. At the Swedish carbon tax of 1,510 SEK per tonne of CO_2e, the total abatement cost is 1,574 SEK per tonne, resulting in slightly negative net welfare at −890 MSEK. Results are sensitive to the societal valuation of carbon emissions. At the Rennert et al. (2022) estimate of 2,000 SEK per tonne, net welfare turns clearly positive at +5,977 MSEK.

The remainder of the paper proceeds as follows. Section 2 provides background on the Reduktionsplikt and the biofuel market, and reviews the related literature. Section 3 develops the theoretical welfare framework. Section 4 describes the empirical strategy. Section 5 presents the empirical results. Section 6 conducts the welfare analysis. Section 7 discusses validity and policy implications. Section 8 concludes.

2. Background

Sweden's Reduktionsplikt is a greenhouse gas reduction mandate requiring fuel suppliers to ensure that gasoline and diesel they place on the Swedish market achieves a specified annual percentage reduction in average lifecycle GHG intensity relative to a fossil reference value (Sveriges riksdag, 2017). The reduction target is defined in emissions terms rather than volume terms. Suppliers are obligated to reduce the carbon intensity of their fuel, not to blend a specific share of renewable fuel. In practice, however, compliance has been achieved almost exclusively through blending renewable fuels, primarily hydrotreated vegetable oil (HVO) and fatty acid methyl esters (FAME) in diesel, and ethanol in gasoline, since these are the available pathways for reducing lifecycle GHG intensity at scale (Energimyndigheten, 2025b). The policy's climate rationale rests on lifecycle accounting. CO_2e released at combustion is assumed to be offset by greenhouse gas uptake during biomass growth in the feedstock supply chain, conditional on sustainability criteria (Ekonomifakta, 2026). Suppliers report compliance annually to the Swedish Energy Agency and shortfalls incur a fee proportional to the gap (Sveriges riksdag, 2025).

Historically, biofuel use in road transport has been largely policy-driven, and in the EU it has mainly been shaped by the Renewable Energy Directive framework. RED II required a minimum renewable energy share in transport by 2030, while RED III kept the transport focus but allowed more flexibility in how Member States comply (European Environment Agency, 2025; Joint Research Centre, 2023). National implementations nevertheless differ substantially, so similar targets on paper can imply different actual blending levels and compliance costs (Lundberg et al., 2023). Similar approaches also exist outside Europe, including the U.S. Renewable Fuel Standard and Brazil's RenovaBio (Brazilian Ministry of Mines and Energy, 2024; U.S. Environmental Protection Agency, 2024).

Sweden has stood out both in the European and international context through the ambition and structure of its system, particularly its greenhouse-gas reduction logic and its comparatively high renewable fuel use, especially HVO in diesel (2030-miljöbarometern, 2026b; Lundberg et al., 2023).

2.1 Reduction Levels

Table 2.1(a) shows the reduction path originally legislated in Prop. 2020/21:180. The diesel mandate was set at 19.3 percent in the second half of 2018 and intended to reach 68 percent by 2030. In practice, the escalation did not continue as planned. As shown in Table (b) in 2.1, from January 2024 the requirement was lowered to the EU minimum of 6 percent for both fuels, where it remained through the first half of 2025, before being raised again to 10 percent from July 2025 (Sajtos, 2025).

Table 2.1: Intended and Actual Emission Reduction Levels

(a) Intended

Year	Gasoline (%)	Diesel (%)
2018 (Jul–Dec)	2.6	19.3
2019	2.6	20
2020	4.2	21
2021 (Jan–Jul)	4.2	21
2021 (Aug–Dec)	6.0	26
2022	7.8	30.5
2023	7.8	30.5
2024	12.5	40
2030	28	68

(b) Actual

Year	Gasoline (%)	Diesel (%)
2018 (Jul–Dec)	2.6	19.3
2019	2.6	20
2020	4.2	21
2021 (Jan–Jul)	4.2	21
2021 (Aug–Dec)	6.0	26
2022	7.8	30.5
2023	7.8	30.5
2024	6.0	6.0
2025 (Jan–Jun)	6.0	6.0
2025 (Jul–Dec)	10	10

Source: Authors' rendering of reduction mandate levels from Regeringen (2021) and Sajtos (2025).

2.2 Pre-Policy Context

Before 2018, Sweden promoted renewable transport fuels primarily through tax exemptions within the Energy Tax Act, while fossil fuels faced regular energy and CO_2 taxes (Regeringen, 2014). Because these exemptions constituted state aid under EU law, they were repeatedly revised to address overcompensation concerns, creating an unstable support environment (Skatteutskottet, 2017). Despite this, the tax-based system supported strong HVO growth during the 2010s. As Figure 2.1 shows, the HVO share in Swedish diesel rose from near zero in the mid-2000s to around 20 percent by the time the Reduktionsplikt was introduced in 2018, while the FAME share remained broadly stable at around 5 percent throughout the period.

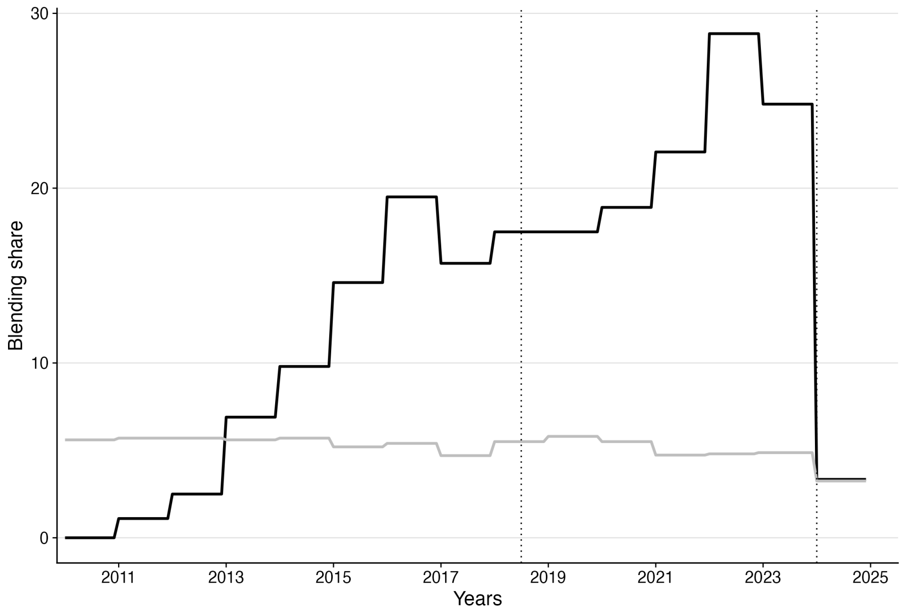


Figure 2.1: HVO *(black)* and FAME *(grey)* Shares in Swedish Diesel (Percentage Points), 2010–2025.

Source: Authors' rendering of data from 2030-miljöbarometern (2026b).

HVO was not much more expensive than fossil diesel during this time, so the tax exemptions were successful in promoting its use. Sweden therefore entered the mandate period with biofuel blending shares substantially above the EU average (2030-miljöbarometern, 2026b), meaning the mandate did not immediately lead to a large increase in blending and appears to have become binding only later, when the required reduction levels rose toward 25–30 percent. The introduction of the Reduktionsplikt thus represented a structural shift in regulatory approach from tax-based incentives toward a binding emissions-reduction obligation on fuel suppliers (Sveriges riksdag, 2017). From the policy's introduction, biofuels and diesel have been taxed the same. In the same year, Sweden introduced the Bonus-Malus vehicle taxation system, together marking a move toward a broader climate policy package targeting both fuels and vehicles (Statens offentliga utredningar, 2016).

2.3 Biofuel Blenders and Feedstocks

Compliance with the diesel mandate has relied primarily on HVO and FAME (Energimyndigheten, 2018). HVO is a paraffinic drop-in substitute that can be blended at high shares while meeting fuel quality requirements and has been the dominant compliance component in Swedish diesel. Karlsson et al., 2020 show that only a small share of HVO sold in Sweden in 2018 was produced from domestic raw materials, while the overwhelming majority of raw materials used for HVO production in Sweden were imported. As Figure 2.1 illustrates, the HVO share tracked the mandate escalation closely, rising to around 30 percent at the 30.5 percent mandate level before reverting sharply at the 2024 rollback. FAME, which is predominantly rapeseed methyl ester (RME) in Sweden, is an ester-based biodiesel typically constrained by blending limits of around 7 percent, making it an important complement but insufficient as a sole compliance pathway at high mandate levels (2030-miljöbarometern, 2026b; Energimyndigheten, 2018).

The climate performance of these blends depends critically on feedstock and production pathway. HVO produced from waste and residue feedstocks such as used cooking oil and certain animal by-products carries substantially lower lifecycle emissions than crop-based alternatives. HVO can also be produced from virgin vegetable oils, including palm oil-related inputs, which raises concerns about indirect land-use change (Energimyndigheten, 2018; Widengård, 2025). The governance of sustainability criteria around these feedstocks has been a recurring source of contention in the Swedish policy debate (Riksrevisionen, 2023).

Because Sweden has relied heavily on HVO, compliance costs have been closely tied to international biofuel markets, where limited short-run supply scalability can amplify price effects as mandated demand increases (2030-miljöbarometern, 2026b). Figure 2.2 shows retail prices for HVO100, B100, and blended diesel over the period 2016–2025 [1]. All three prices moved broadly in parallel through 2020, before rising sharply during the European energy crisis of 2021–2022 and subsequently falling as supply conditions after the energy crisis improved and the Reduktionsplikt was rolled back. It should be highlighted, that the HVO100 price increased more than the blended diesel price. The close co-movement between HVO100, B100, and fossil diesel prices reflects the role of HVO as a close substitute for fossil diesel on both the demand and supply side. Critically for our identification strategy, this co-movement also makes it difficult to separately identify the contribution of mandate induced demand for biofuels from the general energy price shock in driving the Sweden–Denmark diesel price gap during 2021–2023; we return

[1] We follow Konjunkturinstitutet, 2023b and use HVO100 and B100 as proxies for the non-accessible raw material prices. HVO100 consists almost entirely of HVO, while B100 is a biodiesel within the FAME family (Circle K Sweden, 2026)

to this issue in Section 7.3.

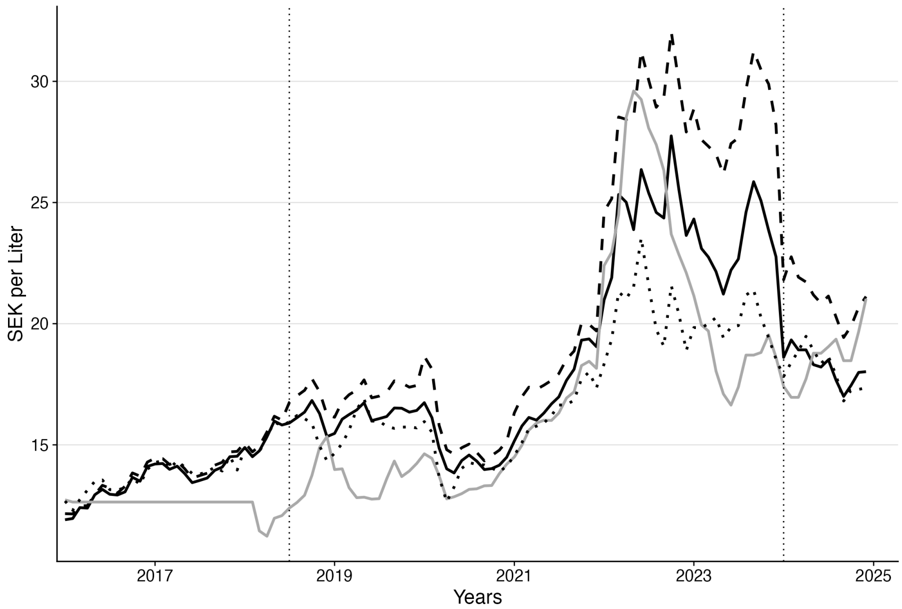


Figure 2.2: Retail prices for HVO100 *(dashed)*, B100 *(grey)*, and blended diesel *(black)* and gasoline *(dotted)* in Sweden, 2016–2025 (SEK per litre, inclusive of taxes).

Source: Authors' rendering of price data from Circle K Sweden (2026).

2.4 Policy Debate and Recent Reforms

Over time, the Reduktionsplikt became increasingly contested. The debate shifted from the technical design of the mandate toward broader concerns about fuel prices, distributional effects, biofuel scalability, and the environmental credibility of high mandated blending levels (Riksrevisionen, 2023). These concerns culminated in a major policy reversal. In late 2023, the government proposed lowering the obligation to 6 percent for both gasoline and diesel from 2024 to 2026 and removing the previously decided reduction levels for 2027–2030. The reform entered into force on 1 January 2024 (Regeringen, 2023b).

The cost channel was central to this debate. Since compliance relied mainly on blending renewable fuels into fossil fuels, higher mandated reductions increased exposure to the price of biofuel components, especially HVO in diesel. When HVO prices rose sharply during 2022–2023, the policy became more visibly connected to high pump prices, and the government later noted that this weakened the perceived cost-effectiveness of the instrument (Regeringen, 2023a). The post-2022 energy crisis therefore amplified an existing vulnerability in the policy design. The mandate was partly dependent on relatively thin and internationally traded biofuel markets, where short-run supply constraints could translate into higher compliance costs (2030-miljöbarometern, 2026b; Energimyndigheten, 2018).

The debate also concerned environmental integrity. Critics questioned whether high blending levels could be scaled without increasing reliance on contested feedstocks, indirect land-use change risks, or uncertain lifecycle accounting assumptions, including disputes over feedstock classifications such as PFAD (Riksrevisionen, 2023; Widengård, 2025). The rollback was therefore not only a response to fuel-price pressure, but also reflected wider uncertainty about the robustness of biofuel-based compliance at very high reduction levels.

After the rollback, several assessments warned that the lower mandate widened the gap to

Sweden's 2030 transport-sector target (Klimatpolitiska rådet, 2024, 2025). From 1 July 2025, the obligation was therefore raised again to 10 percent for both gasoline and diesel. At the same time, the system was adjusted in line with RED III and supplemented with electricity credits, allowing suppliers to use renewable electricity in transport as an additional compliance option. This broadened the instrument beyond conventional biofuel blending and reduced reliance on volatile HVO markets, although the new mandate level remained far below the pre-2024 trajectory (Ekonomifakta, 2026; Energimyndigheten, 2025a; Regeringen, 2025).

2.5 Related Literature

The literature relevant to this paper falls into three strands: studies of the Reduktionsplikt and Swedish transport-climate policy; estimates of abatement costs from relevant policies and societal valuations of emissions; and the theoretical and welfare-economic literature on fuel mandates.

The closest methodological reference points are Konjunkturinstitutet (2023b), C. Andersson and Thorell (2024), and Sajtos (2025), all of which estimate the price effect of the Reduktionsplikt using difference-in-differences designs with Denmark as the counterfactual. Their central finding is that early mandate levels had no detectable price effect, while the step increases at 26 and 30.5 percent raised pre-tax diesel prices substantially, and the 2024 rollback produced a large price reduction. Importantly, none of these studies translates the estimated price changes into demand responses, emissions reductions, or welfare outcomes. A gap this paper fills. Carlén and Hill (2023) compare the Reduktionsplikt with alternative pathways to the 2030 transport target using a general equilibrium model, finding that meeting the target under a low-mandate path would require large increases in fuel taxation. Riksrevisionen (2023) identifies implementation and efficiency risks in the policy, including concerns about lifecycle accounting and feedstock governance.

Table 2.2 summarises the benchmarks we use to interpret our abatement cost estimates, with all values converted to 2026 SEK for comparability. Gillingham and Stock (2018) review abatement costs across transport-related climate policies and report a wide range for low-carbon fuel standards and biofuel mandates, reflecting sensitivity to compliance pathway and market conditions. Hansson et al. (2023) estimate abatement costs specifically for diesel-compatible biofuel pathways relevant to the Swedish context. We use the Swedish carbon tax as our primary benchmark, since it represents the explicit price Sweden has placed on fossil CO_2 emissions and is therefore the most direct measure of the social value against which the mandate's abatement cost should be evaluated (Government Offices of Sweden, n.d.). We additionally report net welfare against a range of social cost of carbon estimates. SCC estimates have risen substantially over time, driven by both methodological advances and, importantly, the choice of discount rate (Drupp et al., 2018). The estimates in Table 2.2 span roughly 440–2,000 SEK/tCO_2 and illustrate this evolution. Nordhaus's estimate reflects a relatively high discount rate and represents the lower end, while more recent work converges on higher values. Rennert et al. (2022), which is currently among the most cited contemporary estimates, yields $\sim$2,000 SEK/tCO_2.

Table 2.2: Abatement Cost Benchmarks

Source	Measure	Approx. value (SEK/tCO_2)
Rennert et al. (2022)[a]	Social cost of carbon	∼2,000
Stern (2007)[b]	Social cost of carbon	∼1,450
Nordhaus (2017)[c]	Social cost of carbon	∼440
Swedish carbon tax (2025)	Explicit carbon price	1,510
Gillingham and Stock (2018)[d]	LCFS and biofuel mandates	1,200–34,000
Hansson et al. (2023)[e]	Abatement costs biofuel	1,000–3,100

[*] USD values are converted to 2026 SEK using US CPI inflation adjustments and a spot exchange rate of 9.2 SEK/USD (May 2026).

[a] Original estimate: \$185/tCO_2 in 2022 USD (\$216 in 2026 USD).

[b] Original estimate: ∼\$85/tCO_2 in 2000 USD (\$157 in 2026 USD).

[c] Original estimate: ∼\$31/tCO_2 in 2010 USD (\$48 in 2026 USD).

[d] Original estimate: \$100–2,900/tCO_2 in 2018 USD (\$127–3,680 in 2026 USD).

[e] Reported in SEK/tCO_2; no currency conversion required.

The theoretical literature establishes that fuel mandates must be evaluated in an equilibrium framework. de Gorter and Just (2009) show that the price effect of a blending mandate depends on relative supply elasticities and the interaction with pre-existing fuel taxes, and need not equal the per-litre compliance cost. Lapan and Moschini (2012) show in a second-best welfare framework that quantity mandates dominate biofuel subsidies and that combining mandates with fuel taxes can be welfare-enhancing. Holland et al. (2009) demonstrate that intensity-based standards such as low-carbon fuel standards create weaker abatement incentives than quantity- based instruments because they allow compliance through fuel-mix changes that do not reduce total emissions. Using EU panel data, Lundberg et al. (2023) find that mandates increase biofuel consumption and reduce emissions, but that price effects depend strongly on country-specific market conditions. Korting et al. (2019) show in the U.S. context that tight renewable fuel mandates can concentrate welfare costs on consumers when technical blending limits constrain compliance flexibility. Taken together, this literature motivates our approach of evaluating the Reduktionsplikt through a surplus-based welfare framework rather than relying on compliance costs or engineering abatement estimates alone.

3. Theoretical Framework

This section establishes the theoretical framework used to evaluate the Reduktionsplikt. It first explains the policy in theoretical terms and defines the underlying market failure it is intended to address. The section then develops the welfare-economic framework used to measure net social welfare and abatement costs. This makes it possible to compare the policy's economic costs with its climate benefits from an efficiency perspective.

3.1 Diesel Consumption and Externalities

In a competitive equilibrium with complete markets, the First Welfare Theorem states that resources are allocated efficiently (Arrow & Debreu, 1954). This result requires that all relevant costs and benefits are reflected in market prices. Combustion generates CO_2 emissions and local air pollutants that impose costs on third parties through climate change and adverse health effects. If left unaddressed, these costs are not fully borne by the consumer at the point of purchase (Phaneuf & Requate, 2016). In a consumption-externality framework, the marginal private benefit (MPB) of diesel consumption therefore exceeds its marginal social benefit (MSB). This relationship can be written as

$$MSB = MPB - MD, \tag{3.1}$$

where MD denotes the marginal external damage generated by an additional litre of diesel. Because consumers evaluate diesel according to its private usefulness while society must also account for the external harm, an unregulated market involves over-consumption relative to the social optimum (Pigou, 1920).

The socially optimal level of consumption Q^* in this framework can be interpreted as the level consistent with Sweden's 2030 emissions target. It is the quantity at which the associated emissions follow a path compatible with the mandated reduction. However, the relevant benchmark is not an entirely unregulated diesel market. Diesel is already subject to substantial energy and CO_2 taxation, which shifts the marginal private cost (MPC) upward and reduces consumption relative to the unregulated equilibrium. If the resulting quantity, Q_τ, remains above Q^*, existing taxes are still insufficient to place emissions on the target path. The Reduktionsplikt is therefore introduced as an additional instrument to close the remaining gap between Q_τ and the 2030-consistent optimum. Thus, the relevant question is not whether the policy is first-best relative to an ideal Pigouvian tax, but whether it reduces emissions at a reasonable welfare cost in a setting where existing taxes do not fully achieve the relevant climate target. This perspective is consistent with Moschini et al. (2012), who analyse biofuel policy in a second-best welfare framework, and with Holland et al. (2009), who show that low-carbon fuel standards affect both carbon intensity and fuel-use incentives and, therefore, need to be evaluated in equilibrium rather than only by their technical emissions effects. Figure 3.1 illustrates. The unregulated equilibrium quantity is Q_m, where $MPB = MPC$. Because diesel consumption generates external damages, MSB lies below MPB, and the socially relevant quantity is Q^*, where $MSB = MPC$. Fuel taxes shift the private cost curve upward from MPC to $MPC + \tau$, reducing consumption from Q_m to Q_τ. If $Q_\tau > Q^*$, diesel remains over-consumed relative to the social optimum, and a residual welfare loss remains. A + B in the figure represents the externality before a tax, while A is what remains after a tax. The role of additional policy is therefore to reduce A and move the quantity closer to Q^*.

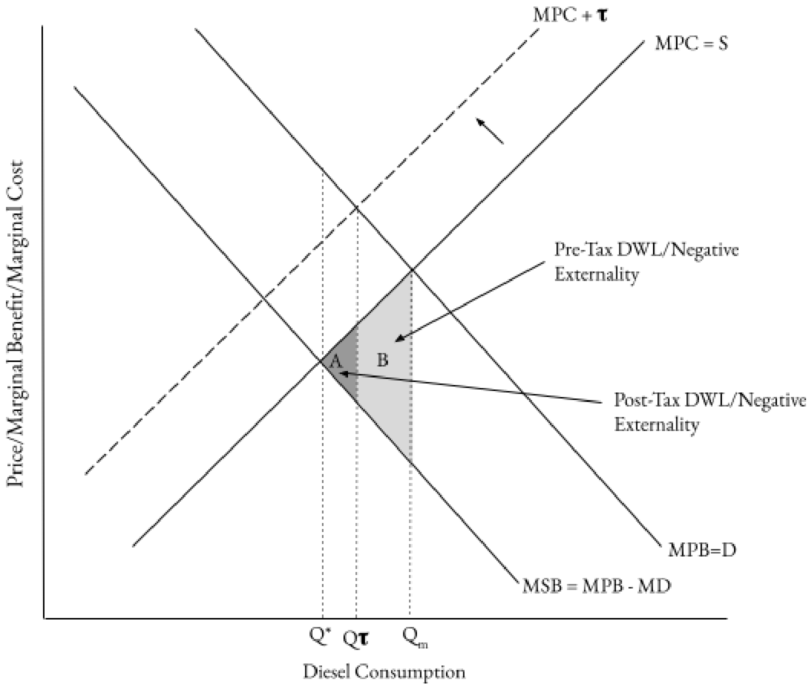


Figure 3.1: Diesel Over-Consumption in an Already-Taxed Market

Marginal external damage (MD) is not directly observable. In the empirical analysis, we therefore quantify its climate component using the social cost of carbon (SCC).[1] If diesel emits EF_{diesel} kg CO_2 per litre, the marginal external climate damage per litre can be written as:

$$MD = SCC \times \frac{EF_{diesel}}{1000}. \tag{3.2}$$

In the theoretical diagram, MD can be interpreted more broadly as total marginal external damage from diesel consumption, including both climate and local pollution damages. Equation (3.2) provides the empirical link between the theoretical externality and the welfare valuation used below.

3.2 Two Channels of the Reduktionsplikt

The Reduktionsplikt ideally operates through a single channel. By blending a greater share of biofuel into diesel, each litre sold becomes less carbon-intensive, reducing total emissions without affecting the price consumers pay. In practice, a second channel may arise. If biofuels are more costly than the fossil diesel, the pump price may increase which in turn dampens consumption if consumption is elastic. The direction of this price effect is not theoretically guaranteed. Were biofuels cheaper than fossil diesel, the mandate would instead put downward pressure on prices. Distinguishing between the two channels matters for welfare analysis, since each operates through a different mechanism and carries different welfare implications, as the figures below illustrate.

Formalizing the technical substitution channel, let α denote the biofuel blending share, EF_{fossil} the emissions factor of pure fossil diesel, and EF_{bio} the emissions factor of the bio-

[1] The SCC is defined per tonne of CO_2.

fuel component, with $EF_{bio} < EF_{fossil}$. The emissions factor of the resulting blend is

$$EF(\alpha) = \alpha \, EF_{bio} + (1-\alpha) \, EF_{fossil}, \tag{3.3}$$

which is strictly decreasing in α: a higher biofuel share produces a cleaner blend. This lowers the marginal external climate damage per litre, and from equations (3.1) and (3.2):

$$MD(\alpha) = SCC \times \frac{EF(\alpha)}{1000}, \qquad MSB(\alpha) = MPB - MD(\alpha).$$

A higher mandate therefore shifts MSB upward, narrowing the gap between the private and social optimum. Figure 3.2 illustrates this: when α rises from α_0 to α_1, the blend becomes cleaner, the damage curve falls, and MSB shifts from MSB_0 to MSB_1, raising the socially desirable quantity from $Q^*(\alpha_0)$ to $Q^*(\alpha_1)$ while the market quantity Q_0 is unchanged. In the figure, MSB does not shift all the way to MPB, so area B remains as a residual externality. In the limiting case where the mandate is sufficiently stringent, $Q^*(\alpha_1) = Q_0$ and the externality is fully closed.

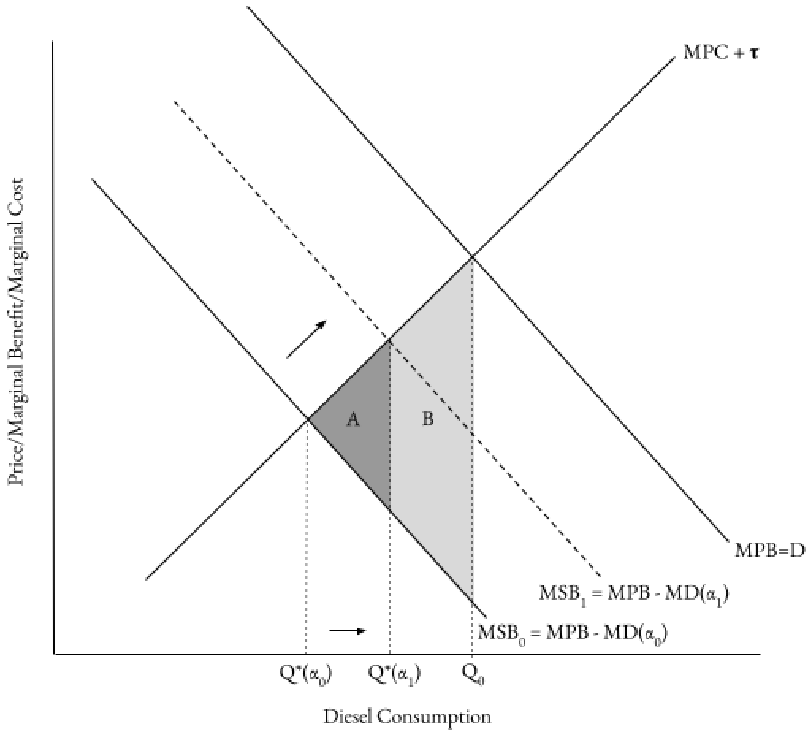


Figure 3.2: Technical Substitution Channel

Notes: The figure isolates the technical substitution channel, holding the price channel fixed.

The price channel works through marginal private cost. If blending requirements increase production costs the MPC curve shifts upward. In an already-taxed market, the baseline private cost curve is $MPC + \tau$, and the mandate-induced cost increase shifts this to $MPC + \tau + \Delta c$, where Δc is the additional marginal cost caused by the Reduktionsplikt. Figure 3.3 illustrates this in a case where the technical substitution channel has already been fully successful. MSB has shifted up to MPB, closing the externality, so that $Q_0 = Q^*(\alpha_1)$. In this setting, the upward shift in marginal private cost reduces consumption from Q_0 to $Q_1 < Q^*(\alpha_1)$, pushing the market below the social optimum. Area A represents the resulting welfare loss from forgone diesel consumption caused by the mandate-induced price increase.

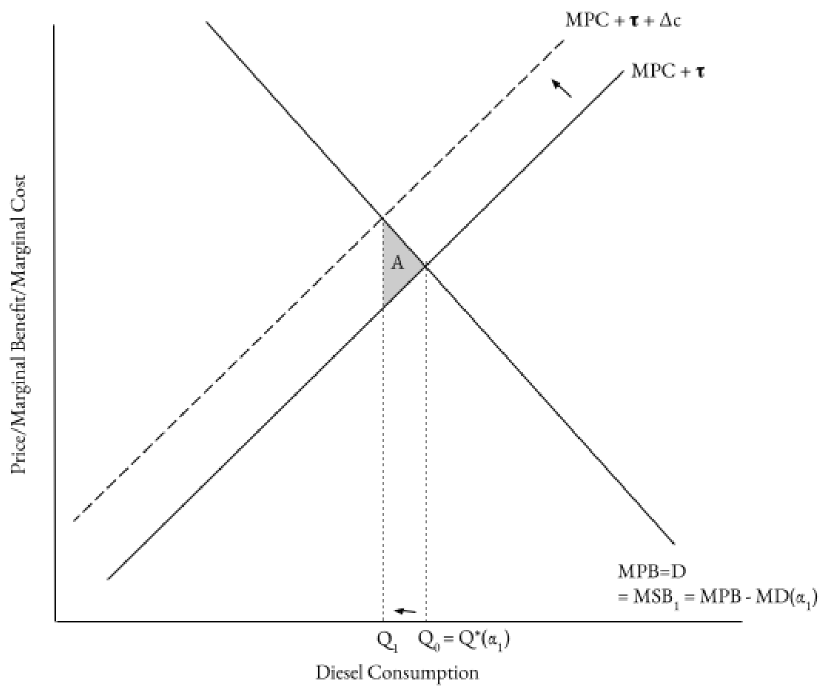


Figure 3.3: Price Channel

Notes: Area A denotes the welfare loss from a mandate-induced price increase, given that $Q_0 = Q^*(\alpha_1)$.

Whether the Reduktionsplikt improves welfare therefore depends on the relative magnitudes of these two effects. If the mandate operates mainly through cleaner fuel with little or no price effect, the technical substitution channel narrows the externality gap. If biofuels differ in cost from fossil diesel, however, the resulting price channel can also shift the market equilibrium. Depending on how far the technical substitution channel has already moved the market toward Q^*, this price channel may either bring consumption closer to Q^* or move it further away. The figures above are illustrative rather than predictive. The empirical analysis below estimates the size of each channel.

3.3 Emissions Reduction and its Economic Benefit

Emissions reductions are the social benefit of the Reduktionsplikt. As established above, the technical substitution channel is the intended mechanism. By mandating a higher biofuel share α, the emissions factor of each litre sold falls from EF_{fossil} towards EF_{bio}. The saving per litre of additional blending relative to the counterfactual is the difference in emissions factors between the fossil and biofuel components. Let α denote observed biofuel blending and $\bar{\alpha}$ the counterfactual baseline absent the mandate. The emissions reduction from the technical channel is then:

$$\Delta CO_2^{tech} = (\alpha - \bar{\alpha}) \cdot (EF_{fossil} - EF_{bio}). \tag{3.4}$$

The key identifying assumption in this expression is the counterfactual blending level $\bar{\alpha}$, since a lower assumed baseline mechanically attributes more emissions reductions to the Reduktionsplikt. We assume that $\alpha - \bar{\alpha} \geq 0$, meaning that the mandate sets a binding blending floor above the counterfactual level. In the main welfare analysis, we use a 6 percent reduction requirement — like the EU minimum and close to Denmark — as the counterfactual baseline, and discuss the implications of this choice in Section 7.3. We further assume that all producers comply with the policy, which is also discussed in Section 7.3.

If compliance is costly, the price channel may act on top of this. Each litre of demand that is priced out avoids emissions equal to the blend's current emissions factor $EF(\alpha)$. Let $\theta \in (0, 1]$ denote the share of the mandate-induced cost increase passed through to consumer prices, defined formally in Section 3.4. The emissions reduction through the price channel is then:

$$\Delta CO_2^{pc}(\theta) = \theta \, |\Delta Q| \cdot EF(\alpha). \tag{3.5}$$

This is a secondary and unintended source of emissions reductions. Total emissions reductions over the policy horizon, aggregating both channels across periods, are:

$$\Delta CO_2^{total}(\theta) = \sum_t \left[\Delta CO_2^{tech} + \Delta CO_2^{pc}(\theta) \right]. \tag{3.6}$$

The economic benefit of these reductions is the avoided external climate damage. The SCC converts each tonne of avoided CO_2 into a monetary value, and therefore governs the magnitude of the climate benefit. A higher SCC raises the benefit attributed to every tonne avoided through either channel, making the policy look more favourable. A lower SCC shrinks the benefit side. The total climate benefit is:

$$\textit{Climate Benefit}(\theta) = SCC \times \Delta CO_2^{total}(\theta). \tag{3.7}$$

3.4 Welfare Cost and Surplus Distribution

In an idealised setting where biofuels are cost-competitive with fossil diesel, the Reduktionsplikt would constitute a costless improvement. Emissions fall while consumer prices and fuel consumption is unaffected. But if compliance is costly, producers face a higher marginal cost of supply. This cost increase may then be passed through to consumers, raising price and reducing demand. The price channel is therefore an unwanted distortion, not a policy instrument in its own right, and it is the sole source of welfare cost in this framework.

Figure 3.4 illustrates these surplus effects. The baseline cost curve is $MPC+\tau$. The mandate shifts it upward to $MPC + \tau + \Delta c$, raising the consumer price from P_0 to P_1 and reducing consumption from Q_0 to Q_1. The consumer surplus loss is area $G+C$ and the producer surplus loss is area $F+E$. Together, $G+F$ represents the inframarginal compliance cost burden on litres still consumed, while $C+E$ is the triangular loss from consumption that is priced out. The total economic cost of the price channel is therefore $G+F+C+E$.

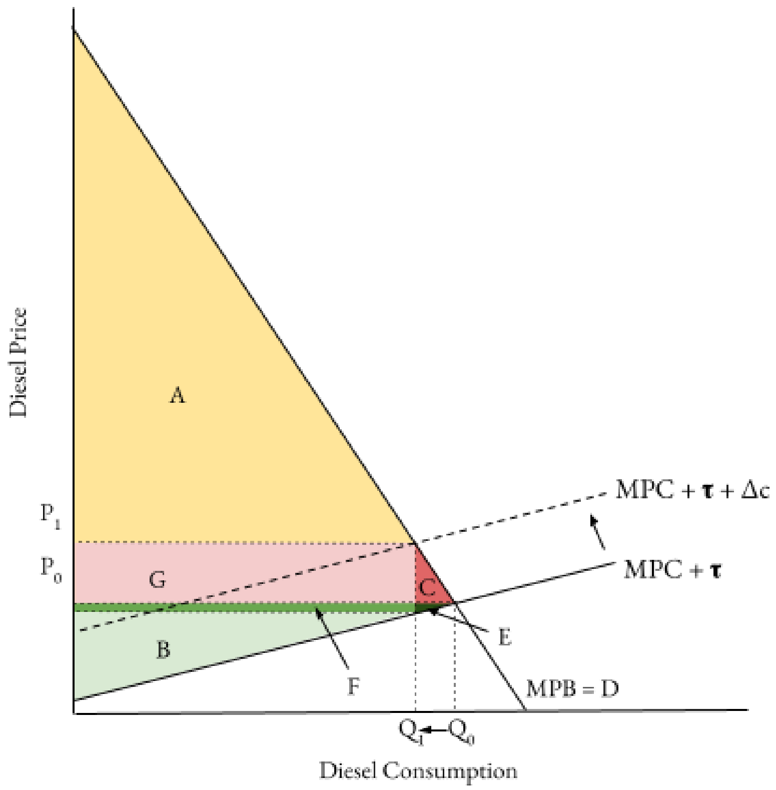


Figure 3.4: Surplus Distribution and Welfare Cost of the Price Channel

We now formalise these surplus effects. Let Δc denote the mandate-induced marginal cost increase per litre and $\theta \in (0, 1]$ the pass-through rate to consumer prices. All variables defined below are period-specific and later aggregated over the policy horizon. The consumer price increase is $\Delta P_c = \theta\, \Delta c$, and the producer-absorbed share is $\Delta P_p = (1 - \theta)\, \Delta c$. Let Q_0 denote counterfactual consumption and $|\Delta Q|$ the quantity reduction under full pass-through. The demand response scales linearly with pass-through, $|\Delta Q(\theta)| = \theta\, |\Delta Q|$, so the post-policy quantity is ($Q_1 = Q_0 - \theta|\Delta Q|$). Using a linear demand approximation, the change in consumer surplus is

$$\Delta CS(\theta) = -\theta\, \Delta c\, Q_0 + \tfrac{1}{2}\, \theta^2\, \Delta c\, |\Delta Q|, \tag{3.8}$$

where the first term is the inframarginal price burden on Q_0 (area G) and the second term recovers the triangle on litres no longer consumed (area C). The change in producer surplus is the cost burden absorbed on the remaining quantity,

$$\Delta PS(\theta) = -(1 - \theta)\, \Delta c\, (Q_0 - \theta\, |\Delta Q|)\,, \tag{3.9}$$

corresponding to area $F + E$ in the figure. At $\theta = 1$ this term vanishes. Producers bear none of the cost. At $\theta < 1$ they absorb the remainder.[2]

The value of θ is therefore important to how the welfare burden is distributed between consumers and producers. In a standard competitive market it depends on the relative elasticities

[2] Under a tax, the surplus transfers $G + F$ would accrue as public revenue rather than reflecting a real resource cost, and the net welfare loss would shrink to the deadweight triangle $C + E$ alone: $DWL = \frac{1}{2}\, \Delta c\, \theta\, |\Delta Q|$. Under the Reduktionsplikt there is no such transfer; $G + F$ represents a genuine compliance cost borne within the fuel market, which is why the full surplus loss $G + F + C + E$ is the relevant welfare measure.

of supply and demand (Weyl & Fabinger, 2013):

$$\theta = \frac{\varepsilon_s}{\varepsilon_s - \varepsilon_d}, \tag{3.10}$$

where $\varepsilon_s > 0$ is the supply elasticity and ε_d is the demand elasticity. When supply is relatively elastic and demand relatively inelastic, most of the burden falls on consumers. The empirically relevant case for diesel, where short-run demand is typically price-inelastic. Harju et al. (2022) estimate diesel carbon-tax pass-through of around 80 percent in Finland, and Marion and Muehlegger (2011) find near-full pass-through for U.S. fuel taxes. For Sweden, J. Andersson and Tippmann (2022) finds almost one-for-one pass-through of the 2022 gasoline tax cut; since diesel demand is typically more inelastic than gasoline demand, pass-through for diesel is likely at least as high, consistent with Konkurrensverket (2024) description of a concentrated Swedish fuel retail market. We therefore use full pass-through ($\theta = 1$) as the baseline and report sensitivity results for $\theta = 0.9$ and $\theta = 0.8$.

3.5 Net Welfare and Abatement Cost

The framework combines the climate benefit and the surplus loss into a single net welfare measure. Since ΔCS and ΔPS are negative when the policy raises costs, net welfare in any period is:

$$NW(\theta) = SCC \times [\Delta CO_2^{tech} + \Delta CO_2^{pc}(\theta)] + \Delta CS(\theta) + \Delta PS(\theta). \tag{3.11}$$

The Reduktionsplikt improves welfare only if the climate benefit on the left exceeds the surplus loss on the right.

We define three abatement cost measures, all aggregated over the policy horizon [3]. The primary measure is the total welfare cost per tonne of emissions reduced across both channels:

$$AC_{total}(\theta) = \frac{\sum_t (|\Delta CS(\theta)| + |\Delta PS(\theta)|)}{\Delta CO_2^{total}(\theta)}. \tag{3.12}$$

Although the total social cost is what matters for efficiency, the distribution between consumers and producers can be relevant for political feasibility discussions in 7 that go beyond the total net-welfare evaluation. We therefore also report the incidence decomposition:

$$AC_{consumer}(\theta) = \frac{\sum_t |\Delta CS(\theta)|}{\Delta CO_2^{total}(\theta)} \qquad AC_{producer}(\theta) = \frac{\sum_t |\Delta PS(\theta)|}{\Delta CO_2^{total}(\theta)}. \tag{3.13}$$

The Reduktionsplikt raised diesel prices visibly at the pump, so the burden was likely concentrated on consumers rather than producers.

Finally, we define AC_{pc} as the abatement cost that would obtain if the same price increase had been delivered by a carbon tax rather than a blending mandate. A carbon tax of equivalent magnitude would generate the same surplus losses and the same quantity reduction ΔCO_2^{pc}, but no technical substitution. AC_{pc} isolates exactly this hypothetical by attributing the full welfare cost to the price-channel reductions alone:

$$AC_{pc}(\theta) = \frac{\sum_t (|\Delta CS(\theta)| + |\Delta PS(\theta)|)}{\sum_t \Delta CO_2^{pc}(\theta)}. \tag{3.14}$$

[3]Due to the short time frame of the evaluated policy, we do not discount abatement costs.

Since the numerator is identical in AC_{pc} and $AC_{welfare}$ while $\Delta CO_2^{total} \geq \Delta CO_2^{pc}$, it follows that:

$$AC_{pc}(\theta) \geq AC_{total}(\theta), \tag{3.15}$$

with equality only if the mandate induces no additional blending beyond the counterfactual. The gap between the two is a direct measure of the value added by the mandate over a carbon tax of equivalent price effect. The wider the gap, the more the technical substitution channel contributes reductions that a price instrument alone could not have delivered. All three abatement cost measures will be compared against the benchmarks in Table 2.2, asking whether the welfare cost of a tonne of CO_2e avoided through the Reduktionsplikt falls below the value Sweden and the broader literature assign to avoiding it.

To summarize, the theoretical framework above defines the channels through which the Reduktionsplikt affects welfare. The next step is to quantify these objects empirically.

4. Empirical Methodology

To perform the welfare analysis outlined in Section 3, we need to empirically identify the price channel of the Reduktionsplikt, including its impact on diesel consumption and carbon emissions. The technical substitution channel requires no separate causal estimation in the same sense, since observed blending levels and emissions factors are directly available. However, its magnitude still depends on the assumed counterfactual blending baseline $\bar{\alpha}$, which we set in the welfare analysis and discuss in Section 7.3. The empirical strategy therefore focuses on the the price channel. We separate the estimation into three steps:

(1) The causal effect of the Reduktionsplikt on diesel prices.

(2) The price elasticity of demand for diesel.

(3) The response of demand to the price effect using the results from (1) and (2).

Combined, these results provide the empirical values necessary to calculate the price channel and perform the welfare analysis, giving values for the change in price and quantity.

4.1 Data

We use two datasets corresponding to the first two stages of the empirical strategy. The differences in frequency and price definitions of the two datasets reflect the distinct identification requirements of the two steps.

4.1.1 Price Effect

For step (1) we use daily diesel prices reported by Circle K Sweden (2026) in SEK and Circle K Danmark (2026) in DKK, converted to SEK using the daily exchange rate from Sveriges riksbank (2026). Because tax rates and the tax treatment of biofuels differ across countries and vary over time, with-tax prices would confound mandate effects with unrelated tax changes. With data on historical taxes and blending, we calculate the prices wot for Sweden, as described in Appendix A[1]. Similar to Konjunkturinstitutet (2023b), the retail pump price can be written as

$$P_{\text{pump},t} = \left[\alpha_t C_{\text{diesel},t} + (1-\alpha_t) C_{\text{biofuel},t} + \text{markup}_t\right] \cdot \text{VAT}_t \tag{4.1}$$

where

$$C_{i,t} = P_{i,t} + \zeta_i \tau_{\text{energy},t} + \gamma_i \tau_{\text{CO2},t}, \quad i \in \{\text{diesel}, \text{biofuel}\}.$$

Here, $P_{i,t}$ denotes the wholesale fuel price, α_t the blending share, and $\tau_{\text{energy},t}$ and $\tau_{\text{CO}_2,t}$ the relevant taxes with ζ_t and γ_t denoting the tax impact. Tax exemptions on biofuels lower the per-liter effective tax on diesel when the sold product is a blend of biofuels and fossil. By using prices wot, we remove the time-varying tax component and isolate the cost margin affected by the mandate without imposing restrictive assumptions on tax wedges. In the absence of taxes, the price reduces to

$$P_{\text{wot},t} = \alpha_t P_{\text{diesel},t} + (1-\alpha_t) P_{\text{biofuel},t} + \text{markup}_t \tag{4.2}$$

[1] Circle K reports fuel prices wot for Denmark, therefore we do not need to do the same calculation for Denmark as for Sweden.

For time-invariant markups, variation in price reflect changes to the input costs and blending of fuels. Thus, when input costs are common for countries, differences in price are driven by blending and therefore orthogonal to contemporaneous tax policy changes. We interpret any estimated mandate-induced price increase as a ceteris paribus effect. That is, the amount by which pump prices were higher than they would have been in the absence of the Reduktionsplikt, holding all other factors constant. Concurrent tax changes such as the 2022 fuel tax reduction may have cushioned the consumer burden in the observed data, but shift rather than eliminate the cost, with the difference absorbed by the government as forgone tax revenue.

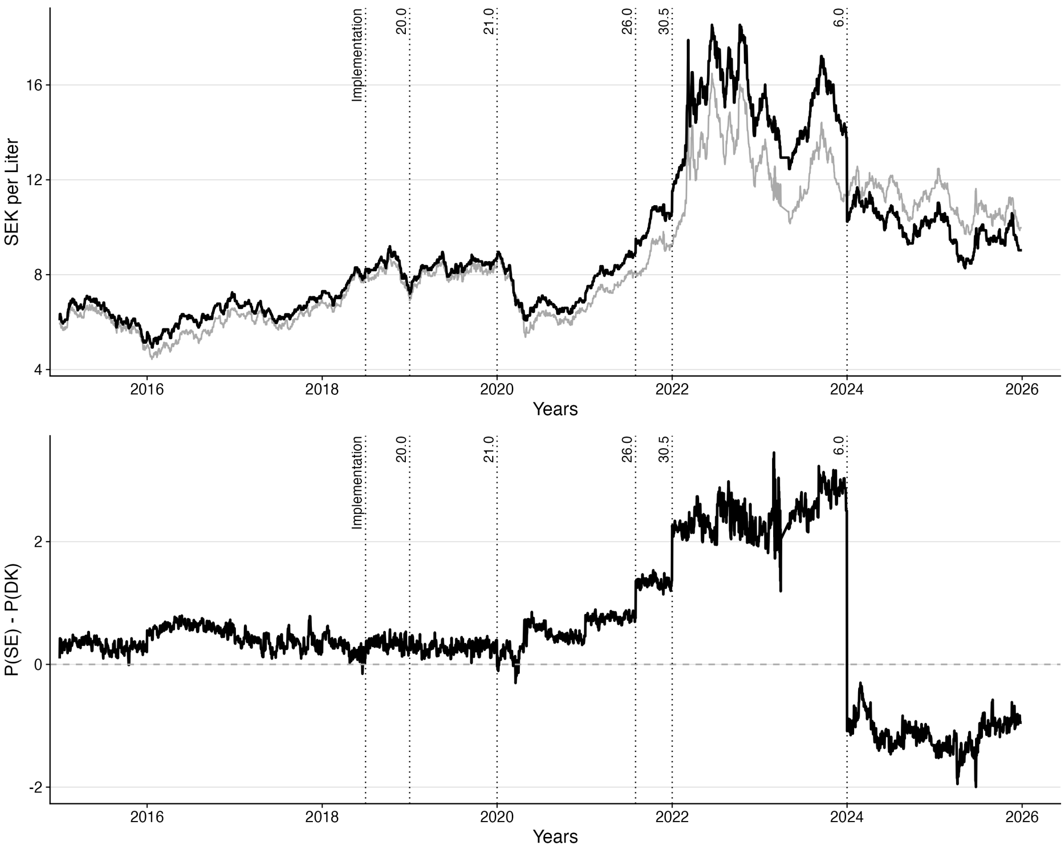


Figure 4.1: *(top)* Diesel prices in Sweden *(black)* and Denmark *(grey)* in SEK; *(bottom)* Absolute price gap $P_{SE,t} - P_{DK,t}$.

Source: Authors' rendering of price data from Circle K Danmark (2026) and Circle K Sweden (2026) using the daily SEK/DKK exchange rate reported by Sveriges riksbank (2026).

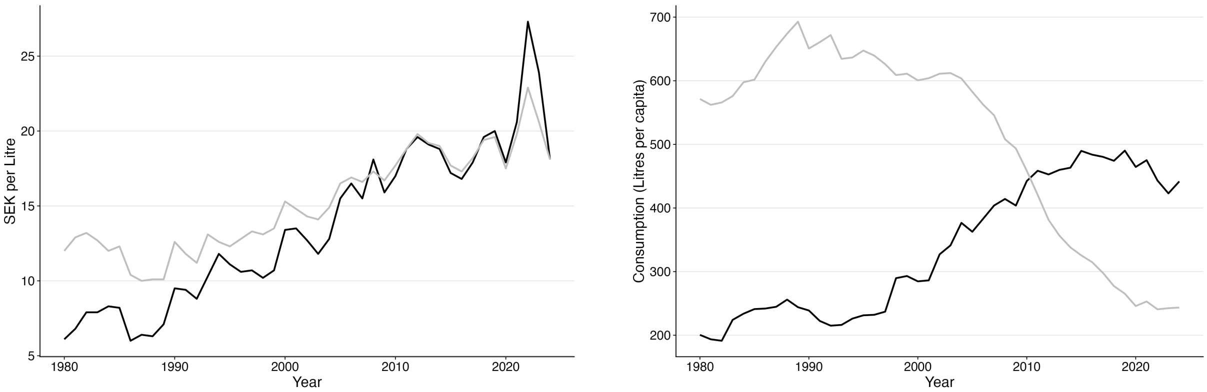
Figure 4.1 plots daily diesel prices wot for Sweden (black) and Denmark (grey) alongside their difference over the full sample period.[2] Prior to the Reduktionsplikt's implementation in 2018, the two series track each other closely with a near-zero gap. The gap widens markedly at each successive mandate increase, reaching approximately 3 SEK per litre at the 30.5 percent level in 2022–2023, before collapsing sharply at the January 2024 rollback to 6 percent. Notably, the gap turns negative following the rollback, likely reflecting a combination of the contemporaneous weakening of the SEK and Denmark's simultaneously rising blending requirement, though changes in market structure cannot be ruled out. This potential confound is addressed

[2] Circle K Denmark sets prices at midnight while Circle K Sweden updates later in the day, resulting in Danish peaks and troughs appearing one day later in the data. The analysis therefore uses a one-day lead-adjusted Danish price series.

in Section 4.2.

4.1.2 Price Elasticity of Demand

In step (2), demand elasticities are estimated using annual Swedish data from 1980 to 2024. The dependent variable is per-capita road diesel consumption, obtained from Statens energimyndighet (2026b). The price variable is the consumer pump price, inclusive of all taxes, sourced from the same agency(Statens energimyndighet, 2026a). Nominal prices and GDP are deflated to real 2023 SEK using the harmonised consumer price index from Statistiska centralbyrån (2025); consumption and GDP are expressed in per-capita terms using Statistiska centralbyrån (2024) population data.



(a) Real Prices for Fuel (b) Fuel Consumption

Figure 4.2: *(black)* Diesel; *(grey)* Gasoline

Source: Authors' rendering of price and consumption data from Statens energimyndighet (2026a, 2026b).

Figures 4.2a and 4.2b display the two main variables used in the elasticity estimation. Real diesel prices (black) have risen broadly from around 6 SEK per litre in 1980 to approximately 18–27 SEK in recent years, with a pronounced spike around 2022 driven by the energy crisis. Gasoline prices (grey) follow a near-identical trajectory throughout the sample. Per-capita diesel consumption rose steadily from around 200 litres in 1980 to a peak of roughly 490 litres around 2016–2019, before declining modestly in more recent years. Gasoline consumption followed the opposite trajectory, declining persistently from its 1980s peak as diesel vehicles became dominant. The long-run positive comovement between prices and quantities for diesel motivates the error-correction specification used in Section 4.3.2.

4.2 Denmark as a Counterfactual

The estimation strategy in 4.3.1 requires a credible counterfactual. Since Sweden has no untreated identical twin, we argue that Denmark is the best available comparison when looking at Swedish diesel prices wot. The countries are geographically close, belong to the same broader northwest European fuel market, and are exposed to similar shocks in crude-oil prices, refinery conditions, transport costs, and regional supply conditions. They are also structurally similar in several fuel-market and macroeconomic dimensions, as shown in A. Denmark has further been used as a comparator in previous Swedish fuel-price evaluations to absorb common market shocks unrelated to Swedish policy (C. Andersson & Thorell, 2024; Konjunkturinstitutet, 2023c; Sajtos, 2025).

Denmark was not untreated in a strict sense, since it also had biofuel regulation during the sample period. However, Danish policy did not change drastically during the Swedish treatment period. As shown in Table 4.1, Denmark's obligation increased from 5.75 percent in 2012–2019 to 7.6 percent from 2020 onward, while Sweden's diesel reduction mandate rose from 19.3 percent in 2018 to 30.5 percent in 2022–2023. The Danish obligation is measured by energy content and is therefore not directly equivalent to the Swedish Reduktionsplikt, which is defined in terms of lifecycle greenhouse-gas reductions.[3] Earlier work also describes Danish blending as relatively low and stable in practice (Carlén & Hill, 2023; Konjunkturinstitutet, 2023b). The estimates should therefore be interpreted as the additional Swedish price premium relative to a low- and stable-policy counterfactual, not relative to a no-policy counterfactual.

Table 4.1: Danish Biofuel Obligation for Diesel, 2010–2024

Period	Obligation (% energy content)
2010	0.75
2011	3.35
2012–2019	5.75
2020–2024	7.60

Note: Values refer to Denmark's biofuel obligation measured by energy content. Sources: IEA Bioenergy (2018, 2021, 2024), International Energy Agency (2012, 2024), and U.S. Department of Agriculture Foreign Agricultural Service (2021).

Other nearby countries provide less convincing comparisons. Finland also pursued an active biofuel policy above the EU minimum, while Norway is outside the EU and has a more distinct transport market, particularly due to rapid electrification. Denmark is therefore the most transparent nearby comparator. Nonetheless, the empirical evidence is ultimately more important than institutional similarity alone. Figure 4.1 shows that Swedish and Danish diesel prices wot moved closely together before the Reduktionsplikt was introduced. The lower panel also shows a small and relatively stable bilateral price gap before treatment. This visual parallel-trends pattern supports the idea that the two price series were driven by similar underlying market conditions before the policy became active. The post-2018 divergence therefore appears more consistent with Sweden's changing mandate intensity than with an obvious pre-existing break between the countries. Still, visual evidence is only suggestive. The most important support for the identifying assumption is that the formal parallel-trends tests pass. More sophisticated diagnostics, including pre-trends tests, placebo treatment checks and sensitivity checks are reported in Section 5.1.

We do not assume that Swedish and Danish retail markups are identical. Comparable markup data is not available, so this cannot be tested directly. Instead, cross-country markup differences must either be approximately time-invariant or not systematically correlated with Swedish mandate changes. Under this condition, changes in the bilateral diesel price gap wot can be interpreted primarily as reflecting policy-induced differences in fuel composition rather than un-

[3] The two obligations are not directly comparable, as Denmark's is defined by energy share while Sweden's is defined by GHG intensity. A 7.6 percent energy share nevertheless corresponds to roughly a 6 percent GHG reduction, assuming an average lifecycle saving of around 80 percent (European Parliament and Council of the European Union, 2018, Annex V, Part C).

related changes in retail pricing behaviour. Some variation in retail margins across the sample period cannot be ruled out, but the sharp collapse of the price gap at the January 2024 rollback, visible in Figure 2.2, suggests that markup changes are unlikely to account for a substantial share of the estimated gap.

Finally, we use synthetic control as a diagnostic check. The purpose is not to confirm Denmark mechanically, but to examine whether the Denmark-only design overlooks another plausible control country. Using weekly pre-treatment diesel prices wot from January 2015 to July 2018, together with structural fuel-market and macroeconomic predictors, the synthetic-control exercise checks whether a data-driven donor pool points to a different comparator. In the full donor-pool specifications, Denmark receives a weight of 0.884. Austria receives almost all remaining weight, while all other countries receive zero. When Denmark is excluded, the pre-treatment fit worsens. This suggests that no clearly better control country has been missed. We therefore retain Denmark as the sole counterfactual. It is more transparent, easier to motivate institutionally. A synthetic counterfactual would add complexity without clearly improving identification. The donor countries are themselves exposed to biofuel rules and climate-policy adjustments, while Denmark already exhibits strong pre-treatment parallel trends. The synthetic-control exercise supports this choice by showing that the donor pool does not reveal a more convincing alternative counterfactual. The results and discussions related to this exercise can be found in Appendix B.

A possible threat to identification that requires separate discussion is the exchange rate. A specific concern in the Sweden–Denmark comparison is that the Danish diesel price is observed in DKK but enters the analysis in SEK. The price gap between the two countries can be written as

$$Y_t = P_t^{SE} - FX_t^{SEK/DKK} P_t^{DK}, \tag{4.3}$$

where P_t^{SE} is the Swedish diesel price without taxes, P_t^{DK} is the Danish diesel price without taxes in DKK, and $FX_t^{SEK/DKK}$ is the exchange rate in $\frac{SEK}{DKK}$. Exchange-rate movements therefore enter the dependent variable mechanically. When the SEK weakens, the Danish comparison price rises in SEK terms, compressing the measured price gap. Konjunkturinstitutet (2023c) discuss the same issue and address it by including the exchange rate as a control variable.

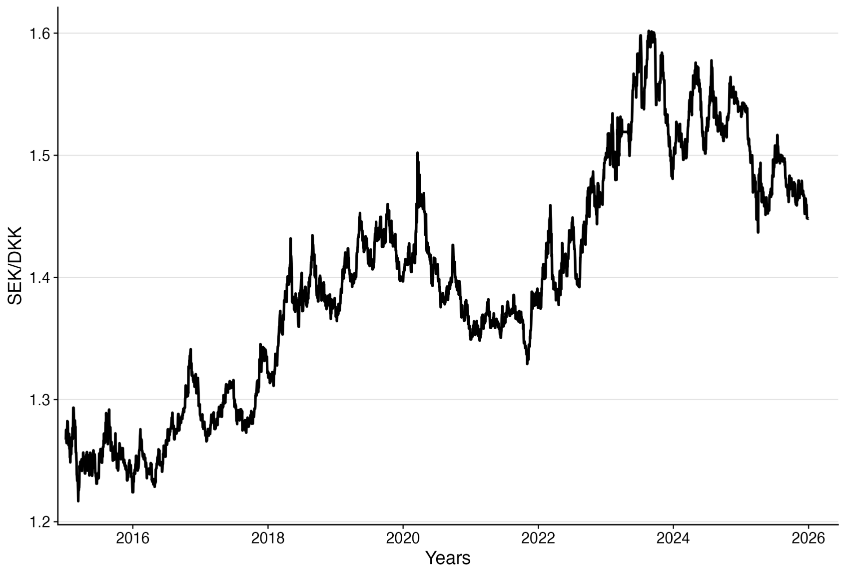


Figure 4.3: SEK/DKK exchange rate.

Source: Authors' rendering of daily SEK/DKK exchange-rate data from Sveriges riksbank (2026).

Figure 4.3 illustrates the relevance of this issue in our setting. Over the sample period, the Swedish krona depreciates against the Danish krone. Since the Danish krone is pegged to the euro, this can also be interpreted as a weakening of the SEK against a relatively stable euro-linked currency. This creates a possible threat to the parallel-trends assumption. If exchange-rate movements generate systematic trends in the bilateral price gap, part of the variation attributed to Swedish mandate regimes could instead reflect currency movements.

The most direct threat to identification would be if a sizeable exchange-rate movement coincided with one of the mandate changes. Such a shift could be mistaken for a discrete policy effect. We therefore include the exchange rate as a control and test whether the regime estimates are sensitive to its inclusion. The more persistent concern, however, is that the accumulated depreciation of approximately 0.3 SEK mechanically shifts the converted Danish series upward over time, compressing the estimated Swedish price premium. This makes our estimates more likely to be conservative than overstated, and helps explain why the two series do not fully recouple after the 2024 rollback in Figure 4.1.[4] Appendix B confirms that the series recouple more closely when the Danish price is converted at a flat exchange rate.

For these reasons, we need to take the daily SEK/DKK exchange rate into consideration in the empirical estimation of the mandate-induced price gap. We therefore include the daily SEK/DKK rate as a control variable and test whether the mandate-regime coefficients are sensitive to its inclusion.

4.3 Specifications

4.3.1 Price Effect

We estimate the causal effect of the Reduktionsplikt on diesel prices wot using a difference-in-differences design with Denmark as the control unit, defended in Section 4.2. The identifying assumption is that, absent the Swedish mandate, the SE–DK price gap would have followed a

[4] It could be a combination of different factors, including Denmark's marginally higher biofuel obligation and potential differences in markups or contract adjustment. We do not evaluate this further as it falls after the paper's studied time period.

stable, drift-free path during the treatment period. With only two countries, country and time fixed effects reduce to a single intercept difference and a day-by-day control absorbed entirely by the Danish price series, so subtracting the Danish price from the Swedish price recovers all identifying variation by construction.[5] We therefore work directly with the price gap 4.3. Since the mandate changed at six distinct dates, a single binary post-treatment indicator would average across heterogeneous levels of biofuel cost exposure. We instead estimate a mandate level-based decomposition:

$$Y_t = \alpha + \sum_{k \in \mathcal{K}} \beta_k \, W_{k,t} + \varepsilon_t, \tag{4.4}$$

where $k = \{19.3\%, 20\%, 21\%, 26\%, 30.5\%, 6\%\}$, $W_{k,t}$ equals one during mandate level k and zero otherwise, and the pre-mandate period (January 2017 to June 2018) serves as the omitted baseline. The baseline is restricted to January 2017 onward because the price gap exhibits greater stability from this point, as visible in Figure 4.1.[6] Each $\hat{\beta}_k$ estimates the average realised biofuel cost premium borne by Swedish consumers during mandate level k relative to this baseline. The mandate rollback ($k = 6\%$) provides an additional test of the causal link between the Reduktionsplikt and diesel prices. We also estimate a specification controlling for the exchange rate:

$$Y_t = \alpha + \sum_{k \in \mathcal{K}} \beta_k \, W_{k,t} + \gamma FX_t^{SEK/DKK} + \varepsilon_t. \tag{4.5}$$

We select equation (4.5) as our primary specification on the basis of the intuition provided in 4.2 and parallel pre-treatment trends reported in 5.1 and appendix C. We report (4.4) as a robustness check.[7] All specifications are estimated by OLS on daily observations with Newey-West HAC standard errors (Newey & West, 1987) using bandwidth $L = \lfloor 4(T/100)^{2/9} \rfloor$ (Newey & West, 1994). One remaining identification concern is SUTVA. If Swedish biofuel demand was large enough to tighten northwest European biofuel markets and raise Danish input costs, the Danish series would partially absorb the Swedish price premium. Sajtos (2025) notes that such spillover is not unlikely given the scale of Swedish biofuel procurement. If present, our estimates constitute a lower bound on the true mandate cost, discussed further in Section 7.3.

4.3.2 Price Elasticity of Demand

In step (2) we estimate the price elasticity of demand for diesel $\varepsilon_p \equiv \frac{\partial \ln Q}{\partial \ln P}$ in Sweden, which is the prerequisite to translate the price effect from step (1) into a demand response. We replicate the two-step error-correction methodology of Engle and Granger (1987) as applied by Brännlund (2013) and Cuddington and Dagher (2015), using annual data from 1980 to 2024. Two assumptions underpin the elasticity estimation. First, we treat real diesel prices as weakly exogenous to Swedish aggregate demand. Sweden is a price-taker on northwest European wholesale fuel markets, so domestic demand shocks do not feed back into input costs. Second, the long-run price elasticity β_1 is assumed to be stable across the sample. Given structural changes in the Swedish vehicle fleet and energy policy over 1980–2024, this is a strong assumption, which we assess by comparing our estimate against the literature range.

[5] Formally, $P_{i,t} = \alpha_i + \gamma_t + \beta D_{i,t} + \varepsilon_{i,t}$, where $D_{i,t} = \mathbf{1}[i = \text{SE}, \, t \geq t_0]$. With $i \in \{\text{SE}, \text{DK}\}$, differencing eliminates α_i and γ_t simultaneously, yielding $Y_t = \mu + \beta D_t + u_t$, where $\mu = \alpha_{\text{SE}} - \alpha_{\text{DK}}$.

[6] The 2015–2016 period coincided with a sharp global oil price collapse that may have affected Sweden and Denmark differently, making the earlier pre-period a less reliable baseline.

[7] As a further robustness check we replace the daily FX_t with its full-sample mean $\bar{FX}$, so that all residual variation in Y_t is attributable solely to local-currency price differences.

We estimate the cointegrating relationship between diesel consumption and its determinants in log levels:

$$\ln Q_t^D = \beta_0 + \beta_1 \ln P_t^D + \beta_2 \ln P_t^G + \beta_3 \ln Y_t + \beta_4 t + \varepsilon_t, \tag{4.6}$$

where Q_t^D is per-capita road diesel consumption, P_t^D and P_t^G are the real consumer prices of diesel and gasoline, Y_t is real GDP per capita, and t is a linear trend capturing autonomous efficiency improvements. Under cointegration, ε_t is stationary and β_1 has the interpretation of the long-run price elasticity of demand. The long-run price elasticity is interpreted as the percentage change in consumption after all dynamic adjustments are complete following a permanent one-percent increase in price. We test stationarity of $\hat{\varepsilon}_t$ using the Augmented Dickey-Fuller test (Dickey & Fuller, 1979). We include D_t^{BM}, a level-shift indicator equal to one from 2018 onward. The inclusion is motivated by the fact that Bonus-malus shifts the long-run equilibrium level of diesel demand through vehicle fleet composition, not through the price channel. Omitting it leaves the post-2018 structural decline in consumption unexplained. Since Bonus-malus was introduced when real diesel prices were elevated, the omitted demand reduction is spuriously attributed to the price variable, biasing $\hat{\beta}_1$ toward zero.[8]

Given equation (4.6), the short-run error-correction model is:

$$\Delta \ln Q_t^D = \beta_0 + \beta_1 \Delta \ln P_t^D + \beta_2 \Delta \ln P_t^G + \beta_3 \Delta \ln Y_t + \beta_4 \hat{\varepsilon}_{t-1} + u_t, \tag{4.7}$$

where $\hat{\varepsilon}_{t-1}$ is the lagged residual from equation (4.6). Here β_1 is the short-run price elasticity. That is, the immediate within-year percentage change in consumption following a one-percent price increase, before any further adjustment has occurred. The error-correction coefficient $\beta_4 < 0$ measures the adjustment speed at which consumption moves to its long-run equilibrium after a shock. [9] Standard errors are Newey-West HAC following Newey and West (1994).

From basic economic intuition, the short-run elasticity should be negative and smaller in absolute value than the long-run elasticity, since consumers face adjustment costs in switching vehicles or changing behaviour in response to price changes. The gasoline cross-price elasticity should be positive (substitutability), and the income elasticity positive.

Since the ECM rests on cointegration, which is difficult to establish formally in samples of $n \approx 45$ annual observations (Karpaty et al., 2024), we validate our estimates against the existing literature. Table 4.2 summarizes prior estimates for Sweden and comparable northern European economies. We use the resulting range as a plausibility check on our own estimates and as bounds for the demand response calculation.

Table 4.2: Summary of Price Elasticity Estimates from the Literature

Authors	SR	LR	MR	Method	Region
Brännlund (2013)	−0.17	−0.40		ECM	Sweden
Aklilu (2020)	−0.158	−0.421		ARDL-Bounds	Sweden
Labandeira et al. (2017)	−0.153	−0.443		Meta-analysis	Sweden
Dahl (2012)			−0.25		Sweden
Dahl (2012)			−0.27		High-income

[8] A Covid-19 indicator was also tested but was consistently insignificant across all specifications and is therefore excluded from the final model.

[9] A value of −0.3 implies that 30 percent of any disequilibrium is closed within one year, with full adjustment taking approximately three to four years

Short-run estimates range from -0.153 to -0.17 and long-run estimates from -0.40 to -0.443. The medium-run estimates from Dahl (2012) come from static rather than dynamic specifications and are therefore best interpreted as falling between the short- and long-run values, which they do. We use -0.153 to -0.443 as the literature bounds in the demand response calculation, with our own preferred ECM estimates as the central case.

4.3.3 Demand Response to the Price Effect

This section translates the estimated price effect of the Reduktionsplikt into an estimated change in diesel consumption. Higher diesel prices reduce demand, but the response is not immediate, and since the mandate changed several times, each price shock creates its own adjustment path. At any evaluation date we therefore sum the demand responses from all previous mandate changes, where the size of each response depends on how much time consumers and firms have had to adjust.

To combine the price effect from step 1 with the elasticity estimates from step 2, we derive a formula for the cumulative demand response to sequential price shocks over time. The demand response is derived as an analytical consequence of the ECM methodology, which defines the connection between long-and short-run elasticities. Throughout, Δp denotes a proportional price change, i.e. $\Delta p = \Delta\hat{\beta}_k/\bar{P}_{\text{SE}}$, where $\Delta\hat{\beta}_k$ is the estimated SEK/litre price change at mandate step k and $\bar{P}_{\text{SE}}$ is the mean Swedish wot price in the pre-window of that transition. The long-run equilibrium condition states that after a price shock Δp, starting from equilibrium, demand eventually adjusts fully by $\varepsilon_{LR}\Delta p$. Since the Reduktionsplikt implied multiple price shocks over time, we decompose the cumulative demand response into individual responses to each shock and sum them.

Define C_t as the cumulative demand response at time t to a single shock Δp. The immediate response is $C_0 = \varepsilon_{SR}\Delta p$ and the long-run response is $C_\infty = \varepsilon_{LR}\Delta p$. The outstanding adjustment gap at time t is

$$u_t = C_t - C_\infty = C_t - \varepsilon_{LR}\Delta p,$$

which equals zero only at $t = \infty$. The ECM coefficient λ on the lagged error-correction term governs how quickly this gap closes each period. Specifically,

$$u_t = (1+\lambda)\, u_{t-1}, \qquad 0 < |\lambda| < 1,$$

since u_t and the error correction term $\hat{\varepsilon}_t$ from 4.3.2 are the same object.[10] Both measure the log-percentage deviation of actual consumption from its current long-run equilibrium. Applying λ to u_t is therefore an exact transfer from the ECM, not an additional assumption. Since the same fraction $|\lambda|$ of the remaining gap is closed each period, this generalises to $u_t = (1+\lambda)^t u_0$. The initial gap is $u_0 = C_0 - C_\infty = (\varepsilon_{SR} - \varepsilon_{LR})\Delta p > 0$, since $|\varepsilon_{SR}| < |\varepsilon_{LR}|$ and both elasticities are negative, so $\varepsilon_{SR} - \varepsilon_{LR} = |\varepsilon_{LR}| - |\varepsilon_{SR}| > 0$. Substituting into $C_t = \varepsilon_{LR}\Delta p + u_t$ yields:

$$C_t = \left[\varepsilon_{LR} + (\varepsilon_{SR} - \varepsilon_{LR})(1+\lambda)^t\right]\Delta p.$$

[10] In the short-run ECM (4.7), $\hat{\varepsilon}_{t-1}$ measures how far consumption deviated from its long-run equilibrium in the previous period. The coefficient λ on this term is estimated from the regression of $\Delta \ln Q_t$ on $\hat{\varepsilon}_{t-1}$, so it captures the fraction of last period's disequilibrium that is corrected within one year. If consumption was x percent above its long-run equilibrium, it falls back by $|\lambda| \cdot x$ percent the following year. In the demand response framework, u_t plays the same role as $\hat{\varepsilon}_t$ in the ECM, measuring the gap between the current and long-run demand response, so the same coefficient governs its evolution: $u_t = u_{t-1} + \lambda\, u_{t-1} = (1+\lambda)\, u_{t-1}$.

At $t = 0$ this collapses to $C_0 = \varepsilon_{SR}\Delta p$ and as $t \to \infty$ it converges to $C_\infty = \varepsilon_{LR}\Delta p$, as required. To account for mandate changes arriving at different points within the year, we work in half-year units ($t = 0, 0.5, 1.0, \ldots$). Since the short- and long-run elasticities are defined over annual periods, we impose that a fraction f of the first-year demand response occurs within the first half-year, with $f = \frac{1}{2}$.[11] The initial response at $t = 0$ is therefore $C_0 = f\varepsilon_{SR}\Delta p$, giving $u_0 = (f\varepsilon_{SR} - \varepsilon_{LR})\Delta p > 0$ since $|f\varepsilon_{SR}| < |\varepsilon_{LR}|$. The general formula becomes:

$$C_t = \left[\varepsilon_{LR} + (f\varepsilon_{SR} - \varepsilon_{LR})(1+\lambda)^t\right]\Delta p. \tag{4.8}$$

The total demand response to the Reduktionsplikt at any evaluation date T is then the sum of the individual adjustment paths from all mandate steps k that occurred before T:

$$D(T) = \sum_{k:\, s_k \leq T} C^{(k)}_{T-s_k}, \tag{4.9}$$

[12] where s_k is the arrival date of shock k and $C^{(k)}_{T-s_k}$ is evaluated at the elapsed time since that shock using equation (4.8) with the corresponding Δp_k. Setting T equal to the January 1 2024 rollback date gives the total reduction in diesel consumption attributable to the mandate over its escalation phase, but excluding potentially ongoing demand responses that materialize in the rollback period. The true behavioural effect of the high-mandate period partly persists beyond 2024, since some consumers and firms that adjusted during the escalation phase may have continued those habits or investments after the rollback. At the same time, the rollback itself likely generated an opposite demand response, as lower fuel prices may have encouraged higher diesel consumption or delayed further adjustment. We do not estimate these post-rollback dynamics here.

[11] $f = \frac{1}{2}$ assumes a linear within-year adjustment path. Since our interest is in the cumulative demand response rather than its precise timing within the first year, this choice is of secondary importance to the final result.

[12] The demand response compounds estimation uncertainty from two stages (the DiD regime coefficients and the ECM elasticity estimates) and formally propagating both would yield wide confidence intervals. The reported demand responses should therefore be read as central estimates.

5. Empirical Results

5.1 Price Effect

We begin by evaluating the parallel trends assumption across specifications, as the evidence bears directly on the choice of primary estimator. We then present and discuss the main results.

Regressing the gap on a linear time trend over the 546-day pre-treatment baseline yields different conclusions across specifications. Without FX control, the time coefficient is −0.000252 SEK per day ($p < 0.001$), implying a cumulative downward drift of approximately 0.14 SEK over the baseline, rejecting the null of no-drift. With FX control, the time coefficient is +0.000166 SEK per day ($p = 0.237$), statistically indistinguishable from zero. The SEK depreciated against the DKK during 2017–2018, mechanically compressing the SEK-denominated gap through the term $P_t^{DK} \cdot FX_t$ even when both local-currency prices move in parallel. Controlling for FX_t at least partially adjusts for this artefact.

Figure 5.1 presents pre-treatment bin coefficients from both specifications around the July 2018 treatment date. In the no-FX panel, all six pre-period bins are individually significant and uniformly elevated at approximately 0.09–0.18 SEK relative to the reference bin $k = -1$. The joint F-test strongly rejects the null ($F_{6,1983} = 9.03$, $p < 0.001$). Importantly, the pre-period coefficients do not exhibit a monotone or accelerating pattern indicating a level shift near the reference period rather than a genuine diverging trend. This is consistent with the exchange rate compressing the gap in the final 90-day window before treatment, deflating the reference bin relative to earlier pre-period observations. In the FX-controlled panel, five of six pre-period bins are individually insignificant and close to zero; the joint F-test gives $F_{6,1982} = 3.15$ ($p = 0.004$), with the rejection driven entirely by the single $k = -2$ bin (0.110 SEK, $p = 0.022$). The absence of a monotone pre-trend in the FX-controlled specification, and the transitory, non-accelerating nature of the $k = -2$ deviation, supports the parallel trends assumption in local-currency terms.

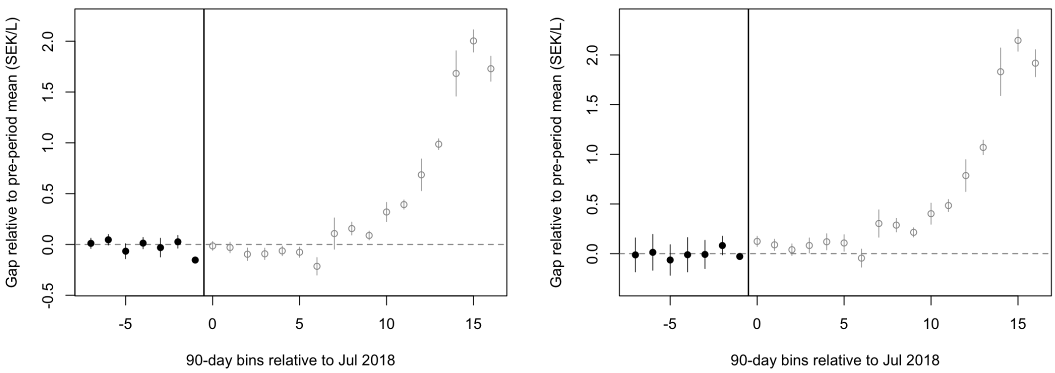


Figure 5.1: Each panel shows 90-day bin coefficients relative to the reference bin $k = -1$, re-centred on the pre-period mean. Black dots are pre-treatment bins with 95% confidence intervals; grey dots are post-treatment bins shown for context only. The vertical line marks the treatment date. Left panel: without FX control ($F_{6,1983} = 9.03$, $p < 0.001$). Right panel: FX-controlled ($F_{6,1982} = 3.15$, $p = 0.004$).

As a further check on parallel trends, we assign false treatment dates at monthly intervals within the pre-mandate period and re-estimate the DiD for each. Under the null of no spurious pre-trends, at most one of twelve placebo tests should be significant at the five percent level by chance. Without FX control, 7 of 12 placebo estimates are significant, suggesting the raw series does not satisfy parallel trends. With FX control, only 2 of 12 are significant (November 2017 and January 2018), both coinciding with the transient elevation visible in the $k = -2$ event-study bin and reverting before the true treatment date. Full results are reported in Table C.2.

Augmented Dickey–Fuller tests reject a unit root in the pre-treatment gap at the 1% level for the January 2017 – June 2018 baseline (ADF = -4.18, $p = 0.010$) and at the 5% level for the extended January 2015 – June 2018 period (ADF = -3.51, $p = 0.041$). As the ADF test operates on the raw gap series, these results apply to both specifications equally and support stationarity of the pre-mandate gap.

The parallel trends evidence consistently favours the FX-controlled specification. The no-FX specification fails both the pre-treatment trend test and the event study joint F-test through mechanisms that are mechanically attributable to exchange rate movements rather than genuine divergence in diesel market conditions between the two countries. The FX-controlled specification passes the trend test cleanly and yields a substantially cleaner event study, with pre-period coefficients uniformly close to zero. We therefore adopt equation (4.5) as our primary specification and treat equation (4.4) and the fixed-rate specification as secondary checks. We note that the FX coefficient in equation (4.5) is not cleanly identified due to the mechanical relationship between FX_t and the dependent variable discussed in Section 4.3.1. However, since the alternative specification demonstrably violates parallel trends for mechanical reasons, the FX-controlled specification provides the more credible causal estimates. The near-zero and insignificant $\hat{\gamma} = 0.310$ ($p = 0.336$) further suggests that conditioning on FX_t does not materially distort the mandate coefficient estimates, as the two columns differ by at most 0.05 SEK/L across all regime dummies.

Table 5.1 reports estimates of equations (4.5) and (4.4) alongside the fixed-rate robustness specification. Column (1) is the primary FX-controlled specification. Column (2) omits the exchange rate control and is included to confirm that the mandate coefficient estimates are stable across the two columns. Column (3) converts Danish prices at the full-sample mean rate of 1.424 SEK/DKK, isolating local-currency price differences and providing a further robustness check on the exchange rate dimension.

The mandate coefficient estimates in columns (1) and (2) are strikingly consistent, differing by at most 0.05 SEK/L across all regimes. This stability confirms that the over-control concern raised in Section 4.3.1 does not materially affect the results. The FX coefficient itself is small and insignificant (0.310, $p = 0.336$), consistent with the mandate-level dummies absorbing the discrete policy variation and leaving little systematic co-movement between the exchange rate and the residual gap.

The primary estimates in column (1) tell a clear and economically coherent story. The pre-mandate baseline gap is -0.074 SEK/L, statistically indistinguishable from zero. The 19.3% and 20% regime coefficients are -0.020 and -0.084 SEK/L respectively, both small and the latter marginally significant ($p = 0.027$), together indicating that the earliest blending increments generated no detectable biofuel cost premium above the pre-mandate level. From the 21% regime onward the pattern is monotone and economically large. The gap exceeds baseline by 0.173 SEK/L at 21%, 0.988 SEK/L at 26%, and 2.049 SEK/L at 30.5%, all significant at the 0.1% level. The escalating magnitude is consistent with increasing biofuel cost exposure as blending shares rise and biofuel markets tighten, generating an indirect price effect that compounds the direct blending cost. The rollback coefficient of −1.576 SEK/L ($p < 0.001$) places the post-rollback gap 3.6 SEK/L below the 30.5% peak, providing strong confirmation of the causal link between the Reduktionsplikt and the Swedish price premium. The reversal of the mandate produces a rapid and large reversal of the gap.

Table 5.1: Mandate-Level Decomposition of the SE–DK Price Gap

	(1)	(2)	(3)
$W_{19.3\%}$	−0.020	0.003	0.320***
	(0.030)	(0.018)	(0.031)
$W_{20\%}$	−0.084*	−0.053**	0.430***
	(0.038)	(0.017)	(0.028)
$W_{21\%}$	0.173***	0.195***	0.540***
	(0.038)	(0.034)	(0.030)
$W_{26\%}$	0.988***	1.003***	1.135***
	(0.026)	(0.020)	(0.037)
$W_{30.5\%}$	2.049***	2.100***	3.097***
	(0.057)	(0.034)	(0.078)
$W_{6\%}$ (rollback)	−1.576***	−1.514***	−0.296***
	(0.078)	(0.035)	(0.054)
FX rate (SEK/DKK)	0.310	—	—
	(0.322)		
Intercept	−0.074	0.335***	−0.183***
	(0.424)	(0.014)	(0.021)
Observations	3,103	3,103	3,103

Notes: OLS estimates of the mandate-level decomposition. The outcome is the daily SE–DK pre-tax diesel price gap in SEK per litre. The omitted baseline is January 2017 – June 2018. Column (1) is the primary specification. Column (2) omits the exchange rate control. Column (3) converts Danish prices at the full-sample mean exchange rate of 1.424 SEK/DKK. Standard errors in parentheses are Newey–West HAC with bandwidth $L = \lfloor 4(T/100)^{2/9} \rfloor$. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Column (3) reveals the exchange rate dimension of these estimates. Because the SEK depreciated substantially over the sample period — from approximately 1.28 SEK/DKK in the pre-mandate baseline to around 1.55 at the 30.5% peak — converting Danish prices at the historical mean rate amplifies the gap estimates during the high-depreciation years. The 30.5% coefficient rises to 3.097 SEK/L, reflecting that the consumer-facing gap was partly compressed by the weak SEK during 2022–2023. More notably, the rollback coefficient shrinks to −0.296 SEK/L, implying that in local-currency terms the post-rollback gap is only modestly negative. This is consistent with the discussion in Section 4.2. The post-rollback negative gap in SEK terms is substantially driven by the long-run SEK depreciation, with the residual reflecting Denmark's approximately 7% blending obligation now exceeding Sweden's 6% mandate. Columns (1) and (3) therefore bracket the mandate effect from two complementary perspectives. Column (1) measures prices as consumers face them in SEK, while column (3) isolates the underlying local-currency price differential.[1]

5.2 Price Elasticity of Demand

Table C.5 reports ADF tests for each variable in levels and first differences. All four series fail to reject the unit-root null in levels and reject it in first differences, confirming $I(1)$ status and satisfying the preconditions for cointegration.[2]

Table 5.2 reports ECM estimates for two specifications: a baseline that replicates the Brännlund (2013) structure on the extended 1980–2024 sample, and a preferred specification that augments it with a level-shift dummy for the Bonus-Malus reform introduced in 2018. The cointegration residuals from the preferred specification yield Engle-Granger ADF statistics of -4.02, -3.49, and -2.25 at lags 1–3 respectively; the lag-1 result is significant at the 1% level, supporting a long-run equilibrium relationship.[3]

The long-run price elasticity is $\hat{\varepsilon}_{LR} = -0.321$ ($p < 0.05$) in the preferred specification. The baseline replication yields $\hat{\varepsilon}_{LR} = -0.142$ ($p > 0.10$), an attenuation attributable to omitted variable bias: without a level-shift dummy, the post-2018 decline in diesel demand driven by EV adoption under Bonus-Malus is partially absorbed by the price coefficient. The Bonus-Malus dummy itself enters negatively and precisely estimated in both the long run ($\hat{\beta} = -0.135$, $p < 0.01$) and short run ($\hat{\beta} = -0.024$, $p < 0.05$), consistent with a structural reduction in demand operating independently of the price channel.

The short-run price elasticity is $\hat{\varepsilon}_{SR} = -0.195$ ($p < 0.10$) in the preferred specification, stable against the baseline estimate of -0.177. The borderline significance reflects the limited statistical power of $n = 44$ annual first differences rather than a weak relationship; the point estimate is stable across specifications and consistent with adjustment costs that prevent full within-year response to price changes. The ordering $|\hat{\varepsilon}_{SR}| < |\hat{\varepsilon}_{LR}|$ holds as expected. The income elasticity is large and precisely estimated ($\hat{\beta}_{GDP} \approx 1.18$–$1.30$, $p < 0.001$). The gasoline cross-price elasticity is positive and significant in the long-run equation ($\hat{\beta}_{pg} = 0.533$, $p < 0.05$), indicating substitutability between fuels over the horizon relevant for vehicle and route choices, but falls short of conventional significance in the short run ($\hat{\beta}_{pg} \approx 0.181$, $p > 0.10$), consistent with limited scope for fuel switching within a single year. The error-correction coefficient $\hat{\lambda} = -0.344$ ($p < 0.01$) implies that approximately one-third of any deviation from long-run equilibrium is corrected within one year.

[1] The early mandate regime coefficients in column (3) — 0.320 SEK/L at 19.3% and 0.430 SEK/L at 20% — appear large relative to columns (1) and (2). This is a mechanical artefact. The pre-mandate SEK/DKK of approximately 1.28–1.32 lies well below the full-sample mean of 1.424, so fixing the conversion rate at the mean renders the baseline gap more negative than it actually was, inflating all subsequent regime coefficients by a common upward shift.

[2] The result for $\ln \text{GDP}_{pc}$ is borderline at the first-difference stage (-3.08, significant at the 5% level against the τ_2 distribution). A supplementary KPSS test on the first difference (level = 0.084, $p > 0.10$) and an ADF on the second difference (stat = -7.03) corroborate the $I(1)$ classification; we proceed on this basis. $\ln P_{\text{gasoline}}$ is similarly borderline in levels (-3.484, against a 5% critical value of approximately -3.45), but rejects clearly in first differences (-4.036); given the ambiguity we treat it as $I(1)$, consistent with the broader literature on fuel price series.

[3] Deterioration of the statistic at longer lags is a known feature of Engle-Granger tests in short samples and does not alter the interpretation. The significantly negative error-correction coefficient in Panel B provides independent economic confirmation of mean reversion. Given $n = 45$ annual observations, we treat the long-run estimate as an implied equilibrium elasticity and validate it through the literature comparison in Table 4.2.

Table 5.2: Long-Run Cointegrating Equation and Short-Run Error Correction Model

	Panel A: Long-Run OLS $\ln Q_{\text{diesel},pc}$		*Panel B: Short-Run ECM* $\Delta \ln Q_{\text{diesel},pc}$	
	(1)	(2)	(1)	(2)
$\ln P_{\text{diesel}}$	−0.142	−0.321**		
	(0.152)	(0.149)		
$\ln P_{\text{gasoline}}$	0.368*	0.533**		
	(0.223)	(0.199)		
$\ln \text{GDP}_{pc}$	1.704***	1.424***		
	(0.213)	(0.225)		
Trend	−0.010*	0.000		
	(0.006)	(0.007)		
$\Delta \ln P_{\text{diesel}}$			−0.177*	−0.195*
			(0.107)	(0.104)
$\Delta \ln P_{\text{gasoline}}$			0.191	0.181
			(0.153)	(0.158)
$\Delta \ln \text{GDP}_{pc}$			1.295***	1.177***
			(0.267)	(0.225)
ECT_{t-1}			−0.248**	−0.344***
			(0.116)	(0.107)
$D_{\text{BonusMalus}}$		−0.135***		−0.024**
		(0.047)		(0.010)
Constant	6.801***	6.356***	−0.000	0.006
	(0.515)	(0.436)	(0.008)	(0.007)
R^2	0.956	0.967	0.381	0.451
DW	0.582	0.764	1.780	1.923
N	45	45	44	44

Notes: Specification (1) replicates Brännlund (2013) on the 1980–2024 sample. Specification (2) augments with $D_{\text{BonusMalus}}$, a level-shift dummy equal to one from 2018 onward. ECT_{t-1} is the lagged residual from Panel A specification (2). Standard errors are Newey-West HAC ($k = 3$ lags in Panel A column (1); $k = 2$ lags otherwise).
*** $p < 0.01$, [**] $p < 0.05$, [*] $p < 0.10$.

Table 4.2 places our estimates in the context of the existing literature on Swedish and European fuel demand. Our preferred long-run elasticity of −0.321 lies below the range of −0.40 to −0.443 reported by Brännlund (2013), Aklilu (2020), and Labandeira et al. (2017) for Sweden, and below the medium-run estimates of −0.25 to −0.27 in Dahl (2012). Two factors plausibly account for this. First, our sample extends to 2024 and encompasses a period of accelerating EV and hybrid car adoption and structural demand decline; controlling for this with the Bonus-Malus dummy recovers a cleaner price signal, but the post-2018 observations may nonetheless attenuate the long-run estimate relative to samples ending in the early 2010s. Second, the sharp real-price increases of 2021–2022 may have generated a different demand response than the moderate price variation in earlier decades. Our short-run estimate of −0.195 lies slightly above the −0.153 to −0.177 range reported for Sweden, though the difference is small relative to the standard errors involved. Taken together, the estimates carry the expected sign, magnitude ordering, and error-correction structure; we treat them as reasonable central values for the demand response calculations in Section 5.3, with the full literature range as bounds for sensitivity analysis. Finllay, we also test the sensitivity of our demand-response and welfare results using different literature elasticities in Appendix D.

5.3 Demand Response to the Price Effect

Combining the price effect estimates from Section 5.1 with the elasticity estimates from Section 5.2, we compute the cumulative demand response to each mandate transition using equation (4.8). The incremental price shocks Δp_k are constructed as first differences of the FX-controlled regime coefficients from Table 5.1, setting $\hat{\beta}_0 = 0$ for the pre-mandate baseline, and dividing by the mean Swedish pre-tax diesel price in the pre-window of each transition to obtain proportional price changes.[4] All results use the preferred ECM parameters $\varepsilon_{SR} = -0.195$, $\varepsilon_{LR} = -0.321$, and $\hat{\lambda} = -0.344$ from specification (2) of Table 5.2.

As introduced in Section 3, we assume full pass-through ($\theta = 1$) as the baseline. Since the Reduktionsplikt imposes a binding input cost requirement on fuel distributors, the mandate-induced increase in blending costs is expected to be fully reflected in the pre-tax price, which is precisely what the regime coefficient differences measure. This is consistent with the identification strategy: the gap estimates already embed whatever pass-through occurred.

Two further assumptions underlie the demand calculations. First, the welfare calculations assume a linear demand curve with a constant price elasticity equal to the ECM estimates. Departures from linearity have negligible consequences for the aggregate results because the price channel accounts for only approximately 8 percent of total estimated emissions reductions. Even substantial misspecification of the demand curvature would leave the aggregate abatement cost materially unchanged. Second, we assume markup stability and full pass-through ($\theta = 1$) as the baseline, consistent with the empirical literature on fuel tax incidence (Harju et al., 2022; Marion & Muehlegger, 2011). Table C.6 in the Appendix reports the total cumulative demand response under alternative pass-through assumptions. The peak demand reduction ranges from -4.06% at $\theta = 0.8$ to -5.07% at $\theta = 1.0$, a difference of approximately one percentage point. The qualitative pattern is unchanged across all three scenarios, and the implications for abatement cost are discussed in Section 6.

Table 5.3 reports the period-by-period demand response from each shock evaluated at half-year intervals from H2 2018 to H2 2024. Three features of the results are worth noting. First, the demand responses to the initial mandate steps (19.3%, 20%, 21%) are small in magnitude, consistent with the small price premia estimated for those regimes. The apparent positive entry for the 20% transition reflects the marginally negative gap estimate at that step and implies a trivially small increase in demand, not a genuine expansion; the estimated coefficient is statistically indistinguishable from zero (Table 5.1). Second, the large simultaneous appearance of the 26% and 30.5% shocks at H1 2022 reflects the evaluation timing: the August 2021 and January 2022 transitions both precede H1 2022, so their effects accumulate before the first evaluation point at which both can be observed. Third, the total demand response peaks at -5.077% in H2 2023, just before the January 2024 rollback. Following the rollback the gap begins to recover, reaching -2.57% by H2 2024, consistent with the large estimated rollback

[4] Incremental shocks: $\Delta\hat{\beta}_k = \hat{\beta}_k - \hat{\beta}_{k-1}$, where $\hat{\beta}_k$ are the FX-controlled regime estimates from column (1) of Table 5.1. Reference prices used to convert to proportional changes: 6.88, 8.38, 8.33, 7.43, 10.22, and 15.10 SEK/litre for transitions 1–6 respectively.

effect of −1.576 SEK/L reversing a substantial portion of the mandate-induced price premium. The ongoing negative demand response at H2 2024 reflects the partial adjustment dynamics of the ECM: with $|\hat{\lambda}| = 0.344$, only approximately one-third of the remaining disequilibrium is corrected each year, implying that the full demand recovery extends beyond the sample window. The peak-to-H2-2024 recovery of 2.51 percentage points also implies that the rollback generated a meaningful demand stimulus, which partly offsets the emissions reductions accumulated during the escalation phase; this dynamic is discussed further in Section 7.

Table 5.3: Cumulative Demand Response by Half-Year Period (%)

Period	Contribution of each price shock (%)						$D(T)$
	$\Delta\hat{\beta}_1$ 19.3%	$\Delta\hat{\beta}_2$ 20%	$\Delta\hat{\beta}_3$ 21%	$\Delta\hat{\beta}_4$ 26%	$\Delta\hat{\beta}_5$ 30.5%	$\Delta\hat{\beta}_6$ Rollback	
H2 2018	0.000	—	—	—	—	—	0.000
H1 2019	0.000	0.098	—	—	—	—	0.098
H2 2019	0.000	0.140	—	—	—	—	0.140
H1 2020	0.000	0.175	−0.301	—	—	—	−0.126
H2 2020	0.000	0.203	−0.432	—	—	—	−0.229
H1 2021	0.000	0.226	−0.538	—	—	—	−0.313
H2 2021	0.000	0.244	−0.624	—	—	—	−0.380
H1 2022	0.000	0.259	−0.694	−1.465	−1.012	—	−2.912
H2 2022	0.000	0.271	−0.751	−1.857	−1.453	—	−3.790
H1 2023	0.000	0.281	−0.796	−2.174	−1.811	—	−4.501
H2 2023	**0.000**	**0.289**	**−0.833**	**−2.431**	**−2.101**	—	**−5.077**
H1 2024	0.000	0.295	−0.863	−2.639	−2.335	2.340	−3.203
H2 2024	0.000	0.300	−0.888	−2.807	−2.525	3.362	−2.558

Notes: Each cell reports $C(T - s_k)$ from equation (4.8), the cumulative percentage demand change at period T attributable to shock k arriving at s_k. Dashes indicate periods prior to the relevant shock. $D(T) = \sum_{k:\, s_k \leq T} C(T - s_k)$ is the total cumulative response (rightmost column). Incremental price shocks are first differences of the FX-controlled regime coefficients in Table 5.1, converted to proportional changes using pre-window reference prices. Parameters: $\varepsilon_{SR} = -0.195$, $\varepsilon_{LR} = -0.321$, $\hat{\lambda} = -0.344$; full pass-through ($\theta = 1$), $f = 0.5$. The 19.3% shock ($\Delta\hat{\beta}_1 \approx 0$) is statistically insignificant and contributes zero throughout.

6. Welfare Analysis

This section combines the price-effect estimates from Section 5.1 and the demand responses from Section 5.3 with the framework of Section 3 to quantify the welfare consequences of the Reduktionsplikt over its mandate phase (H2 2018–H2 2023). Detailed derivations are provided in the Appendix D. Inputs are the FX-controlled regime coefficients $\hat{\beta}(t)$ (Table 5.1) and the half-year demand responses $D(t)$ (Table 5.3). Swedish road diesel consumption is from Statens energimyndighet (2026b). The counterfactual emissions baseline is set at 6 percent, corresponding to Denmark's blending obligation and the EU RED minimum, so that ΔCO_2^{tech} captures reductions attributable to Sweden's mandate above the floor that EU law would have imposed regardless. The choice of baseline is as mentioned discussed in Section 7.3. Under mandate accounting, qualifying biofuels are assigned zero lifecycle emissions, so the technology-channel saving per mandated litre equals the full fossil emissions factor $EF_{diesel} = 2.68$ kg CO_2e/L.

Table 6.1: Consumer Surplus, Emissions, and Net Welfare by Half-Year Period ($\theta = 1$, SCC = 1,510 SEK/t)

Period	ΔP (SEK/L)	$\lvert\Delta Q\rvert$ (Ml)	$\Delta CS(t)$ (MSEK)	ΔCO_2^{pc} (kt)	ΔCO_2^{tech} (kt)	Climate benefit (MSEK)	$NW(t)$ (MSEK)
H2 2018	0.000	0.0	0.0	0.0	864.5	1,305.5	1,305.5
H1 2019	−0.084	2.5	212.3	5.3	948.7	1,440.6	1,652.9
H2 2019	−0.084	3.5	212.2	7.6	948.3	1,443.4	1,655.6
H1 2020	0.173	3.0	−417.3	6.4	970.2	1,474.8	1,057.5
H2 2020	0.173	5.5	−417.5	11.7	971.2	1,484.3	1,066.8
H1 2021	0.173	7.8	−430.2	16.5	1,001.3	1,536.9	1,106.7
H2 2021	0.852	9.5	−2,120.0	19.0	1,280.3	1,961.9	− 158.0
H1 2022	2.049	69.9	−4,847.8	130.1	1,576.4	2,576.9	−2,270.9
H2 2022	2.049	91.8	−4,870.3	171.0	1,590.8	2,660.4	−2,209.9
H1 2023	2.049	105.0	−4,679.9	195.6	1,534.2	2,612.0	−2,068.0
H2 2023	2.049	119.3	−4,694.5	222.2	1,543.5	2,666.2	−2,028.4
Total			**−22,053**	**785.5**	**13,230**	**21,163**	**−890**

$\Delta P(t) = \hat{\beta}(t)$ from Table 5.1 (FX-controlled specification). H2 2021 uses a weighted average ($\frac{1}{6} \times 0.173 + \frac{5}{6} \times 0.988 = 0.852$) reflecting the August 2021 mandate change partway through the period. The 19.3 % mandate coefficient is statistically insignificant and set to zero. $\lvert\Delta Q\rvert$ is the demand reduction implied by Table 5.3. Under $\theta = 1$ all mandate cost is passed through to consumers, so $\Delta PS = 0$. ΔCO_2^{tech} is the incremental mandate reduction above the 6 % EU-minimum baseline applied to counterfactual consumption, valued at $EF_{diesel} = 2.68$ kg CO_2e/L. ΔCO_2^{pc} uses the blend emissions factor $(1 - \alpha_t) \cdot EF_{diesel}$. Climate benefit = 1,510 × $(\Delta CO_2^{pc} + \Delta CO_2^{tech})$/1,000 in MSEK. $NW(t)$ follows equation (3.11).

Table 6.1 reports period-by-period surplus flows, climate benefits, and net welfare under full pass-through ($\theta = 1$) at the Swedish carbon tax SCC of 1,510 SEK/tonne. During the initial mandate windows (H2 2018–H2 2019), the price premium is either statistically indistinguishable from zero or marginally negative, so consumers experience no surplus loss and the 20 % regime generates a small consumer gain of 212 MSEK per half-year. Net welfare over this period is strongly positive at 1,306–1,656 MSEK per half-year, driven almost entirely by technology-channel reductions of approximately 950 kt CO_2e per period. The 21 % mandate window (H1 2020–H1 2021) introduces a 0.173 SEK/L premium and consumer surplus losses of 417–430 MSEK per half-year, but these remain well outweighed by climate benefits of 1,475–1,537 MSEK, leaving net welfare positive at 1,067–1,107 MSEK per period. The welfare turning point occurs in H2 2021, the transition half-year in which the August 2021 mandate increase to 26 % takes effect for five of the six months: the resulting weighted-average premium of 0.852 SEK/L generates consumer surplus losses of 2,120 MSEK that for the first time exceed the climate benefit of 1,962 MSEK, yielding net welfare of −158 MSEK. From H1 2022 onward, under the full 2.049 SEK/L premium coinciding with the peak of the European energy crisis, consumer surplus losses reach 4,577–4,870 MSEK per half-year against climate benefits of 2,663–2,666 MSEK, with net welfare ranging from −2,028 to −2,271 MSEK per period and a cumulative loss of −8,577 MSEK over the four half-years of the 30.5 % mandate window. Over the full mandate phase, aggregate net welfare is −890 MSEK at the Swedish carbon tax, reflecting the sharp contrast between Phases 1–2 (+7,845 MSEK combined) and Phases 3–4 (−8,735 MSEK combined). The mandate was welfare-enhancing during its early, low-premium phase and welfare-reducing once blending shares and biofuel prices rose simultaneously in 2021–2022.

Table 6.2 reports aggregate emissions reductions and abatement costs. Under full pass-through, the price channel accounts for 785.5 kt CO_2e and the technology channel for 13,230 kt CO_2e, totalling 14,015 kt CO_2e over the mandate phase. The technology channel thus generates approximately 94 % of total emissions reductions, underscoring that the Reduktionsplikt operated primarily through biofuel blending rather than price-induced demand compression. This share should be interpreted with caution: to the extent that above-6 % blending would have occurred absent the escalating mandate, the true incremental share attributable to the policy may be lower.

The total abatement cost AC_{total} is approximately invariant to pass-through, ranging from 1,574 to 1,588 SEK/tonne, since the combined surplus loss $|\Delta CS| + |\Delta PS|$ is nearly constant across θ. The welfare verdict depends critically on the choice of SCC. The break-even SCC, at which aggregate net welfare is exactly zero, equals $AC_{total} \approx 1{,}574$ SEK/tonne. The Swedish carbon tax of 1,510 SEK/tonne lies marginally below this threshold, yielding net welfare of −890 to −1,071 MSEK across pass-through assumptions. The Rennert et al. (2022) SCC of 2,000 SEK/tonne lies well above it, yielding robustly positive net welfare of +5,691 to +5,977 MSEK. The Nordhaus (2017) SCC of 450 SEK/tonne implies net welfare of approximately −15,746 MSEK, since it falls far below the mandate abatement cost. The qualitative conclusion, that the welfare sign depends heavily on whether the social cost of carbon exceeds 1,574 SEK/tonne, is robust to the pass-through assumption, since AC_{total} varies by only 14 SEK/tonne across θ.

Table 6.2: Emissions Reductions, Abatement Costs, and Net Welfare

	$\theta = 1.0$	$\theta = 0.9$	$\theta = 0.8$
Emissions reductions (kt $CO_2 e$)			
Price channel (ΔCO_2^{pc})	786	704	623
Technology channel (ΔCO_2^{tech})	13,230	13,202	13,175
Total	14,015	13,906	13,799
Surplus changes (MSEK)			
ΔCS	−22,053	−19,810	−17,576
ΔPS	0	−2,165	−4,330
$\Delta CS + \Delta PS$	−22,053	−21,976	−21,906
Abatement costs (SEK/tonne $CO_2 e$)			
$AC_{consumer}$	1,574	1,425	1,274
$AC_{producer}$	0	156	314
AC_{total}	1,574	1,580	1,588
Net welfare: SCC $\times$ total emissions + ($\Delta CS + \Delta PS$) (MSEK)			
Swedish carbon tax (2025), 1,510 SEK/t	−890	−977	−1,071
Rennert et al. (2022), 2,000 SEK/t	+5,977	+5,837	+5,691
Nordhaus (2017), 450 SEK/t	−15,746	−15,718	−15,697

ΔCO_2^{tech} is evaluated relative to a 6 % EU-minimum counterfactual baseline under mandate accounting ($EF_{bio} = 0$, $EF_{diesel} = 2.68$ kg CO_2e/L). ΔCO_2^{pc} uses the blend emissions factor $(1 - \alpha_t) \cdot EF_{diesel}$. The break-even SCC equals $AC_{total} \approx 1{,}574$ SEK/tonne; any SCC above (below) this threshold implies positive (negative) net welfare. The deadweight loss triangle is embedded within $\Delta CS + \Delta PS$ and is not reported separately.

Two additional sensitity checks can be found in Appendix D. First, even though the elasticity result lies within the literature bound, we want to assess the sensitivity of the abatement cost to these results. Thus we recalculate AC_{total} using alternative elasticity values from the literature and finds very similar abatement costs. Second, a separate sensitivity check shows that the counterfactual blending baseline matters substantially. The baseline leaves the estimated price channel and surplus losses unchanged, but determines how much technology-channel abatement is attributed to the Reduktionsplikt. The most informative alternatives are 0 percent, representing no blending, and 17 percent, approximating the reduction level implied by Sweden's pre-treatment renewable diesel use under the previous tax-exemption system.[1] Table D.1 shows that moving from a 0 to a 17 percent baseline reduces attributed emissions reductions from 18.3 to 6.1 Mt CO_2e and raises AC_{total} from 1,203 to 3,608 SEK/tCO_2e. We nevertheless use 6 percent as our preferred counterfactual. We return to this assumption in Section 7.3.

[1] Figure 2.1 shows that Sweden already had substantial renewable diesel use before the Reduktionsplikt, with roughly 5 percentage points FAME and the remainder mainly HVO. A fossil share of 0.783 implies approximately 21.7 percent renewable blending. Using illustrative lifecycle savings of 71 percent for FAME and 92 percent for HVO, as in Drivkraft Sverige (2023), gives a reduction of roughly 16–18 percent. We therefore use 17 percent as a midpoint sensitivity case.

7. Discussion

The following discussion aims to interpret the welfare results, situate them in the broader policy context, and discuss the assumptions and limitations that bound them. We begin by assessing the results from the welfare analysis of the Reduktionsplikt over its mandate trajectory, before turning to the political economy of its rollback, the unresolved question of how much the energy crisis contributed to its high late-phase costs, and the broader implications for biofuel policy design.

7.1 Interpreting Results and Cost Effectiveness

The welfare results reveal a policy that was not uniformly costly over time. In the early mandate phase (2018–2020), emissions reductions came almost entirely through the technical substitution channel — as intended — while the estimated price premium was close to zero. Climate benefits therefore accrued without a corresponding loss of consumer or producer surplus, and the policy appeared efficient.

From 2021 onward, the picture changes as the unintended price channel becomes more pronounced. The estimated diesel price premium rose from 0.173 SEK/litre at the 21 percent mandate to 0.988 SEK/litre at the 26 percent mandate and 2.049 SEK/litre during the 30.5 percent mandate of 2022–2023, coinciding with the surge in HVO100 and B100 retail prices visible in Figure 2.2. These estimates align closely with those of Konjunkturinstitutet (2023b) and C. Andersson and Thorell (2024), who find no detectable price effect at the 2018 introduction and estimate increases of approximately 0.7 and 1.2 SEK/litre at the 2021 and 2022 mandate steps.[1] Since both our short-run and long-run elasticity estimates are well below one in absolute terms, diesel demand can, as expected, be characterised as rather inelastic. This helps explain why the consumer-surplus loss becomes large while the forgone consumption[2] remains relatively smaller. Many diesel consumers have limited scope to adjust their consumption in response to higher prices, and therefore continue consuming diesel at a higher cost rather than exiting the market. As the price premium rose, the consumer-surplus loss grew large enough to dominate the estimated climate benefit. H2 2021 therefore marks the welfare turning point beyond which the policy becomes welfare-negative, and net welfare over the full mandate phase is slightly negative at the Swedish carbon-tax benchmark.

Considering the full mandate phase, the total abatement cost under full pass-through is estimated to be 1,574 SEK/tCO_2e, marginally above the Swedish carbon-tax benchmark of 1,510 SEK/tCO_2. Since the carbon tax represents Sweden's explicit policy price on fossil carbon, the average abatement cost of the Reduktionsplikt was broadly in line with what Swedish society has determined a tonne of CO_2 costs. Compared with international estimates this appears relatively low. Gillingham and Stock (2018) report substantially higher costs for some low-carbon fuel standards, and Hansson et al. (2023) find that diesel-compatible biofuel pathways in Sweden can reach costs well above our estimate. It is also worth noting that achieving equivalent emissions reductions through higher fuel taxation rather than a mandate would likely have required very high pump prices. Riksrevisionen (2023) report that such a scenario could imply pump prices of around 42 SEK/litre for both gasoline and diesel.

[1] Minor differences likely reflect different treatment of transition windows.

[2] Generally referred to as the DWL triangle.

The central interpretation is that a reduction obligation is not inherently costly. Its welfare cost depends on the price of the renewable fuels required for compliance, and therefore on market conditions at the time the mandate is in force. This is consistent with the international literature. Lundberg et al. (2023) find that the welfare effects of blending mandates are context-dependent, driven by market conditions rather than mandate levels alone. Korting et al. (2019) show that tight mandates can concentrate welfare costs on consumers when blending constraints limit compliance flexibility, a mechanism directly relevant to the large consumer surplus losses estimated at the 26 and 30.5 percent mandate levels. Lapan and Moschini (2012) show that combining mandates with fuel taxes can be welfare-enhancing, suggesting that the welfare outcome of the Reduktionsplikt depended not only on the mandate level but on the broader policy design within which it operated.

This favourable average comparison should nonetheless be interpreted with care. The abatement cost exceeded both the carbon-tax benchmark and several SCC estimates during the high-mandate period, meaning the policy was not uniformly defensible across its mandate trajectory. A policy can be defensible in average cost-per-tonne terms while still becoming politically fragile if costs are concentrated in a short period and clearly visible to consumers. Few prices are more salient to households and firms than fuel prices, and the concentrated cost exposure during 2022–2023 arguably mattered more for the political durability of the Reduktionsplikt than the average cost over the full mandate phase.

7.2 Political Economy and Policy Durability

The welfare results provide a plausible political-economy interpretation of why the Reduktionsplikt was scaled back despite an average abatement cost broadly in line with relevant benchmarks. Political feasibility depends not only on the average cost over the full mandate period, but on who pays, when they pay, and how visible the cost is at the time of the political decision. The politically decisive period was maybe not the cheap phase of 2018–2020 but the high-cost phase of 2021–2023, when the diesel price premium became large and appeared directly at the pump.

The distributional incidence of this cost matters. Much of the estimated welfare cost takes the form of consumer surplus losses, and although we do not estimate distributional incidence directly, the burden is unlikely to have been experienced evenly. It was probably most salient for inelastic groups with high diesel dependence and weak substitution possibilities, like long-distance commuters, freight operators, farmers, and rural households where higher diesel prices are tied to work, location, and everyday mobility rather than being a marginal consumption cost. For these groups, a price increase functions less as an incentive and more as a penalty. This distributional pattern plausibly explains the urban-rural dimension of the political debate. Political support for the mandate was concentrated among parties with stronger urban voter bases, where diesel dependence is lower and alternatives to car use are more available, while opposition was strongest among groups with limited substitution possibilities and high cost exposure (Konjunkturinstitutet, 2023a; Larsson et al., 2020). This does not reduce opposition to the Reduktionsplikt to material self-interest, nor does it mean that all rural voters were affected in the same way, but it suggests that distributional exposure made the policy easier to criticise and harder to sustain. Climate policy is not evaluated only by aggregate cost-effectiveness. It also has to be perceived as fair by the groups asked to carry the most visible costs.

The timing of the backlash reinforces this interpretation. The major political turn against the Reduktionsplikt followed the 2022 energy crisis and the sharp increase in fuel prices accompanying Russia's invasion of Ukraine, at which point lower fuel prices had become an explicit political objective. This suggests the policy was not scaled back primarily because it was judged inefficient on welfare grounds, but because it became politically associated with a broader fuel-price crisis. The distinction is difficult to communicate publicly: voters observe the pump price rather than its decomposition between fossil diesel costs, HVO premia, taxes, and exchange-rate movements. The broader energy-price shock was widely attributed to international disruptions beyond domestic control, but perhaps the Reduktionsplikt offered politicians a concrete and actionable domestic lever. Possibly, the lowering of the mandate therefore became a visible way to respond to fuel-price concerns, even though the underlying price increase reflected international market conditions that domestic policy could only partially address.

A related point is that the Reduktionsplikt is harder to defend politically than a tax-based instrument in one specific respect. A carbon or fuel tax also raises consumer prices and would clearly have faced major political resistance at the levels needed to replace the Reduktionsplikt. The difference though, is that a tax generates public revenue that can, at least in principle, be recycled, used to compensate affected households, or fund other climate measures. The Reduktionsplikt raises costs through mandated input substitution instead. The higher price paid by consumers is not collected by the state, but reflects higher compliance costs in the fuel supply chain. This gave the policy the political visibility of a fuel-price increase, but with fewer direct fiscal tools for compensation.

Finally, it is worth noting that the 2030 transport target provides an additional lens through which to evaluate the policy. By increasing the renewable share in diesel, the Reduktionsplikt reduced measured lifecycle emissions from the existing vehicle fleet without requiring immediate changes in vehicles, infrastructure, or transport behaviour. Scenario analyses suggest that a higher Reduktionsplikt was central to Sweden's ability to reach the 2030 target, and the rollback has made that target harder to meet (Klimatpolitiska rådet, 2024). At the same time, the policy looks strongest as a bridge instrument: effective for near-term compliance, but not a substitute for the deeper structural transition toward electrification and reduced transport demand that a near-zero-emission transport system ultimately requires.

7.3 Validity of the Welfare Estimates

Abatement cost is conventionally defined as the expense incurred by a firm to prevent a given unit of emissions (Phaneuf & Requate, 2016). Our measure departs from this definition by treating the total loss in consumer and producer surplus per tonne of CO_2 reduced as the relevant cost concept. In concrete terms, this captures two things. How much more consumers paid for diesel relative to the counterfactual over the mandate period, and the value of the consumption they foregone as a result of higher prices. The departure from the conventional definition is warranted by the institutional structure of the Reduktionsplikt. Because the mandate raises marginal input costs rather than imposing a direct compliance charge, and because pass-through is high (inelastic consumers), the economic burden does not rest with distributors but is transmitted to consumers through higher wot prices. Measuring only the direct compliance cost would therefore understate the true social burden (Parry et al., 1999). This approach is consistent with Lapan and Moschini (2012), who analyse biofuel policy in a second-best welfare framework and show that mandates affect both the fuel mix and overall fuel-use incentives, supporting the treatment of the Reduktionsplikt as a policy with welfare consequences through the price channel rather than merely a technical emissions instrument. Our welfare analysis is therefore essentially a cost-benefit analysis: we ask whether the economic cost borne by consumers and producers per tonne of CO_2 reduced exceeded the social value of that reduction.

Any cost-benefit evaluation of a climate policy ultimately rests on how society values a tonne of CO_2 reduced. We use the Swedish carbon tax as our primary benchmark since it represents the explicit price Sweden has placed on fossil carbon emissions and is therefore the most coherent reference point for evaluating a domestic climate instrument. However, the welfare conclusion is sensitive to this choice. Using the social cost of carbon instead introduces substantial uncertainty: Nordhaus (2017) and Rennert et al. (2022) arrive at estimates that differ by an order of magnitude, driven primarily by different assumptions about the discount rate. A reader who accepts the higher valuation would conclude that the Reduktionsplikt generated net welfare gains over the mandate period, while a reader who follows Nordhaus would conclude that even the early low-cost phase was difficult to justify on welfare grounds. In addition, it ought to be mentioned that recent SCC estimations often are even higher than the value proposed by Rennert et al. (2022). The sensitivity of the conclusion to the carbon valuation is not a weakness of our analysis but a reflection of a genuine and unresolved disagreement in the literature, and we report net welfare across multiple benchmarks precisely to make this dependence transparent.

A related assumption is that the redistribution of surplus from fossil fuel producers toward biofuel producers and feedstock suppliers carries no additional social cost or benefit beyond what is captured in prices and emissions. This is not necessarily correct. Fossil fuel production may be associated with other negative externalities beyond carbon emissions, including local pollution and labour-related costs, so a shift toward biofuel production could reduce some of these effects. At the same time, biofuel and feedstock production carries its own externalities, including land-use pressure and supply-chain impacts. The direction of the net effect is therefore ambiguous, and we make no adjustment for it. To the extent that these externalities are material, our welfare measure captures an incomplete picture of the true social cost of the policy.

Several further assumptions underlying our emissions and price-effect estimates warrant discussion. Not all of them point in the same direction, and we assess each in turn.

Approximately 94 percent of our estimated emissions reductions are attributed to the technical substitution channel, making the welfare results highly sensitive to the assumed counterfactual blending level. A zero-blending counterfactual is not reasonable. EU legislation implied a non-zero minimum level of renewable fuel use, and the political landscape made some form of continued biofuel policy likely regardless of the Reduktionsplikt. We therefore set the counterfactual at 6 percent, corresponding to the EU Renewable Energy Directive minimum, and broadly consistent with Danish blending practice, noting that a 6 percent reduction requirement corresponds to approximately 7.4 percent volumetric blending (C. Andersson & Thorell, 2024; International Energy Agency, n.d.). This choice is also consistent with Sweden's own decision to roll back to 6 percent following the energy crisis (Regeringen, 2023c). The benchmark is not without limitations. As Figure 2.1 shows, Sweden already maintained substantial biofuel blending before 2018, suggesting the counterfactual may be somewhat low. The political economy also suggests that Sweden might have pursued an alternative biofuel policy implying higher blending than Denmark even without the Reduktionsplikt, given the broad initial parliamentary support for the instrument (Regeringen, 2017). Nonetheless, any attempt to specify such a path becomes highly speculative, and we retain a 6 percent reduction level as a transparent and policy-relevant low-blending benchmark. The sensitivity check in Appendix D confirms that this assumption is not minor. Changing the counterfactual baseline leaves the price channel cost largely unchanged, but substantially changes the amount of technical substitution abatement attributed to the mandate. The 6 percent baseline should therefore be interpreted as a policy-relevant low-blending counterfactual rather than a neutral estimate of what would certainly have happened absent the Reduktionsplikt. Hence, our welfare results should be interpreted as conditional on this counterfactual choice. If Sweden would have maintained substantially higher blending absent the mandate, the true incremental technical substitution effect would be smaller and the abatement cost higher than reported. It also ought to be mentioned, that a different reduction mandate counterfactual, likely would have resulted in a different price premium.

Our emissions reduction estimates also rely on two assumptions about how the mandate translates into actual reductions. First, we assume that fuel suppliers comply with the mandate exactly, blending sufficient renewable fuel to meet the required reduction level but no more. From a profit-maximising perspective this is reasonable. Non-compliance fees exceed the marginal cost of blending, while over-compliance is costly when biofuel prices are high. The sharp drop in blending coinciding with the 2024 rollback is consistent with suppliers tracking the mandate closely. In the early phase, when biofuel prices were close to those of fossil diesel, some over-compliance is more plausible, which would imply a slight understatement of emissions reductions for that period. The net effect is ambiguous and likely small. Second, we assume that the lifecycle emissions factors applied by Swedish authorities to different biofuel types correctly reflect their true climate impact. This is a consequential assumption. Lifecycle emissions are highly sensitive to feedstock origin, production pathway, and land-use effects, and the regulatory framework for calculating them has evolved considerably over time (Searchinger et al., 2008). Earlier periods may therefore have been less precisely accounted for than more recent ones. Errors could run in either direction. Overly generous emissions factors would mean our estimated reductions are overstated, while overly conservative factors would mean they are understated. Systematic bias seems unlikely given that assessments are conducted by professionals under an increasingly detailed framework (Riksrevisionen, 2023), but inaccuracies at particular points in time cannot be ruled out. On balance, this assumption is unlikely to introduce a consistent directional bias into our estimates, but it adds uncertainty around the true magnitude of the emissions reductions attributed to the technical substitution channel.

A further identification concern is whether the Reduktionsplikt itself affected Danish diesel prices through its effect on northwest European biofuel markets. If Swedish demand for HVO and FAME was large enough to tighten regional supply and raise Danish input costs, the Danish price series would partially absorb the Swedish price premium, causing our difference-in-differences estimates to understate the true mandate-induced cost. Sajtos (2025) suggest that such spillovers are not unlikely given the scale of Swedish biofuel demand relative to regional markets. Nevertheless, a violation of this kind would strengthen rather than weaken our central interpretation: the true abatement cost would be higher than reported, since higher Danish prices would compress the estimated Sweden–Denmark price gap and make the observed Swedish premium appear smaller.

Exchange-rate movements point in a similar direction. As discussed in Section 4.2, the gradual depreciation of the SEK against the DKK mechanically raises the Danish comparison price when expressed in SEK, compressing the Sweden–Denmark price gap. This suggests that our estimated mandate-induced price premium is likely conservative. At the same time, the weaker krona may also have increased the realised Swedish cost of compliance, since fossil diesel and biofuel components are traded internationally and the Reduktionsplikt increased Sweden's exposure to biofuel components, especially HVO, during the high-mandate years. However, this is not necessarily a confounder to be removed. Our welfare analysis evaluates the realised cost of the policy under the market and currency conditions that actually prevailed. To the extent that the mechanical conversion effect dominates in the DiD comparison, the price channel, the associated demand response, and the abatement cost attributable to the price channel are understated. Since the technical substitution channel accounts for most of the total emissions reductions, this does not change the central welfare interpretation, but it implies that the price-channel costs for this reason should be read as a lower-bound estimate.

A further assumption concerns the mapping from prices without taxes to consumer-facing pump prices. In the welfare analysis, we assume that the mandate-induced premium estimated in prices without taxes is the same premium consumers face at the pump under full pass-through, holding all tax components fixed.[3] This ceteris paribus assumption also means that contemporaneous tax changes, such as the 2022 fuel-tax reduction, are treated as separate policy decisions that would have occurred also in the counterfactual without the Reduktionsplikt. This may not fully hold. If the tax reduction was partly a response to higher fuel prices caused by the Reduktionsplikt, the effective consumer-facing price channel would be smaller than our estimates imply, and our demand response attributed to the mandate would be overstated. However, in that case part of the cost of the mandate would instead appear as lower government tax revenue, effectively shifting part of the burden from consumers to the state. Modelling such a policy-response counterfactual would be highly speculative, so we retain the simpler assumption that tax changes are exogenous to the mandate effect.

Finally, higher Swedish diesel prices may have induced some cross-border fueling in Denmark or Norway, displacing rather than reducing transport emissions. The effect is likely modest given that most diesel consumption occurs far from border crossings, but it would reduce actual emissions savings below our consumption-based estimates without affecting the surplus loss in the abatement cost ratio, pushing the true AC_{total} upward.

Taken together, the counterfactual blending level is the most consequential assumption and points toward our abatement cost estimates being a lower bound on the true welfare cost per tonne of CO_2e actually abated, since it may attribute too much of the emissions reduction to the Reduktionsplikt. Several identification issues related to the price channel point in the same direction. Potential spillovers to Danish biofuel costs and the gradual depreciation of the SEK may both compress the estimated Sweden–Denmark price gap, implying that the mandate-induced price premium, the price-channel demand response, and the corresponding abatement cost may be understated. The compliance, lifecycle accounting, and cross-border fueling are unlikely to introduce systematic bias in a consistent direction, but collectively add uncertainty around the true magnitude of the emissions reductions and surplus losses attributed to the policy. Our exact number should therefore be interpreted with caution, and the reported abatement costs should be read as conservative rather than precise point estimates.

7.4 The Mandate–Energy Crisis Interaction

A central limitation of our analysis is that we cannot cleanly separate two distinct mechanisms that both contributed to the high biofuel price premium observed during 2021–2023. The first is

[3] In principle, an increase in the price without taxes also increases VAT payments, since VAT is levied on the pre-VAT pump price. We do not add this VAT component to the welfare calculation, as doing so would require modelling the corresponding change in government revenue and would turn the analysis into a broader fiscal-incidence exercise.

the Reduktionsplikt itself. By requiring fuel suppliers to blend increasing volumes of HVO and FAME, the mandate raised Swedish demand for renewable diesel components. If supply is inelastic in the short run, this demand increase would push up biofuel prices, transmitting costs into Swedish diesel prices and ultimately into consumer surplus losses. Under this interpretation, the high welfare cost of the policy during 2022–2023 is at least partly endogenous to the mandate's own ambition. The second mechanism is tied to broader European energy price developments following events such as Covid-19 and more importantly Russia's invasion of Ukraine, which tightened fossil and renewable fuel markets simultaneously and raised HVO and FAME premia independently of Swedish policy. Under this interpretation, the Reduktionsplikt was an unlucky victim of external circumstances: it increased Sweden's exposure to biofuel input costs, so that an externally driven price shock transmitted more directly into Swedish diesel prices than into Danish prices, but the shock itself was not caused by the mandate. The depreciation of the SEK during the same period may have reinforced this mechanism, since internationally traded biofuel components became more expensive in SEK precisely when Sweden's required exposure to them was highest.

Technically, both mechanisms could have been present. The surge in HVO100 and B100 proxy prices visible in Figure 2.2 coincided with the broader energy-price spike, suggesting a strong external component.[4] At the same time, Sajtos (2025) note a correlation between the level of the Swedish mandate and the biofuel price premium, which is consistent with demand-driven price pressure. However, Sweden already had relatively high biofuel blending before the sharpest price increases without seeing the same dramatic cost response, which speaks against a purely mandate-driven explanation. Formally, separating the two contributions would require granular data on raw biofuel feedstock prices and supply-side capacity across European markets, which falls outside the scope of this paper.

This distinction matters substantially for the policy conclusion. If the high-cost phase was primarily driven by the energy crisis, the Reduktionsplikt may have been abandoned too early: Sweden scaled back the mandate at precisely the point when biofuel supply was beginning to expand and premia were likely to fall. The policy would then have suffered mainly from a timing problem rather than a fundamental structural flaw. In other words, a first-mover disadvantage in scaling up a mandate before the biofuel market had matured. Under this view, a more gradually escalating mandate with better-designed cost-containment provisions could have delivered the same emissions reductions at substantially lower welfare cost.

If instead the high prices reflected a structural constraint on the supply of sustainable biofuel feedstocks, the conclusion is more troubling. Blending mandates draw on the cheapest available feedstocks first. As ambition rises, producers must increasingly rely on more expensive inputs, more constrained feedstock categories, or more carbon-intensive production pathways, causing the marginal cost of compliance to rise with the mandate level. If this scalability ceiling is real, the Reduktionsplikt may have been approaching the limits of what biofuel blending can deliver as a climate instrument, with important implications for how the policy should be assessed and designed going forward.

[4] Figure 2.2 suggests that HVO100 began to decouple from blended diesel around the introduction of the Reduktionsplikt. This is consistent with tighter HVO-market conditions, but should be interpreted cautiously. HVO100 is only a proxy for the HVO blending component. Pure HVO used in blending is an internationally traded input, whereas HVO100 is a Swedish retail fuel product that also reflects distribution costs, retail margins, taxes, and product-specific demand. The figure therefore cannot by itself separate Swedish mandate-induced demand from broader international biofuel-market shocks.

7.5 Further Considerations

The scalability question points to a broader issue that our analysis cannot resolve: whether biofuel blending mandates are sustainable as a large-scale climate instrument, not just in Sweden, but globally. Sweden's diesel mandate was among the most ambitious in Europe, yet it remains far below what would be required for full transport decarbonisation. A key policy question is therefore what happens as ambition moves toward 50, 60, or near-100 percent fossil fuel replacement, consistent with the Paris Agreement and Sweden's net-zero target for 2045. At those levels, sustainable feedstock demand would rise sharply. If the EU or major economies adopted similar biofuel-based strategies at scale, demand would multiply many times over. Sweden's HVO supply relies heavily on waste and residue feedstocks such as used cooking oil and tall oil, which are globally limited by definition. Further scaling would likely require more crop-based inputs, increasing risks of land-use competition, deforestation, indirect land-use change, and food security pressures (Searchinger et al., 2008). Since the climate value of biofuels is highly sensitive to these effects, fuels that appear carbon-neutral under mandate-counting conventions may still carry substantial lifecycle emissions. Biofuels may therefore have a role in decarbonisation, but heavy reliance on blending as the primary pathway to net-zero transport possibly faces supply-side limits that become more binding as adoption becomes wider and more ambitious.

Electrification is widely regarded as the primary long-run pathway to near-zero transport emissions. Against this backdrop, the Reduktionsplikt can be evaluated either as a complement to electrification or as a potential substitute for it. A blending mandate can deliver near-term emissions reductions from the existing vehicle fleet while electrification gradually scales up, making it a useful bridge instrument during the transition. At the same time, a strong policy focus on fuel blending may reduce political urgency for the structural changes in vehicle fleets, charging infrastructure, and transport planning that complete decarbonisation ultimately requires. This tension is particularly relevant given that Sweden has recently recorded the lowest share of new electric vehicle registrations among the Nordic countries, raising questions about whether the availability of a biofuel compliance pathway has reduced pressure for faster fleet transition (International Energy Agency, 2025). Whether the Reduktionsplikt complemented or crowded out electrification cannot be determined from our data, but it is an important question for future research.

A high blending requirement reduces dependence on fossil diesel but increases exposure to imported biofuels and internationally traded feedstocks, shifting the type of supply risk rather than eliminating it. Sweden's experience in 2021–2023, when HVO premia rose sharply alongside broader energy-market stress, illustrates this vulnerability. The newer version of the policy, which allows compliance through electric credits linked to domestic renewable electricity, partially addresses this concern by reducing dependence on internationally traded liquid biofuels and linking compliance more directly to the long-run electrification pathway.

8. Conclusion

"Government investigator Svante Mandell argues that the Reduktionsplikt, currently at 10 percent may need to be increased. The electrification of the transport sector is moving too slow. [...] Everything indicates that the current level will not be enough to meet the climate target by 2030" — Omni (2026)

"Romina Pourmokhtari (L) believes that one of the most debated climate targets should be scrapped. [...] The target was to reduce emissions in the transport sector by 70 percent before 2030, but so far Sweden has only reduced emissions by 19 percent. [...] The Liberal Party calls out for an electrification target" — SVT (2026)

Ten years have passed since Sweden set up its ambitious climate goals, and this is where the Swedish pre-2026 election debate currently stands. A central question remains: *Can* the Reduktionsplikt, or some version of it, be a tool going forward — and should it be?

This paper provides a welfare-economic evaluation of the Swedish Reduktionsplikt for diesel during 2018–2024. While previous work has mainly examined the policy's effect on pump prices, our contribution is to connect the mandate-induced price premium to demand responses, emissions reductions, surplus losses, net welfare, and abatement costs. This distinction matters because higher fuel prices are not, in themselves, evidence that the policy was inefficient. The relevant question is whether the climate benefits generated by the mandate exceed the economic costs imposed on consumers and producers.

Our results show that the welfare effect of the Reduktionsplikt changed markedly over time. In the early mandate years, the diesel price premium was close to zero while higher renewable content generated sizeable emissions reductions, making the policy clearly welfare-positive with a low abatement cost. From 2021 onward, however, higher mandate levels and rising biofuel prices sharply increased the price premium, and from H2 2021 consumer surplus losses exceeded estimated climate benefits. Over H2 2018–H2 2023, we estimate total emissions reductions of approximately 14 Mt CO_2, about 94 percent of which came from technical substitution. The full-period abatement cost is estimated at 1,574 SEK per tonne of CO_2 under full pass-through, slightly above the Swedish carbon-tax benchmark of 1,510 SEK per tonne, implying modestly negative net welfare at this benchmark, around −890 MSEK, clearly positive welfare under Rennert's higher SCC estimate, and clearly negative welfare under Nordhaus. The central conclusion is therefore not that the Reduktionsplikt was simply efficient or inefficient, but that its cost-effectiveness depended strongly on mandate ambition, biofuel-market conditions, and timing. The early phase suggests that a reduction obligation can work as an effective bridge instrument when renewable fuel premia are low, while the high-mandate phase shows that the same instrument can become costly and politically fragile when compliance depends on expensive, internationally traded biofuel inputs. This helps explain the 2024 political reversal. Even if the average abatement cost was close to Sweden's explicit carbon price, the costs were concentrated in a short period, highly visible at the pump, and likely most salient for inelastic diesel-dependent households and firms with limited substitution possibilities.

Several features of our analysis caution against taking the exact estimates at face value. The counterfactual blending assumption is the most consequential. We argue that a 6 percent counterfactual is the most reasonable choice. But, as the technical substitution channel creates the majority of emission reductions, our abatement cost and net-welfare results can become either an upper or a lower bound depending on assumed counterfactual mandate. At the same time, exchange-rate movements and potential Danish biofuel-market spillovers may compress the estimated Sweden–Denmark price gap, implying that the price-channel cost is also likely conservative. We also cannot fully separate whether the high biofuel premium during 2021–2023 reflected mandate-induced demand, broader energy-market stress, or the weaker SEK, meaning the welfare cost during the high-mandate phase may partly reflect circumstances beyond the policy's design. Finally, our analysis is partial equilibrium and focuses exclusively on diesel, so it does not capture distributional effects across different groups of consumers, nor any interaction between the mandate and the broader transition toward electrification. The qualitative pattern across mandate phases is more robust than the exact figures.

The external validity of our results is conditional. Sweden is a useful case because it implemented one of Europe's most ambitious diesel reduction mandates and relied heavily on HVO, making it informative about the welfare consequences of high biofuel blending requirements. However, the results should not be directly transferred to other countries, periods in time, with different fuel-market structures, domestic biofuel supply, tax systems, vehicle fleets, or electrification trajectories. The broader lesson is that mandate policies are most likely to be cost-effective where sustainable biofuel supply is elastic, compliance pathways are flexible, and distributional exposure is limited. Where sustainable feedstocks are scarce and fuel consumers have few short-run substitutes, similar mandates may generate high and politically fragile welfare costs.

Gaps for future research remain. Some about the Reduktionsplikt itself, and some about biofuels in general. First, more granular data on HVO, FAME, and feedstock markets are needed to separate mandate-driven biofuel price effects from broader energy-crisis effects, and to assess whether sustainable biofuels can be scaled without rising costs, feedstock competition, indirect land-use change, or other sustainability concerns. Second, distributional impacts should be evaluated directly, especially across rural and urban households, freight operators, farmers, and other diesel-dependent groups. Third, future work should assess whether biofuel mandates complement or delay electrification, ideally in a general equilibrium framework that captures vehicle markets, charging infrastructure, tax interactions, and long-run transition incentives. The redesigned Reduktionsplikt, with electric credits alongside biofuel blending, may address some vulnerabilities by reducing dependence on volatile HVO and FAME premia and linking compliance more directly to electrification. Whether this is enough to make the policy cost-effective and politically durable remains an open question.

So: *Can* the Reduktionsplikt be a tool going forward — and should it be?

That question is ultimately for policy-makers to answer. What this paper attempts to provide is the welfare-economic evidence base on which such a decision can be more transparently informed.

This is our contribution.

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A. Calculating Prices without Taxes

We calculate the daily Swedish diesel price wot from Circle K's pump price by removing VAT and the effective energy and carbon tax in the blended fuel (Circle K Sweden, 2026; Skatteverket, 2024). This follows the product-price logic used in KI's fuel-price studies, where *produktpris* is defined as the pump price net of VAT and excise taxes (C. Andersson & Thorell, 2024; Konjunkturinstitutet, 2023b, 2023c; Sajtos, 2025). We use the actual blending shares and the historical tax treatment of fossil diesel, FAME, and HVO (2030-miljöbarometern, 2026a, 2026c; Skatteutskottet, 2017). Before the Reduktionsplikt, biogenic components were not always taxed in the same way as fossil diesel. After its introduction, low-blended fossil and biogenic components were taxed uniformly, implying full energy and carbon taxation of the blended fuel (Carlén & Hill, 2023; Sveriges riksdag, 2017).

$$P_t^{wot} = \frac{P_t^{CircleK}}{1 + VAT_t} - \sum_{i \in \{diesel, FAME, HVO\}} s_{i,t} \left(\alpha_{i,t}^{E} E_t + \alpha_{i,t}^{CO2} C_t \right), \tag{A.1}$$

where $P_t^{CircleK}$ is the daily pump price, VAT_t is the VAT rate, $s_{i,t}$ is the volume share of component i, E_t and C_t are the statutory energy and carbon tax rates, and $\alpha_{i,t}^{E}$ and $\alpha_{i,t}^{CO2}$ are the applicable tax shares. For example, if the blend is 92 percent fossil diesel and 8 percent FAME, and FAME is taxed at 16 percent of the relevant rate, we deduct the full tax on the fossil share and 16 percent of the tax on the FAME share.

For Denmark, Circle K Denmark reports daily prices excluding VAT and provides separate information on fuel excise duties, so we use the reported Danish product-price series directly (Circle K Danmark, 2026). We convert it into SEK using the daily exchange rate from Sveriges Riksbank (Sveriges riksbank, 2026).

B. Counterfactual Validation with Synthetic Control

To assess whether the Denmark-based comparison overlooks another plausible control country, we conduct a synthetic-control exercise. Synthetic control constructs a counterfactual for Sweden as a weighted average of donor countries, with weights chosen to match Sweden as closely as possible before treatment. The donor pool consists of Denmark, Austria, Spain, Latvia, France, Germany, Belgium, Poland, and Slovakia. For a technical discussion of the method, see Abadie et al. (2010).

The donor pool is restricted to European countries that are plausible comparators for Sweden in diesel-price formation. We include countries that are part of the broader European fuel market, have available weekly diesel prices wot in the European Commission's Oil Bulletin, and can be matched on structural predictors related to fuel demand and macroeconomic conditions. We also exclude countries whose fuel-market or biofuel-policy environments make them unsuitable as untreated or low-treatment comparators. This screening is informed by the cross-country overview of European biofuel policies in Lundberg et al. (2023). The donor pool is therefore not intended to represent all of Europe, but a set of countries that could plausibly have followed a similar pre-treatment diesel-price path to Sweden absent the Reduktionsplikt.

We use the method diagnostically rather than as a separate identification strategy. Since the Swedish Reduktionsplikt changed several times, and other European countries also experienced fuel-tax, blending-rule, or climate-policy changes, a full synthetic-control design would be difficult to interpret as a clean causal design. The narrower purpose is to examine whether a data-driven donor pool identifies a more convincing control country than Denmark in the pre-treatment period.

The outcome variable is the weekly diesel price excluding taxes from January 2015 to July 2018. The matching variables include lagged pre-treatment diesel prices and structural predictors: GDP per capita, passenger cars per 1,000 inhabitants, diesel consumption per capita, urbanisation, and renewable energy in transport. Diesel prices wot are taken from the European Commission's Oil Bulletin (European Commission, 2024).[1] Urbanisation and population data are taken from the World Bank (World Bank, 2026a, 2026b), and the remaining structural predictors from Eurostat (Eurostat, 2026a, 2026b, 2026c). We estimate three versions: a main specification with structural predictors and lagged prices, a price-only specification, and a specification excluding Denmark from the donor pool.

Figure B.1 plots the pre-treatment diesel price series for Sweden and the donor countries. Visually, Sweden and Denmark follow each other more closely than other countries in the donor pool, both in levels and in short-run movements. This is important because the synthetic-control exercise is not only about matching average prices, but about matching the pre-treatment price path. The synthetic-control weights in Table B.1 are consistent with this visual pattern: Denmark receives a weight of 0.884, Austria receives almost all remaining weight, and all other countries receive zero. The main and price-only specifications give almost identical weights, suggesting that the match is mainly driven by the close pre-treatment price relationship between Sweden and Denmark.

[1] For Sweden, we use the same price series as in the main specification, converted to euros. This is because we identified a small inconsistency in the Weekly Oil Bulletin data related to the tax treatment of biofuel components. There is no indication that similar issues affect the other countries' price series during this period.

When Denmark is excluded, Spain receives the full donor weight. However, as shown in Figure B.4, the pre-treatment fit worsens. This suggests that Spain is the best available substitute once Denmark is removed, not an equally strong counterfactual. Overall, the exercise does not reveal a more convincing alternative control country, supporting the use of Denmark as the main comparison country in the DiD analysis.

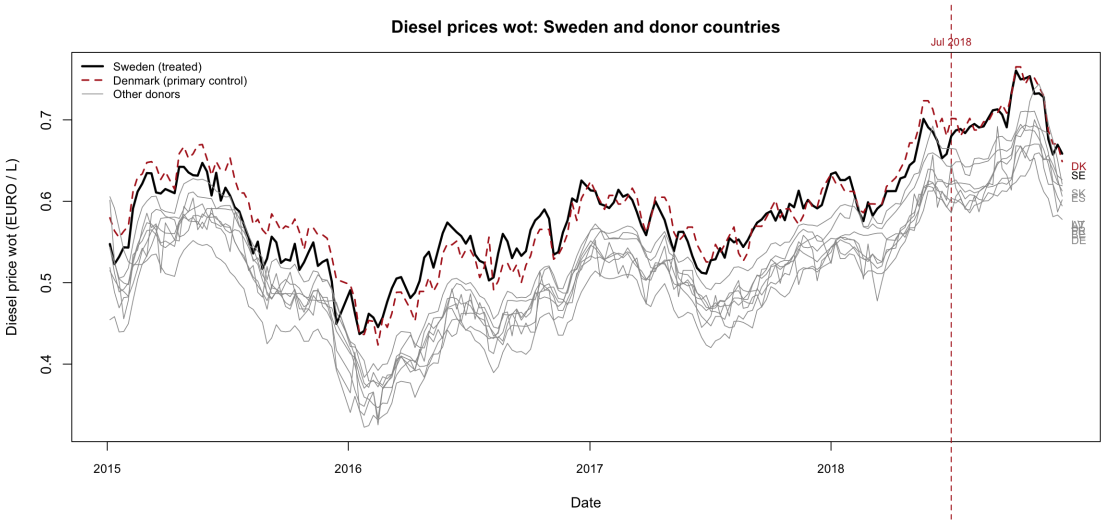

Figure B.1: Pre-treatment diesel prices excluding taxes for Sweden and the synthetic-control donor pool

Table B.1: Synthetic Control Donor Weights Across Specifications

	Full donor pool		No Denmark
Country	Main	Price only	Main
Austria (AT)	0.116	0.115	0.000
Belgium (BE)	0.000	0.000	0.000
Germany (DE)	0.000	0.000	0.000
Denmark (DK)	**0.884**	**0.884**	—
Spain (ES)	0.000	0.000	1.000
France (FR)	0.000	0.000	0.000
Latvia (LV)	0.000	0.000	0.000
Poland (PL)	0.000	0.000	0.000
Slovakia (SK)	0.000	0.000	0.000

Notes: Donor weights from the synthetic-control estimator (Abadie et al., 2010). The treated unit is Sweden. The pre-treatment window is 2015W1–2018W26. The main specification uses structural predictors and lagged pre-treatment prices. The price-only specification omits the structural predictors. The no-Denmark column re-estimates the main specification with Denmark excluded from the donor pool.

Table B.2: Donor Pool Characteristics: Pre-Treatment Price and Structural Predictors

Country	Mean price (wot)	GDP p.c. (euro)	Cars per 1,000	Diesel cons. p.c. (L)	EV share (%)
SE	**0.57**	**47,180**	**479**	**457.7**	**26.84**
DK	**0.58**	**51,060**	**438**	**561.0**	**6.93**
AT	0.51	41,760	555	855.9	9.70
BE	0.50	38,990	509	672.1	6.64
DE	0.50	40,630	561	485.3	7.03
ES	0.53	25,150	529	574.2	5.80
FR	0.47	34,290	569	623.6	8.77
LV	0.51	13,410	356	454.6	2.27
PL	0.50	12,360	507	425.4	4.23
SK	0.52	15,610	408	410.6	6.95

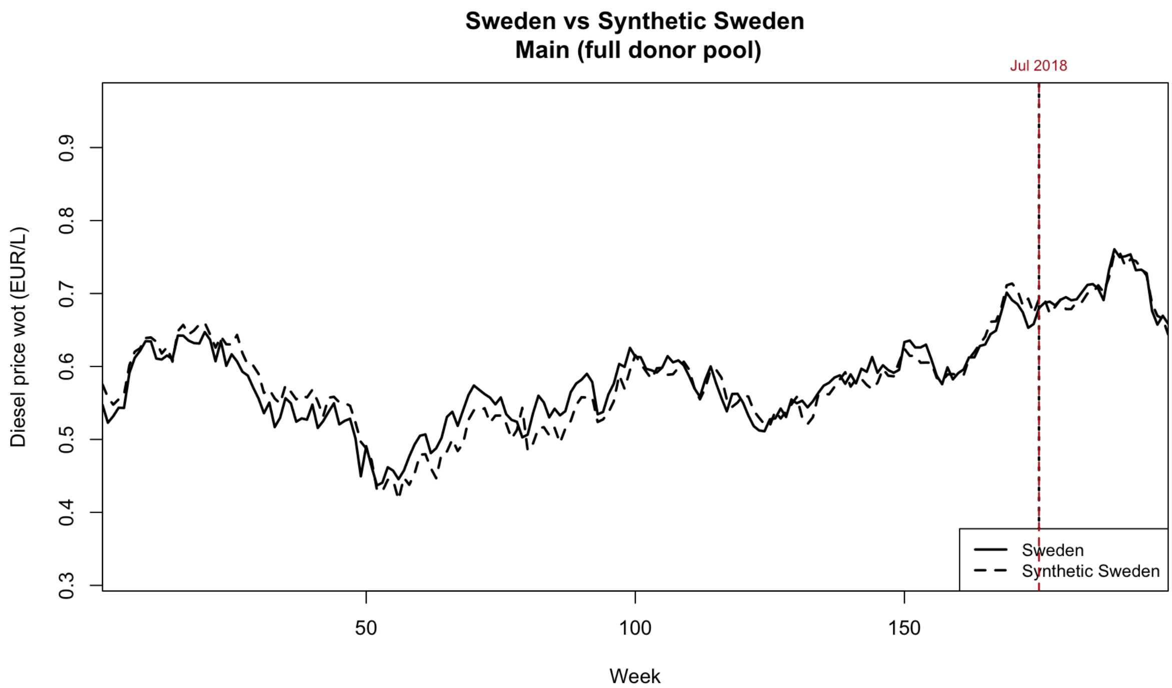

Figure B.2: Sweden and synthetic Sweden using the full donor pool. MSPE = 1.2774.

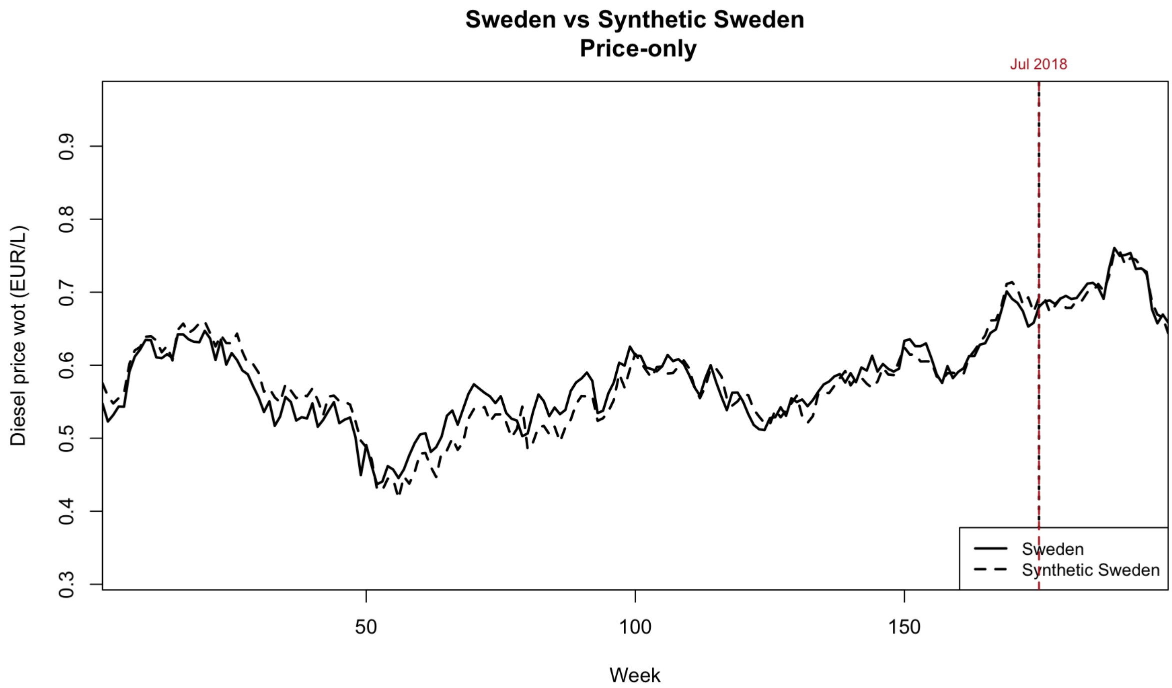

Figure B.3: Sweden and synthetic Sweden, only using price as a predictor. MSPE= 0.2501.

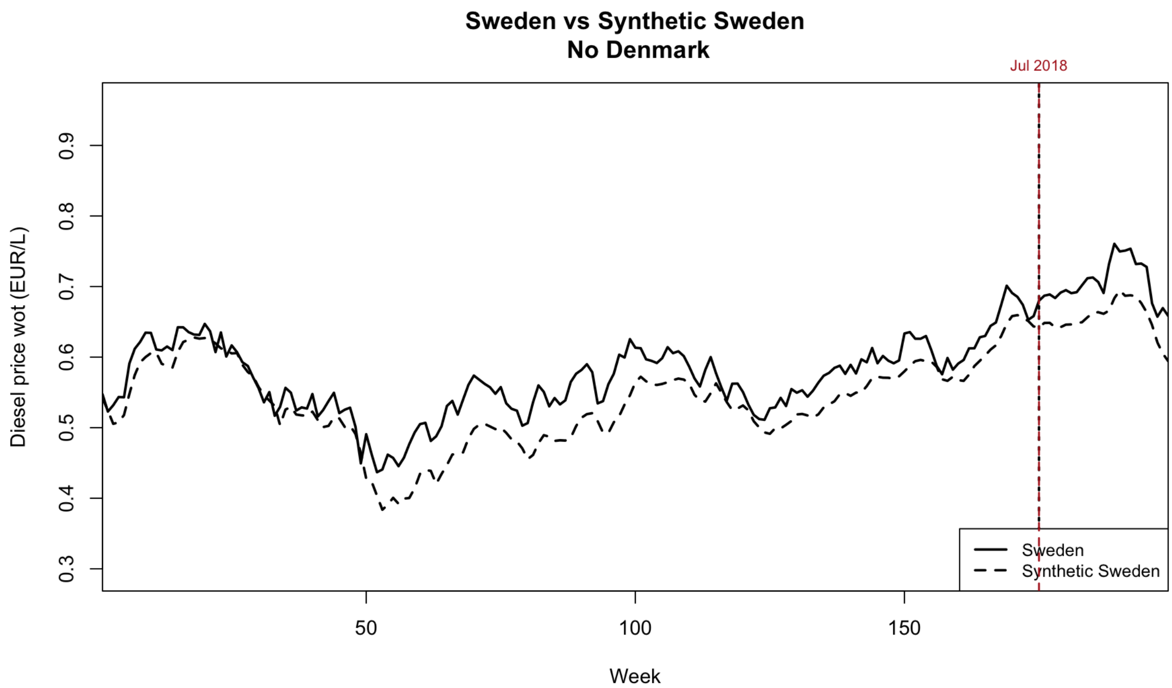

Figure B.4: Sweden and synthetic Sweden when Denmark is excluded from the donor pool. The weaker pre-treatment fit indicates that the best available substitute after removing Denmark is not an equally strong counterfactual. MSPE = 2.7139

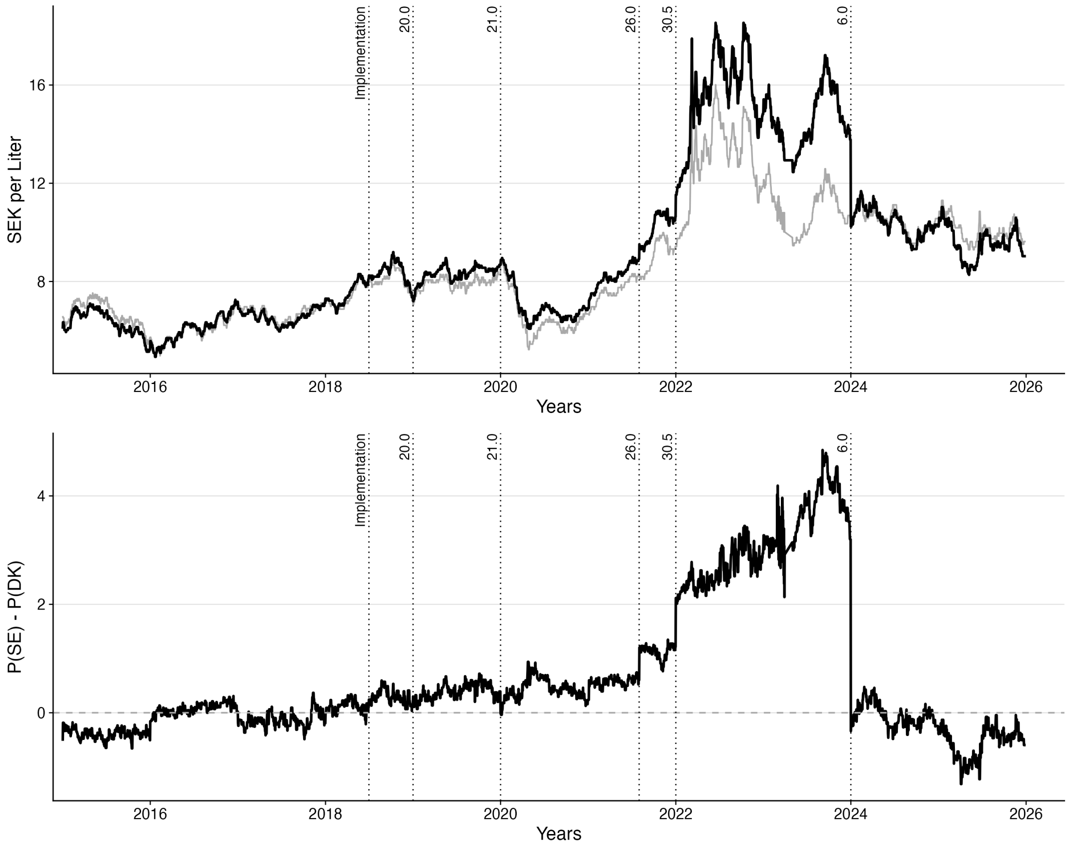

Figure B.5: Sweden-Denmark Prices, Flat FX

Source: Authors' rendering of price data from Circle K Danmark (2026) and Circle K Sweden (2026) using the mean exchange rate over the time period from Sveriges riksbank (2026).

We do not use the flat-exchange-rate series as our baseline because it answers a different counterfactual question: what the price gap would have looked like under a constant exchange rate, rather than what the realised Swedish price premium was under the currency conditions that actually prevailed.

C. Complementary Empirical Results

Table C.1: Pre-Treatment Linear Trend Test

	(1) Without FX control		(2) With FX control	
	Estimate	Std. Error	Estimate	Std. Error
Intercept	0.4037***	0.01936	2.8473***	0.67653
t (days)	−0.000252***	0.0000624	0.000166	0.00014
FX rate (SEK/DKK)			−1.9407***	0.53705
N	546		546	

Sample: Jan 2017 – Jun 2018 (pre-mandate baseline). Dependent variable: daily SE–DK pre-tax diesel price gap (SEK/L). H_0: $\beta_t = 0$ (no drift). HAC standard errors (Newey–West). Significance: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table C.2: Placebo Tests: False Treatment Dates within the Pre-Mandate Period

	(1) Without FX control			(2) With FX control		
Placebo date	Estimate	Std. Err.	p-value	Estimate	Std. Err.	p-value
Apr 2017	−0.0833	0.0215	0.0001***	−0.0232	0.0256	0.3660
May 2017	−0.0613	0.0236	0.0096**	0.0041	0.0276	0.8806
Jun 2017	−0.0629	0.0228	0.0060**	−0.0030	0.0271	0.9113
Jul 2017	−0.0226	0.0250	0.3669	0.0451	0.0281	0.1082
Aug 2017	−0.0259	0.0240	0.2813	0.0524	0.0297	0.0785·
Sep 2017	−0.0434	0.0240	0.0708·	0.0460	0.0346	0.1846
Oct 2017	−0.0521	0.0242	0.0317*	0.0639	0.0474	0.1777
Nov 2017	−0.0318	0.0255	0.2141	0.1844	0.0421	0.0000***
Dec 2017	−0.0713	0.0243	0.0035**	0.0682	0.0473	0.1500
Jan 2018	−0.0539	0.0263	0.0406*	0.1115	0.0386	0.0040**
Feb 2018	−0.1050	0.0226	0.0000***	−0.0060	0.0435	0.8901
Mar 2018	−0.1225	0.0231	0.0000***	−0.0394	0.0489	0.4205
Significant ($p < 0.05$)		7 of 12			2 of 12	

Note: Each row assigns a false treatment date within the pre-mandate period (Jan 2017 – Jun 2018) and re-estimates the post-indicator coefficient from the regime-decomposition specification. HAC standard errors (Newey–West). Significance codes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.10$.

Table C.3: Augmented Dickey–Fuller Test on the Pre-Treatment SE–DK Price Gap

Sample	Lags	ADF statistic	p-value
Jan 2017 – Jun 2018 (baseline)	8	−4.184	0.010
Jan 2015 – Jun 2018 (extended)	10	−3.513	0.041

Note: H_0: the pre-treatment price gap has a unit root. Lag order selected by the ADF procedure.

Table C.4: Event Study: SE–DK Price Gap Around the July 2018 Implementation

	(1) Without FX control				(2) With FX control			
Bin k	Estimate	Std. Err.	t-stat	p-value	Estimate	Std. Err.	t-stat	p-value
$k = -7$	0.164 468	0.025 721	6.3944	0.0000	0.015 861	0.087 441	0.1814	0.8561
$k = -6$	0.199 208	0.026 803	7.4322	0.0000	0.041 709	0.092 350	0.4516	0.6516
$k = -5$	0.087 052	0.037 943	2.2943	0.0219	−0.035 517	0.078 716	−0.4512	0.6519
$k = -4$	0.166 540	0.028 674	5.8081	0.0000	0.017 380	0.088 305	0.1968	0.8440
$k = -3$	0.122 421	0.047 150	2.5964	0.0095	0.020 606	0.072 677	0.2835	0.7768
$k = -2$	0.179 559	0.032 250	5.5678	0.0000	0.109 999	0.048 078	2.2879	0.0222
$k = 0$	0.139 043	0.022 222	6.2571	0.0000	0.151 824	0.026 457	5.7385	0.0000
$k = 1$	0.123 353	0.026 721	4.6163	0.0000	0.117 005	0.028 952	4.0414	0.0001
$k = 2$	0.057 337	0.031 621	1.8133	0.0699	0.067 890	0.030 121	2.2539	0.0243
$k = 3$	0.061 276	0.028 837	2.1249	0.0337	0.110 496	0.038 965	2.8358	0.0046
$k = 4$	0.090 137	0.024 184	3.7271	0.0002	0.147 720	0.041 578	3.5528	0.0004
$k = 5$	0.077 363	0.025 827	2.9954	0.0028	0.135 706	0.042 764	3.1734	0.0015
$k = 6$	−0.061 575	0.044 125	−1.3955	0.1630	−0.016 531	0.046 608	−0.3547	0.7229
$k = 7$	0.260 495	0.078 733	3.3086	0.0010	0.331 605	0.070 452	4.7068	0.0000
$k = 8$	0.309 690	0.032 452	9.5432	0.0000	0.315 379	0.035 055	8.9966	0.0000
$k = 9$	0.241 736	0.022 232	10.8735	0.0000	0.242 664	0.023 951	10.1319	0.0000
$k = 10$	0.472 807	0.048 410	9.7666	0.0000	0.430 680	0.054 510	7.9009	0.0000
$k = 11$	0.546 021	0.023 243	23.4915	0.0000	0.512 784	0.031 058	16.5105	0.0000
$k = 12$	0.838 517	0.079 772	10.5115	0.0000	0.814 150	0.081 988	9.9301	0.0000
$k = 13$	1.139 872	0.027 305	41.7456	0.0000	1.097 827	0.037 433	29.3281	0.0000
$k = 14$	1.835 891	0.113 939	16.1130	0.0000	1.859 154	0.122 384	15.1911	0.0000
$k = 15$	2.155 938	0.056 099	38.4313	0.0000	2.175 005	0.055 792	38.9841	0.0000
$k = 16$	1.882 305	0.063 026	29.8658	0.0000	1.945 458	0.069 516	27.9857	0.0000
FX rate (SEK/DKK)		—			−1.446 761	0.808 096	−1.7903	0.0736
Intercept	0.208 736	0.020 167	10.3506	0.0000	2.216 064	1.121 739	1.9756	0.0483
Joint pre-trend F-test (H_0: all $k \le -2$ coefficients = 0)								
$F_{6,\cdot}$		9.03 ($p < 0.001$)				3.15 ($p = 0.004$)		

Note: 90-day bins relative to the July 2018 treatment date. Reference bin: $k = -1$. The outcome is the daily SE–DK pre-tax diesel price gap (SEK/L). HAC standard errors (Newey–West). Column (1) is the *secondary* specification; column (2) with FX control is the *primary* specification (see Section 5.1).

Table C.5: ADF Unit-Root Tests on Variables Used in the Demand Elasticity Estimation

Variable	Levels	First differences	
	ADF stat	ADF stat	Decision
$\ln(Q_{\text{diesel}})$	−1.311	−3.672	I(1)
$\ln(P_{\text{diesel}})$	−2.879	−4.524	I(1)
$\ln(P_{\text{gasoline}})$	−3.484	−4.036	I(1)
$\ln(\text{GDP}_{pc})$	−2.619	−3.080	I(1)
5% critical value (levels, with trend)	−3.45		
5% critical value (differences, drift)		−2.93	

Note: Annual Swedish data, 1980–2024. Lag order = 3 throughout. Levels regressions include a deterministic trend; first-difference regressions include a drift term. H_0: the series has a unit root. A series is classified I(1) if the null cannot be rejected in levels but is rejected in first differences. $\ln(P_{\text{gasoline}})$ is borderline in levels (−3.484 vs. critical value −3.45); a supplementary KPSS test on the first difference (level = 0.084, $p > 0.10$) corroborates the I(1) classification.

Table C.6: Total Cumulative Demand Response under Alternative Pass-Through Assumptions (%)

Period	$\theta = 1.0$	$\theta = 0.9$	$\theta = 0.8$
H2 2018	0.000	0.000	0.000
H1 2019	0.098	0.088	0.078
H2 2019	0.140	0.126	0.112
H1 2020	−0.126	−0.113	−0.101
H2 2020	−0.229	−0.206	−0.183
H1 2021	−0.313	−0.281	−0.250
H2 2021	−0.380	−0.342	−0.304
H1 2022	−2.912	−2.621	−2.330
H2 2022	−3.790	−3.411	−3.032
H1 2023	−4.501	−4.051	−3.601
H2 2023	−5.077	−4.569	−4.061
H1 2024	−3.203	−2.883	−2.562
H2 2024	−2.558	−2.303	−2.047

Note: $D(T) = \sum_{k:\, s_k \leq T} C^{(k)}_{T-s_k}$ evaluated at the start of each half-year period T under three pass-through assumptions θ. ECM parameters: $\varepsilon_{SR} = -0.195$, $\varepsilon_{LR} = -0.321$, $\hat{\lambda} = -0.344$, $f = 0.5$.

D. Welfare Analysis Sensitivity

All period-level flows in Table 6.1 follow directly from the framework in Section 3. The inputs are the FX-controlled regime coefficients $\hat{\beta}(t)$ (Table 5.1), the half-year demand responses $D(t)$ (Table 5.3), and observed half-year consumption Q_t^{obs}. Counterfactual consumption is recovered by inverting the demand response:

$$Q_0^t = \frac{Q_t^{obs}}{1 + D(t)/100}. \tag{D.1}$$

Setting $\Delta P_t = \hat{\beta}(t)$ and $|\Delta Q_t| = \theta \cdot |D(t)/100| \cdot Q_0^t$, equations (3.8) and (3.9) yield $\Delta CS_t(\theta)$ and $\Delta PS_t(\theta)$ directly. At $\theta = 1$, $\Delta PS_t = 0$. The price- and technology-channel reductions follow from equations (3.5) and (3.4):

$$\Delta CO_2^{pc}(t) = |\Delta Q_t| \cdot EF(\alpha_t) = |\Delta Q_t| \cdot (1 - \alpha_t) \cdot EF_{diesel}, \tag{D.2}$$

$$\Delta CO_2^{tech}(t) = (\alpha_t - \bar{\alpha}) \cdot Q_0^t \cdot EF_{diesel}, \tag{D.3}$$

where $EF_{diesel} = 2.68$ kg CO_2e/L and under mandate accounting $EF(\alpha_t) = (1 - \alpha_t) \cdot EF_{diesel}$ from equation (3.3), and $\bar{\alpha} = 0.06$ is the EU-minimum counterfactual baseline. Period-level net welfare and aggregate abatement cost follow equations (3.11) and (3.12), summing over $t =$ H2 2018 to H2 2023.

Table D.1: Sensitivity of Emissions Reductions, Abatement Costs, and Net Welfare to the Counterfactual Blending Baseline ($\theta = 1$)

	Counterfactual reduction baseline		
	0%	6%	17%
Emissions reductions (kt CO_2e)			
Price channel	786	786	786
Technology channel	17,540	13,230	5,327
Total	18,325	14,015	6,113
Surplus changes (MSEK)			
ΔCS	−22,053	−22,053	−22,053
ΔPS	0	0	0
Abatement cost (SEK/tCO_2e)			
AC_{total}	1,203	1,574	3,608
Net welfare (MSEK)			
Swedish carbon tax (1,510 SEK/t)	+5,618	−890	−12,823
Rennert et al. (2,000 SEK/t)	+14,598	+5,977	−9,827
Nordhaus (450 SEK/t)	−13,807	−15,746	−19,302

Note: Full pass-through ($\theta = 1$) throughout. The price channel, surplus changes, and abatement cost numerator are invariant to the counterfactual baseline; only the technological substitution channel changes.

Table D.2: Sensitivity to Price Elasticity, Panel A: Period Flows ($\theta = 1$, SCC = 1,510 SEK/t)

Period	D_t (%)	$\Delta CS(t)$[a](MSEK)	ΔCO_2^{pc}[b](kt)	ΔCO_2^{tech}[c](kt)
Aklilu (2020): ε_{SR}=−0.158, ε_{LR}=−0.421, $\hat{\lambda}$=−0.374				
H2 2018	0.00	0.0	0.0	864.5
H1 2019	0.08	212.4	4.3	948.9
H2 2019	0.15	212.1	8.2	948.2
H1 2020	−0.04	−417.1	1.9	969.4
H2 2020	−0.21	−417.5	10.8	971.1
H1 2021	−0.35	−430.3	18.5	1001.7
H2 2021	−0.46	−2120.8	23.0	1281.3
H1 2022	−2.90	−4847.5	129.6	1576.2
H2 2022	−4.35	−4884.9	197.6	1600.2
H1 2023	−5.50	−4705.5	242.1	1550.6
H2 2023	**-6.42**	**-4729.1**	**284.9**	**1565.6**
Labandeira et al. (2017): ε_{SR}=−0.153, ε_{LR}=−0.443, $\hat{\lambda}$=−0.344[d]				
H2 2018	0.00	0.0	0.0	864.5
H1 2019	0.08	212.4	4.2	948.9
H2 2019	0.15	212.1	7.9	948.2
H1 2020	−0.03	−417.1	1.7	969.3
H2 2020	−0.20	−417.4	10.3	971.0
H1 2021	−0.34	−430.3	17.9	1001.6
H2 2021	−0.45	−2120.7	22.5	1281.2
H1 2022	−2.82	−4845.6	126.1	1575.0
H2 2022	−4.26	−4882.5	193.2	1598.6
H1 2023	−5.42	−4703.5	238.4	1549.2
H2 2023	**-6.37**	**-4727.8**	**282.6**	**1564.8**
Brännlund (2013): ε_{SR}=−0.170, ε_{LR}=−0.400, $\hat{\lambda}$=−0.610				
H2 2018	0.00	0.0	0.0	864.5
H1 2019	0.09	212.3	4.6	948.8
H2 2019	0.20	212.0	11.0	947.7
H1 2020	0.02	−416.9	0.8	968.9
H2 2020	−0.30	−417.7	15.5	972.0
H1 2021	−0.50	−430.6	26.5	1003.2
H2 2021	−0.63	−2122.6	31.4	1283.5
H1 2022	−3.64	−4866.4	164.0	1588.4
H2 2022	−5.79	−4923.1	267.0	1624.6
H1 2023	−7.14	−4748.1	319.5	1577.8
H2 2023	**-7.98**	**-4770.5**	**360.3**	**1592.2**

[a] $\Delta CS(t)$ is positive in H1–H2 2019 because the biofuel price premium is negative in those periods. Under $\theta = 1$ all mandate cost is passed through to consumers, so $\Delta PS = 0$.

[b] ΔCO_2^{pc}: price-induced emission reduction (kt CO_2e), derived from $|\Delta Q|$ and the blend emissions factor $(1 - \alpha_t) \cdot EF_{diesel}$, where $EF_{diesel} = 2.68$ kg CO_2e/L.

[c] ΔCO_2^{tech}: incremental mandate reduction above the 6% EU-minimum baseline applied to counterfactual consumption, valued at $EF_{diesel} = 2.68$ kg CO_2e/L. Bold row = H2 2023.

[d] Meta-analysis; no ECM adjustment speed reported. Preferred $\hat{\lambda} = -0.344$ retained throughout.

Table D.3: Half-year Elasticity Sensitivity, Panel B: Cumulative Welfare Stocks ($\theta = 1$, SCC = 1,510 SEK/t)

Period	Cum. $\Delta CS(t)$ (MSEK)	Cum. ΔCO_2[a](kt)	NW[b](MSEK)	AC[c](SEK/t)
Aklilu (2020): ε_{SR}=−0.158, ε_{LR}=−0.421, $\hat{\lambda}$=−0.374				
H2 2018	0	865	1305	—
H1 2019	212	1818	2957	117
H2 2019	425	2774	4613	153
H1 2020	7	3745	5663	2
H2 2020	−410	4727	6728	87
H1 2021	−840	5747	7838	146
H2 2021	−2961	7052	7687	420
H1 2022	−7809	8758	5415	892
H2 2022	−12 694	10 556	3245	1203
H1 2023	−17 399	12 348	1247	1409
H2 2023	**-22128**	**14199**	**-688**	**1558**
Labandeira et al. (2017): ε_{SR}=−0.153, ε_{LR}=−0.443, $\hat{\lambda}$=−0.344[d]				
H2 2018	0	865	1305	—
H1 2019	212	1818	2957	117
H2 2019	425	2774	4613	153
H1 2020	7	3745	5662	2
H2 2020	−410	4726	6726	87
H1 2021	−840	5746	7836	146
H2 2021	−2961	7049	7683	420
H1 2022	−7807	8750	5406	892
H2 2022	−12 689	10 542	3230	1204
H1 2023	−17 393	12 330	1225	1411
H2 2023	**-22120**	**14177**	**-713**	**1560**
Brännlund (2013): ε_{SR}=−0.170, ε_{LR}=−0.400, $\hat{\lambda}$=−0.610				
H2 2018	0	865	1305	—
H1 2019	212	1818	2957	117
H2 2019	424	2777	4617	153
H1 2020	7	3746	5664	2
H2 2020	−410	4734	6738	87
H1 2021	−841	5764	7862	146
H2 2021	−2964	7078	7725	419
H1 2022	−7830	8831	5505	887
H2 2022	−12 753	10 722	3438	1189
H1 2023	−17 501	12 620	1555	1387
H2 2023	**-22272**	**14572**	**-268**	**1528**

[a] Cumulative $\Delta CO_2^{pc} + \Delta CO_2^{tech}$ (kt CO_2e). Bold row = H2 2023.
[b] NW = SCC×Cum. ΔCO_2/1,000+Cum. $\Delta CS(t)$, evaluated at SEK 1,510/tCO_2e; follows equation (3.11).
[c] Running abatement cost: $|\text{Cum.}\,\Delta CS(t)|\,/\,\text{Cum.}\,\Delta CO_2 \times 1{,}000$. Undefined in H2 2018.
[d] Meta-analysis; no ECM adjustment speed reported. Preferred $\hat{\lambda} = -0.344$ retained (see Table 5.2).