Institute of Transport Economics
Norwegian Centre for Transport Research

Road Tolls in Norway, 2005-2021

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1903/2022

Title:	Road Tolls in Norway, 2005-2021
Tittel:	Bompenger i Norge, 2005-2021
Author:	Øystein Sand, Bjørn Gjerde Johansen, Askill Harkjerr Halse, Svein Olav Sæther
Date:	08.2022
TØI Report:	1903/2022
Pages:	44
ISSN Electronic:	2535-5104
ISBN Electronic:	978-82-480-1955-8
Project Number:	5173, NFR 267942, NFR 302059, NFR 326814
Funded by:	The Research Council of Norway, The Norwegian Public Roads Administration
Project:	5173 – Bomtakster i Norge
Project Manager:	Bjørn Gjerde Johansen
Quality Manager:	Kjell Werner Johansen
Research Area:	Economic Analysis
Keywords:	Cordon tolls, Electric vehicle incentives, Infrastructure, Road toll

Summary

This report contains (1) an historical account of road toll collection in Norway and (2) a documentation of a dataset with historical toll gates, rates and regulations in the period 2005-2021. A complete dataset of this kind has not been available until now. We focus particularly on the toll cordons in the four largest urban areas, but the data set also contains toll rates in all remaining toll gates. The data show that both the number of toll gates and the toll level have increased over time. In recent years, the discount for electric vehicles and other zero-emission vehicles has been reduced. Detailed historical data of this kind can be used to study a number of transport economic issues, for instance related to travel demand, Pigouvian taxation, electric vehicle incentives and distributional effects. We encourage those who are interested to use the data and contact us if you notice any errors or irregularities.

Kort sammendrag

Denne rapporten inneholder (1) en historisk oversikt over bompengeinnkreving i Norge og (2) en dokumentasjon av et datasett med historiske bomstasjoner, takster og takstregler for perioden 2005-2021. Et komplett datasett av denne typen har ikke vært tilgjengelig tidligere. Vi fokuserer særlig på bomringene i de fire største byområdene, men datasettet inneholder også takster i de øvrige bomstasjonene. Dataene viser at både antallet bomstasjoner og takstnivået har økt over tid. De siste årene har rabatten for elbiler og andre nullutslipps-biler også blitt redusert. Detaljerte historiske data av denne typen kan brukes til å studere en rekke transportøkonomiske problemstillinger knyttet til for eksempel reiseetterspørsel, avgiftspolitikk, elbilfordeler og fordelingsvirkninger. Vi oppfordrer de som er interesserte til å ta dataene i bruk og ta kontakt dersom dere oppdager feil eller mangler.

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Preface

This report gives an historical account of road toll collection in Norway and a documentation of a detailed historical dataset of road tolls. The report and dataset is based on work conducted as part of the projects *Driving towards the low emission society*, *Transport, inequality and political opposition (TRIPOP),* and *Capacity after lockdown. A transport system for the future (CAPSLOCK),* funded by the Research Council of Norway (grant number 267942, 302059 and 326814, respectively). We have also received funding from the National Public Roads Administration for completing and documenting the dataset.

Research assistant Øystein Sand has collected and organized the data described in Chapter 3 under supervision by senior research economist Bjørn Gjerde Johansen and chief research economist Askill Harkjerr Halse at the Institute of Transport Economics (TØI). Research assistant Svein Olav Sæther has made additions and corrections to the data, including adding information about changes in toll rates during the fall of 2021. Johansen has been responsible for the data described in Chapter 5. Sand, Johansen and Halse have written the report.

For helping us in gathering the data, we are grateful to Jan Kristian Jensen, Kristian Hella Bauge, Nina Lysfjord and James Odeck at the National Public Roads Administration as well as the following representatives from the toll companies: Håkon Nordahl at Fjellinjen, Marius Maske at Vegamot and Marit Husa at Ferde. We are also grateful to Philipp Conzett at UiT The Arctic University of Norway for helping us in publishing the data at DataverseNO.

Research Director Kjell W. Johansen at TØI has been responsible for internal quality assessment of the report. Trude Kvalsvik has prepared the report for publication.

Oslo, August 2022
Institute of Transport Economics

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Director of Research

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This report describes a dataset established to document road tolls in Norway for the years 2005-2021. To our knowledge, it represents the most complete overview of historical road tolls in Norway to date. We will update the dataset when we become aware of errors or shortcomings. The data can be downloaded from DataverseNO, a research data repository provided by UIT The Arctic University of Norway. It can be accessed by the following link:

https://doi.org/10.18710/M2D2XP

Background and purpose

Toll revenues in Norway has increased from around 3 billion NOK annually in 2005 to around 11 billion NOK in 2018, constituting 18-19 percent of the revenue from car-related taxes and fees (Fridstrøm, 2020). As such, road tolls is an increasingly important policy instrument for financing transport infrastructure as well as for regulating traffic. The battery electric vehicle (BEV) exemption that lasted until 2018, and the reduced rates for BEVs from 2018 and onwards are also considered important tools for promoting the transition towards a zero-emission car fleet (Halse et al, 2022).

Shedding light on how road toll exposure has varied historically over time and across the population should be of general interest to policymakers. Moreover, the fact that road tolls provide cross-sectional variation in the monetary cost of driving (as well as variation over time) is useful for several empirical applications, such as estimating the value of travel time. However, a complete historical dataset of this kind has not been available until now.

This report serves two purposes: First, as a description and a historic overview of road toll policies in Norway. Second, as a documentation of a panel dataset consisting of all toll gates and toll cordons. The dataset contains coordinates for toll gates, changes in rates over time as well as other special regulations.

Development in road tolls over time

The development from 2005 and onwards is documented in Chapter 4. Figure S1 illustrates where toll gates were located at the end of our data period, December 31st 2021. We describe in detail the developments for the four major urban areas of Norway: Oslo, Bergen, Trondheim and Nord-Jæren (the Stavanger area). The remaining toll gates in Norway are also briefly described.

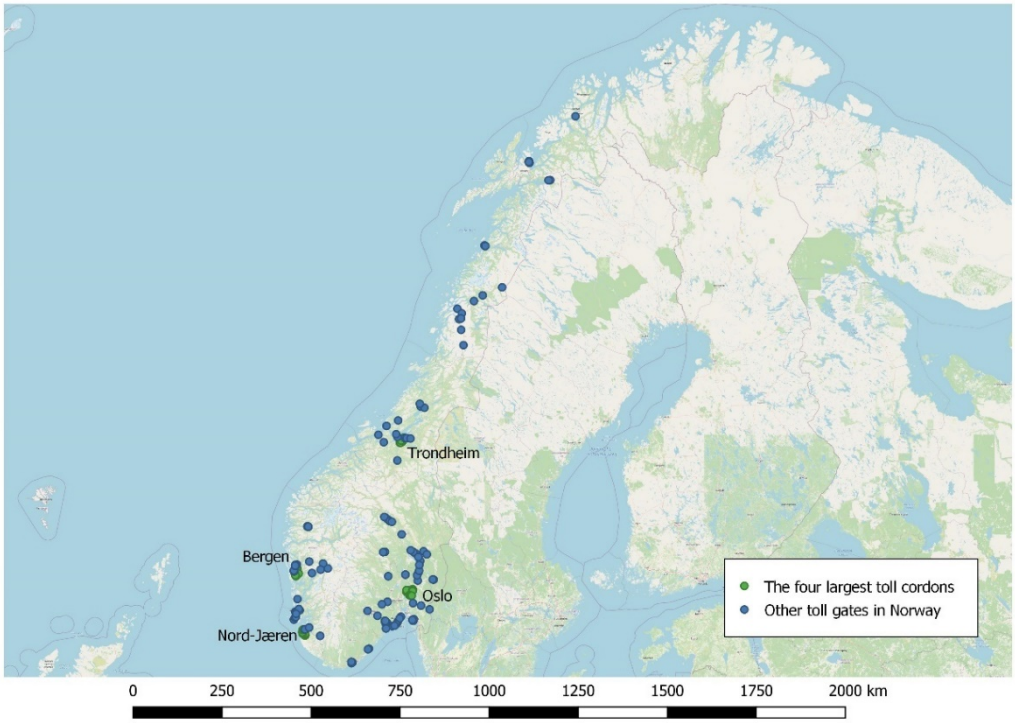

Figure S1: The four largest toll cordons and remaining toll gates in Norway, 2021.

Overall, the number of toll gates has increased significantly, but the average rate per toll gate outside urban areas have been fairly constant. This is in part because collection ceased on some of the more expensive toll gates, since the projects the road tolls were earmarked for were completely financed (e.g. *Rennfast*, *Krifast*, *Imarsundet*, *Eiksundsambandet*, *Finnfast* and *Atlanterhavstunnelen*). Several of the new toll gates are also part of toll cordons around smaller cities, where the rates typically are lower. When it comes to the four largest cities, the trend is that toll rates have increased, the toll cordons have been expanded with new sections, and all cities have implemented congestion charges; i.e., rates that are higher during rush hours. However, the congestion charge in Nord-Jæren was discontinued on February 10th 2020.

In Chapter 5 we also describe how this information can be used to construct a data set consisting of road toll expenses on trips between combinations of neighborhoods ("*grunnkretser*") in Norway. We do this by matching toll gates to a road network, and calculating the fastest route along the network between each neighbourhood pair. By linking this to employer-employee micro data that includes information on residence and workplace locations for the whole Norwegian population, we can characterize how road toll exposure on the commute varies across household types and geographical areas over time.

Note that this will not correspond to actual toll payments, but give an intention-to-treat measure of toll exposure: How much one would be required to pay if travelling to work with an internal combustion engine vehicle along the fastest route every day. According to this measure, the average daily toll exposure on the commute in Norway has increased from 4.4 NOK in 2005 to 19.8 NOK in 2019. The share of working households exposed to tolls on their commutes was 28 percent in 2005 and 44 percent in 2019. The development over time is displayed in Figure S2, where toll exposure is averaged across working individuals within each neighborhood.

Figure S2: Daily toll exposure (NOK) on work commute by year and neighborhood of residence.

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Sammendrag

Bompenger i Norge, 2005-2021

TØI rapport 1903/2022 • Forfattere: Øystein Sand, Bjørn Gjerde Johansen, Askill Harkjerr Halse, Svein Olav Sæther • Oslo, 2022 • 44 sider

Denne rapporten beskriver et datasett som dokumenterer bompenger i Norge for perioden 2005-2021. Datasettet utgjør så vidt vi vet den mest komplette historiske oversikten over bomtakster i Norge som er tilgjengelig. Vi vil prøve å holde datasettet oppdatert, og korrigere feil og mangler ettersom vi finner dem. Dataene kan lastes ned fra DataverseNO, en tjeneste for lagring og deling av data etablert av UiT Norges arktiske universitet, ved å følge lenken under:

https://doi.org/10.18710/M2D2XP

Bakgrunn og formål

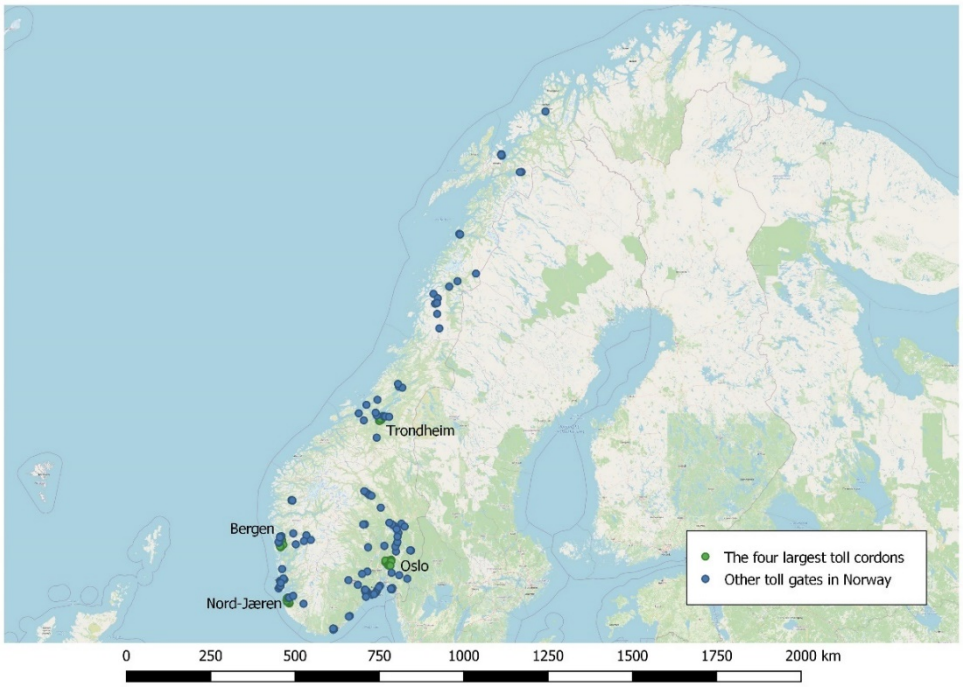
Årlige bompengeinntekter i Norge har økt fra rundt 3 milliarder kroner i 2005 til rundt 11 milliarder i 2018. Dette utgjør 18-19 prosent av totale inntekter fra bilrelaterte skatter og avgifter (Fridstrøm, 2020). Bompenger har vært et viktig virkemiddel i Norge, både for å skaffe øremerket finansiering til infrastrukturprosjekter, men også for å regulere trafikk. Elbilfritaket fra bompenger som varte til 2018, og de reduserte takstene for elbiler fra 2018 og fram til i dag, har også blitt sett på som viktige virkemidler for den politiske målsetningen om å elektrifisere bilparken (Halse mfl, 2022).

Informasjon om hvordan bompengesystemet og bompengeeksponering har variert i befolkningen og over tid burde være av interesse for beslutningstakere. Informasjon om bompenger kan også være nyttig i flere typer empiriske studier, fordi det gir tverrsnittsvariasjon i kjørekostnader, for eksempel til studier som ønsker å estimere tidsverdier. Imidlertid har et historisk datasett som kan kaste lys over dette ikke vært tilgjengelig før nå.

Denne rapporten har to hovedformål. For det første, å gi en beskrivelse av og en historisk oversikt over bompengesystemet i Norge. For det andre, som en dokumentasjon av et paneldatasett over alle bomstasjoner og bomringer. Dette datasettet inneholder koordinater for bomstasjoner, takstendringer over tid og informasjon om andre bomstasjonsspesifikke spesialregler.

Utviklingen av bomstasjoner og takster over tid

Utviklingen fra 2005 fram til 2021 er dokumentert i kapittel 4. Figur S1 viser plasseringen av alle bomstasjoner i Norge på slutten av perioden vi ser på, 31 desember 2021. Vi beskriver i detalj utviklingen i de fire største bomringene: Oslo, Bergen, Trondheim og Nord-Jæren (området rundt Stavanger). Utviklingen for resterende bomstasjoner er beskrevet i litt kortere trekk.



Figur S1: De fire største bomringene og andre bomstasjoner i Norge, 2021.

Den generelle trenden er at antall bomstasjoner har økt, mens den gjennomsnittlige taksten per bomstasjon har holdt seg mer eller mindre konstant. Dette er delvis fordi innkrevingen har opphørt i flere av bomstasjonene med høyest takster, fordi prosjektene som midlene var øremerket for har blitt fullstendig nedbetalt (for eksempel Rennfast, Krifast, Imarsundet, Eiksundsambandet, Finnfast og Atlanterhavstunnelen). En del av de nyere bomstasjonene inngår også i bomringer rundt mindre byer, hvor takstene typisk er lave sammenlignet med andre steder. Når det gjelder de fire storbyene har trenden vært at takstene har økt, det har kommet til flere bomstasjoner og/eller snitt, og rushtidsavgift har blitt innført. Med rushtidsavgift mener vi tidsdifferensierte takster som er høyere i rushtid. Nord-Jæren sluttet med innkreving av rushtidsavgift 10 februar 2020, og er dermed den eneste av disse byene som ikke hadde rushtidsavgift ved utgangen av 2021.

I kapittel 5 beskriver vi hvordan informasjonen om bomstasjoner og takster kan brukes til å beregne bomutlegg for kjøreturer mellom nabolag («grunnkretser»). Vi gjør dette ved å koble bomstasjonene til et vegnett, og beregner den raskeste ruta langs vegnettet mellom nabolagspar. Ved å koble denne informasjonen til registerdata med informasjon over bosted og arbeidssted til hele den norske befolkningen, kan vi karakterisere hvordan bompengeeksponeringen på arbeidsreisen har variert – både på tvers av ulike typer husholdninger og geografiske områder, over tid.

Dette forteller oss ikke hva faktiske innbetalinger i bomstasjoner har vært, men gir et «intention-to-treat»-mål på eksponering, altså hvor mye en person måtte betale dersom hun kjørte til jobb med en diesel- eller bensinbil langs den raskeste ruta hver dag. I følge dette målet har daglig bompengeeksponering på arbeidsreisen økt fra 4,4 kroner i 2005 til 19,8 kroner i 2019 i snitt. Andelen av husholdninger med minst én i jobb som er eksponert for bompenger på arbeidsreisen har økt fra 28 prosent i 2005 til 44 prosent i 2019. Denne utviklingen er vist i Figur S2, hvor fargene reflekterer gjennomsnittlig eksponering blant individer i jobb innad i hvert nabolag.

Figur S2: Daglig bompengeeksponering (kroner) på arbeidsreisen etter bosted.

1 Introduction

1.1 Purpose

This report serves two purposes: First, as a description and a historic overview of road toll policies in Norway. Second, as a documentation of a panel dataset consisting of all toll gates and toll cordons in Norway. The dataset is publicly available and contains coordinates for toll gates, changes in rates over time as well as other special regulations.

We also describe how this data can be used to calculate a data set consisting of road toll expenses on trips between combinations of neighborhoods *("grunnkretser")* in Norway. This data is available upon request.

1.2 Background

Norway has a long tradition for using road tolls to finance new roads (Odeck and Bråthen, 2002; Lauridsen, 2011). More recently, road tolls in urban areas are also used to fund other infrastructure. In some of the metropolitan areas, the stated purpose and the design of the toll system has developed more in the direction of congestion pricing (Isaksen and Johansen, 2021).

An advantage of road tolls from a research perspective is that the toll level varies considerably both geographically and over time. This variation can be useful for studying a number of research topics, for example:

- The trade-offs made by travellers, for instance between travel cost and travel time;
- Pricing as a policy-instrument to reduce external costs from road traffic (Pigouvian taxation);
- Effects of privileges for electric cars on car ownership; and
- Distributional effects and public opposition against pricing instruments.

To this date, however, a complete documentation and data set of historic road tolls has not been available. With this report and the attached data set, we attempt to fill this gap. In particular, we have been interested in the following two issues:

1. Since 2017, the exemption from road tolls for battery-electric vehicles (BEVs) has been partly reversed, and the discount for BEVs now differ between different areas.
2. In recent years, a number of changes have also been made in the toll cordons in the metropolitan areas. Toll rates have become more differentiated and new features have been introduced, for instance price caps within a certain time window.

In order to provide accurate information on this, we have constructed a separate dataset covering the toll cordons in the metropolitan areas of Oslo, Bergen, Trondheim and Stavanger.

1.3 Limitations

The data covers all toll gates in Norway from 2005 to 2021 and their respective roll rates. However, our main emphasis is on the toll cordons in the metropolitan areas of Oslo, Bergen, Trondheim and Nord-Jæren (the Stavanger area). The toll system in these areas will be explained in detail, while specific rules in toll projects outside these areas will not be covered to the same extent. These urban toll cordons are also where we have made the most effort in verifying that the information about toll rates and other features of the system is correct.

While we have focused on the time period starting January 1st 2005, some information in the dataset relates to earlier years. We would however like to stress that information prior to 2005 is incomplete, and must be used with caution.

Despite our efforts in checking the data, some errors will most likely still be present. We encourage those who use the data to contact us if they discover any irregularities.

While the report and the dataset give an historic overview of locations, rates and other rules for toll gates, we have no information about the number of cars passing the toll gates, toll revenues or other operational characteristics. This would require other sources of data.

1.4 Structure of the Report

The rest of the report is structured as follows: In Chapter 2, we explain which sources have been used to gather the data. In Chapter 3, we describe the dataset. In Chapter 4, we present key features of the four urban toll cordons in our dataset as well as the remaining toll gates. In Chapter 5, we explain how we have used the toll gate data to construct a data set with road toll on trips between combinations of neighbourhoods in Norway.

1.5 Definitions

When reading the report, it is useful to know some key terms that are frequently used in descriptions of road toll systems in Norway:

An **hourly rule** is an exemption of additional toll charging when crossing multiple toll gates within an hour. This is typical for toll cordons, but an hourly rule is also applied in some ordinary road toll projects. In most projects the hourly rule is common for all toll gates within the project, while there are some exceptions where the hourly rule is internal for each toll gate. Also, in some projects the hourly rule is valid for 90 minutes.[1]

A **monthly cap** is a limit on how many crossings you can maximally be charged for within a month. When exceeding the monthly cap, additional crossings are free of charge. For example, the Bergen toll cordon has one-way collection and a monthly cap of 60 crossings. Even though having 70 crossings within a month, you will only be charged for 60. Monthly

[1] Eksportvegen in Møre og Romsdal has so called inverse hourly rule on two toll gates to avoid through-traffic, where you are exempt from paying if you use *more* than one hour between two toll gates or only cross one of the gates.

caps are applied both in toll cordons and ordinary road toll projects. The cap can either be internal in each toll gate/section or common for all toll gates in a project.

Rate group 1 (TG1) includes vehicles with an allowed total weight of 3,500 kg, while **rate group 2 (TG2)** includes vehicles with an allowed total weight exceeding 3,500 kg. However, passenger cars heavier than 3,500 kg are included in rate group 1, if they are registered to vehicle class M1 and have tags. Vehicle class M1 is restricted to a maximum of eight seats in addition to the driver's seat. This typically includes caravans, motorhomes and some large cars. See AutoPASS (2021) for more information. When we use the terms "light" and "heavy" vehicles, we are referring to rate group 1 and 2, respectively.

From 2017, **environmental differentiated rates** have been applied in several toll cordons, meaning that more polluting vehicles are faced with higher rates. Rate group 1 is divided into zero-emissions vehicles, plug-in hybrids, diesel and others (including gasoline, gas, ethanol). Rate group 2 is divided into zero-emissions vehicles, plug-in hybrids, Euro VI and Pre-Euro VI. The Euro Standard is an European emission standard for heavy-duty diesel engines. The latest standard Euro VI was approved in 2012, with all heavy diesel vehicles registered after 1 January 2014 having to meet the requirements.

Selected groups and vehicle types are typically exempt from paying road tolls, including people with reduced mobility (in toll cordons), buses, emergency vehicles, motorcycles and ATVs. Some road toll projects also have additional local exemptions, e.g. farmers having to cross a toll gate to get to their field.

AutoPASS is the Norwegian system for road toll collection, owned by Norwegian Public Roads Administration. The system was introduced in 2001 and today all toll collection points on public roads are automated with AutoPASS. Initially an AutoPASS agreement had to be made with each toll company. With the road toll reform in 2015, toll tags became mandatory for heavy vehicles. From 2022, the companies issuing toll tags have to be floated off as separate companies. Before AutoPASS was introduced, *køfribrikke*, another electronic toll collection system was used in some road toll projects. **EasyGo** is a joint venture that enables the use of a single toll tag on toll roads, bridges and ferries in the member countries Norway, Sweden, Denmark and Austria. See more information on AutoPASS (2021).

In 1997 a national policy introduced **electric vehicle exemption**[2] from road tolls. This lasted until May 15 2018, when the Norwegian Parliament passed on that zero-emission vehicles in TG1 could be charged for up to 50 percent of the normal rate (Samferdselsdepartementet, 2018a). In most road projects charging zero-emissions vehicles, the vehicles receive a discount of 50 percent after the 20 percent AutoPASS discount is deducted from the normal rate. In these projects, electric vehicles need a valid toll tag not to be charged the normal rate. However, the toll cordons in Oslo and Bergen have separate reduced rates for electric vehicles, also for vehicles without a toll tag. You will receive a 20 percent discount on these rates having an AutoPASS agreement. Zero-emissions vehicles in TG2 are still fully exempt from paying. Hydrogen powered vehicles still have free crossings in most toll projects, including those where electric vehicles are charged. Note that the dataset does not report rates for hydrogen cars, as there is only about 200 of them across the country.

[2] Note that this only applies to battery-electric vehicles (BEVs), not plug-in hybrid electric vehicles (PHEVs).

In this report, we use the terms **congestion pricing** and **congestion charge** to refer to road tolls that are differentiated by time of day, at fixed intervals. Congestion charges are applied in several toll cordons in Norway, usually during the morning and the afternoon rush hours.[3]

[3] Dynamic congestion pricing, i.e. road tolls that vary with some real-time measure of congestion, have never been implemented in Norway.

2 Method and Data Sources

Data on toll gates have been collected from various sources. The main sources, which are described more in detail below, are:

a) The National Roads Database ("Nasjonal Vegdatabank", NVDB) owned and maintained by the Norwegian Public Roads Administration;
b) Toll companies' websites;
c) Historical records of toll companies websites from internet archives;
d) Online news articles; and
e) Direct dialogue with toll companies and public authorities.

While (a) has been the starting point for the dataset, it lacks several variables and is inaccurate when it comes to historical information. Therefore, the dataset has been expanded with, and cross-checked against, information from sources (b)-(e) as well.

Sometimes different sources contradict each other. Some historical toll gates were operated by companies that no longer exist. Sometimes it has been impossible to find sources with accurate information regarding certain toll projects, or contact information to individuals that know anything about them. Therefore, the dataset is likely to have errors. If any errors are found, the reader is encouraged to contact us so that we can update the dataset accordingly.

The next sections describe each source in more detail.

2.1 Nasjonal vegdatabank API

With the exception of the actual toll rates, most of the data such as coordinates of toll gates is retrieved from Nasjonal vegdatabank (NVDB), a database maintained by Statens vegvesen (the Norwegian Public Roads Administration; NPRA).[4] NPRA offers a REST API (application programming interest), which enables us retrieve current and historic data directly from NVDB (Statens Vegvesen, 2021). Using the programming language Python, we make a request to the web server and retrieve desired information. Further, we transform the data to applicable Excel format. The Python code for this purpose is described in detail in Appendix A.

Using the approach above, we have retrieved data on the first day of the month every month from year 2000 until today. This causes the same version of the same toll gate with the same rate being retrieved multiple times, but duplicate values can easily be removed. The reason for downloading monthly rather than yearly data is to capture cases where a toll gate changed multiple times within a year.

NVDB also holds toll rates, but those are partially incomplete and incorrect. The NVDB data has made the basis for the structure of the dataset, but it has been necessary to supplement the toll rates and rule out errors with the help of other sources. However, in the cases where

[4] See https://dataut.vegvesen.no/en/dataset/nasjonal-vegdatabank for more information.

a more reliable source is not obtained, rates from the NVDB is used. The main shortcomings of NVDB are listed below.

First, the data base only has rate categories for light and heavy vehicles. If rates within the light or heavy vehicle groups are differentiated, NVDB will return the highest rate. E.g. for light vehicles in the toll ring in Oslo, NVDB returns the diesel rate which is higher than the gasoline rate. Second, for heavy vehicles it returns the rate for vehicles with pre Euro VI engines, which is higher than the rate for Euro VI engines. Third, NVDB does not provide information on different discount schemes. Fourth, the start and end dates of the different versions in NVDB are highly doubtful. The dates of a rate change could deviate with several years from the actual rate change in some instances. Therefore, rates for all vehicle classes, dates of rate changes and discount schemes are carefully obtained from other sources and merged with meta data from NVDB.

There are some further particularities with the NVDB data that one should be aware of. Each toll gate has a unique NVDB ID variable, that usually follows the respective toll gate through several years. However, some toll gates change ID through the years, making the variable less suitable for practical purposes. The change in ID is sometimes due to a physical movement of the toll gate, but often a toll gate with changed ID is placed in the exact same position. Further, the variable with the names of the toll gates is kept exactly as the names are retrieved from NVDB. Some toll gates have changed names through different versions of the same ID. E.g. the toll gate Jørstadmoen at Lillehammer was previously referred to as Lundgård. There is also a substantial amount of minor name changes and misspellings, that are kept as they are retrieved.

For variables in the dataset that are reasonable to assume are constant, we have used the latest version retrieved from NVDB. E.g. for a substantial amount of the toll gates, there are minor changes in the position. Only the last position from NVDB is kept.

The variables for municipality *(“kommune")* and county *(“fylke”)* are retroactively applied based on the municipality structure in 2021. E.g. the toll gate at Brennemoen formerly belonged to Eidsberg municipality and Østfold county until 1 January 2020, but the variables say Indre Østfold municipality and Viken county for all time periods.

NVDB also includes road references for each toll gate: a unique variable that allows the toll gate to be placed on an exact location on NVDBs road network. This variable is included in the dataset, but likely to be of limited use for historical toll gates. First, because road references for older toll gates do not have enough information to uniquely identify placement relative to a road link. Second, a new road reference system was introduced in 2018, meaning that road references are inconsistent over time. Therefore, we suggest to make use of the geographical coordinates for toll gate placement instead.

2.2 Wayback Machine

Using Wayback Machine,[5] which is a digital archive of the World Wide Web, we have been able to obtain and quality check toll rates and discount schemes through historical websites. Wayback Machine is a freely available digital archive of the internet owned and maintained

[5] Wayback Machine is available at https://archive.org/web/.

by the American digital library *Internet Archive*, which has archived hundreds of billions of websites since 1996. This has made us able to find original information on rates, discount schemes and changes to toll gates.

As a result of the road toll reform in 2015, about 60 toll companies were reduced to five regional toll companies (Fjellinjen, Ferde, Vegamot, Vegfinans and BPS Nord). Historical information has not in all cases been passed on in a structured format to the new regional companies. However, using Wayback Machine, we have been able to access websites of discontinued toll companies and retrieve historical information. Through NVDB we were able to retrieve some of the addresses to websites that are no longer in operation, but still stored in the internet archive.

Also, we have retrieved rates from the websites of AutoPASS and Norvegfinans. AutoPASS published rates for every road toll project until 2019. Norvegfinans (Norske vegfinansierings-selskapers forening) was a former special interest organization for Norwegian toll operator companies. All the way back to 2002 Norvegfinans published rates on their website.

2.3 Other sources

The introduction of new toll gates and increases in rates typically spark public debate in national and local newspapers. Therefore, the digital newspaper archive Atekst (from Retriever Norge) has proven useful to find historical information on changes in road toll projects, particularly opening dates of road toll projects and dates of rate changes.

The toll companies Fjellinjen, Ferde and Vegamot have provided partial documentation of historical toll rates. NPRA has also provided some information that is not from NVDB. Discussions by phone and e-mail with representatives from these companies (their names are listed in the preface) have been helpful in establishing correct rates in cases where documentation is hard to find, and as a quality check in general.

3 Description of datasets

The dataset collected on locations of toll gates, toll rates and other regulations are contained in three separate files that can be downloaded from Dataverse, a research data repository provided by The Arctic University of Norway (UiT). Data can be accessed by the following link:

https://doi.org/10.18710/M2D2XP

Dataverse includes a version control, and it is our ambition to update and improve the dataset whenever errors are uncovered. For any descriptives in this report, version 2.0 of the dataset is used. The three files that can be accessed from the URL above are called "toll_gates_OBST", "toll_rates_OBST" and "other_toll_gates", and will be described below. The two first files relate to the toll cordons in Oslo, Bergen, Nord-Jæren and Trondheim, while the third file contains information on the remaining toll gates in Norway.

The file "toll_gates_OBST" contains data on the physical toll gates that are part of the four main toll cordons, and has one observation for each unique toll gate. Most importantly, the file has information about when the toll gate opened, when the toll gate closed, the geographical location as well as which toll cordon section the toll gate belongs to. Table 3.1 gives a description of each variable in the dataset.

Table 3.1: Variable description for the dataset toll_gates_OBST.

Variable name	Description
Toll_cordon	The name of the toll cordon. "Oslo", "Bergen", "Trondheim" or "Nord-Jæren".
Toll_cordon_section	The name of the section within each toll cordon. Different sections often have different rates and other rules.
Station_name	The most recent name of the toll gate as it is recorded in NVDB.
Date_start	The date the toll gate first opened. Format: YYYYMMDD (YYYY = year; MM = month; DD = day).
Date_end	The date the toll gate closed. Format: YYYYMMDD (YYYY = year; MM = month; DD = day). For toll gates that were still open at December 31st 2021, the value is set to 99991231.
Id_NVDB	The most recent ID variable the toll gate has from NVDB.
Id_NVDB_previous	Earlier ID variables used for the same toll gate, in case the ID variable recorded in NVDB has changed over time.
Road_reference_system	A variable that allows a toll gate to be merged accurately to the NVDB road network. This variable is incomplete for older toll gates.
Toll_company	The name of the company in charge of toll collection.
Municipality	The name of the municipality where the toll gate is located.
Coordinate_latitude	Y coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Coordinate_longitude	X coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Coordinate_altitude	Z coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Station_name_other	Other names used for the same toll gate in earlier versions of NVDB.
Road_category	Administrative category of road (European road, national road or county road).

Table 3.2 contains information on the specific rates and regulations that apply to each toll cordon section at different time intervals. The unit of observation in the dataset is "toll

cordon section" by "time interval", with the exception of Nord-Jæren where the same rules apply to all sections of the toll cordon. The variables "toll_cordon" and "toll_cordon_section" can be used to map the rates and regulations in each section to specific toll gates from the file "toll_gates_OBST".

Table 3.2: Variable description for the dataset "toll_rates_OBST".

Variable name	Description
Toll_cordon	The name of the toll cordon. "Oslo", "Bergen", "Trondheim" or "Nord-Jæren".
Toll_cordon_section	The name of the section within each toll cordon. Different sections often have different rates and other rules.
Date_start	The first date the specific rates and rules apply to. Format: YYYYMMDD (YYYY = year; MM = month; DD = day).
Date_end	The last date the specific rates and rules apply to. Format: YYYYMMDD (YYYY = year; MM = month; DD = day). For rates and rules that were still in place December 31st 2021, the value is set to 99991231.
Rate_small_gasoline	The standard rate in NOK for gasoline vehicles below 3.5 tonnes (TG1)
Rate_small_diesel	The standard rate in NOK for diesel vehicles below 3.5 tonnes (TG1)
Rate_small_zero_emission	The rate in NOK, including the AutoPASS discount, for BEVs below 3.5 tonnes (TG1) outside rush hours (in case a BEV does not have an AutoPASS tag, it pays the standard rate for gasoline cars).
Rate_small_gasoline_rush	Standard rate in NOK for gasoline vehicles below 3.5 tonnes (TG1) during rush hours. If the variable is empty, there is no congestion charge in place.
Rate_small_diesel_rush	Standard rate in NOK for diesel vehicles below 3.5 tonnes (TG1) during rush hours. If the variable is empty, there is no congestion charge in place.
Rate_small_zero_emission_rush	The rate in NOK, including the AutoPASS discount, for BEVs below 3.5 tonnes (TG1) during rush hours (in case a BEV does not have an AutoPASS tag, it pays the standard rate for gasoline cars). If the variable is empty, there is no congestion charge in place.
Rate_large_pre_Euro_VI	Standard rate for heavy duty vehicles above 3.5 tonnes (TG2) with Euro V engines or older standards outside of rush hours
Rate_large_Euro_VI	Standard rate for heavy duty vehicles above 3.5 tonnes (TG2) with Euro VI engines outside of rush hour. The Euro VI standard was approved in 2012, and this variable is therefore empty for years prior to this.
Rate_large_zero_emission	Standard rate for zero-emission vehicles above 3.5 tonnes (TG2). This rate is zero for all toll cordon sections.
	Rate for heavy duty vehicles above 3.5 tonnes (TG2) with Euro V engines or older standards during rush hours. If the variable is empty, there is no congestion charge in place.
	Rate for heavy duty vehicles above 3.5 tonnes (TG2) with Euro VI engines during of rush hour. If the variable is empty, there is no congestion charge in place. The Euro VI standard was approved in 2012, and this variable is therefore empty for years prior to this.
	Standard rate for zero-emission vehicles above 3.5 tonnes (TG2) during rush hours. This rate is zero for all toll cordon sections. If the variable is empty, there is no congestion charge in place.
	The time period when the congestion charge is active during the morning rush hours. If the variable is empty, there is no congestion charge during the morning rush hours.
rush_hour_evening	The time period when the congestion charge is active during the afternoon rush hours. If the variable is empty, there is no congestion charge during the afternoon rush hours.
direction_of_collection	The direction of toll collection. Either "one way" or "both ways".
hourly_rule	Whether the toll gate has an hourly rule, and which sections of the toll cordon the rule applies to.
monthly_cap	Whether the toll gate has a monthly cap and which sections of the toll cordon the cap applies to.
monthly_cap_passthroughs	If there is a monthly cap, the number of crossings needed to reach the cap.
rate_small_discount_agreement	Standard discount rate outside of rush hour for TG1 vehicles with toll tag issued by the operator of the toll cordon

Variable name	Description
rate_small_discount_agreement_rush	Discount rate during rush hour for TG1 vehicles with toll tag issued by the operator of the toll cordon. The variable is empty if there is no congestion charge in place.
rate_small_discount_agreement_external	Standard discount rate outside of rush hour for TG1 vehicles with toll tag issued by another company than the operator of the toll cordon.
rate_large_discount_agreement	Standard discount rate for TG2 vehicles with toll tag issued by another company than the operator of the toll cordon.
rate_large_discount_agreement_rush	Discount rate during rush hour for TG2 vehicles with toll tag issued by the operator of the toll cordon. The variable is empty if there is no congestion charge in place.
rate_large_discount_agreement_external	Standard discount rate for TG2 vehicles with toll tag issued by another company than the one operating the toll gate.

Table 3.3 gives a variable description of the file “other_toll_gates”, which contains information about rates and regulations for the remaining toll gates in Norway. The unit of observation in this file is “toll gate” by “time interval”, where “id_NVDB” is the ID variable of the toll gate and “date_start” and “date_end” determines the time interval. The earliest “date_start” for a certain toll gate is the time the toll gate was first opened. This file does not distinguish between rates for gasoline and diesel vehicles, as all zero-emission vehicles (ZEVs) within TG1 and TG2 typically are charged the same rate.

Table 3.3: Variable description for the dataset “other_toll_gates”.

Variable name	Description
Toll_cordon	Name of the toll cordon the toll gate belongs to. “no” if the toll gate does not belong to a toll cordon.
Toll_project	Name of the project the toll gate belongs to.
Station_name	The most recent name of the toll gate as it is recorded in NVDB.
Municipality_name	Name of the municipality where the toll gate is located. The municipality name has retroactively been updated to the name in 2021.
Municipality_id	Municipality code. The code has been retroactively been updated to the name in 2021.
County_name	Name of the county where the toll gate is located. The county name has retroactively been updated to the name in 2021.
County_id	County code. The code has been retroactively been updated to the name in 2021.
Coordinate_latitude	Y coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Coordinate_longitude	X coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Coordinate_altitude	Z coordinate in the WGS84 system. WGS84 is a mathematical model of the Earth used for positioning and mapping of the Earth's surface, used in standard GPS and Google Maps.
Road_reference_system	A variable that allows a toll gate to be merged accurately to the NVDB road network. This variable is incomplete for older toll gates.
Road_type	Type of road where the toll gate is located. Either “simple road”, “ramp” or “channelled road”.
Road_category	Road category for the road where the toll gate is located. Either “European road”, “national road”, “county road”, “municipal road” or “forest road”.
Id_NVDB	The ID variable the toll gate has from NVDB.
Date_start	The first date the specific rates and rules apply to. Format: YYYYMMDD (YYYY = year; MM = month; DD = day). The earliest date for each toll gate is when the toll gate was first opened.

Variable name	Description
Date_end	The last date the specific rates and rules apply to. Format: YYYYMMDD (YYYY = year; MM = month; DD = day). For rates and rules that were still in place December 31st 2021, the value is set to 99991231. If the last date of a certain toll gate is smaller than that, it denotes the date the toll gate was closed.
Rate_small	The standard rate in NOK for non-ZEV vehicles below 3.5 tonnes (TG1)
Rate_large	The standard rate in NOK for non-ZEV vehicles above 3.5 tonnes (TG2)
congestion_charge	Whether a congestion charge applies to the toll gate (“yes”/”no”)
Rate_small_rush	The rate during rush hours in NOK for non-ZEV vehicles below 3.5 tonnes (TG1). If the variable is empty, there is no congestion charge in place.
Rate_large_rush	The rate during rush hours in NOK for non-ZEV vehicles above 3.5 tonnes (TG2). If the variable is empty, there is no congestion charge in place.
Hourly_rule	Whether the toll gate has an hourly rule and which sections of the toll cordon the rule applies to.
Hourly_rule_duration	Duration of the hourly rule in minutes. This variable is mostly “60”, however some toll projects have a 90 minutes rule.
Monthly_cap	Whether the toll gate has a monthly cap and which sections of the toll cordon the cap applies to.
Monthly_cap_passthroughs	If there is a monthly cap, the number of crossings needed to reach the cap.
Rate_small_discount_agreement	Standard discount rate outside of rush hour for TG1 vehicles with toll tag issued by the operator of the toll cordon
Rate_small_discount_agreement_external	Standard discount rate outside of rush hour for TG1 vehicles with toll tag issued by another company than the operator of the toll cordon.
Rate_large_discount_agreement	Standard discount rate for TG2 vehicles with toll tag issued by another company than the operator of the toll cordon.
Rate_small_discount_zero-emission	Discount for zero-emissions vehicles in TG1. This discount comes on top of the standard AutoPASS discount
Rate_large_discount_zero-emission	Discount for zero-emissions vehicles in TG2.
Direction_of_collection	Whether collection of tolls is in one or both directions
Rush_hour_morning	The time period when the congestion charge is active during the morning rush hours. If the variable is empty, there is no congestion charge during the morning rush hours.
Rush_hour_evening	The time period when the congestion charge is active during the afternoon rush hours. If the variable is empty, there is no congestion charge during the afternoon rush hours.
Exemption_mobility_impaired	Cars with HC chip for mobility impaired are exempted from paying tolls (“yes”/”no”).

4 Road tolls

4.1 Toll cordons

4.1.1 Oslo

The Oslo toll cordon was initiated in 1990 as a result of Oslo Package 1 *(Oslopakke 1)*, a political agreement and plan for investments in road infrastructure in Oslo and Akershus. Initially, the cordon consisted of 18 toll gates, charging in one direction towards Oslo city centre.

The initial rates were NOK 10 for light vehicles and NOK 20 for heavy vehicles. However, road users could get discounted prices by purchasing a punch card for up to 350 crossings, or periodical season tickets for up to a year. Rates were decided to grow with the consumer price index. In 1997, electric vehicles were exempted from road tolls. When introducing the Oslo Package 2 *(Oslopakke 2)* for public transport in 2001, the toll rates increased by 25 percent.

The follow-up, Oslo Package 3 *(Oslopakke 3)*, was introduced in 2008. The toll cordon got fully automated and the payment system was changed. The rate was politically decided to be NOK 25 for light vehicles, and three times as big for heavy vehicles. Introducing the electronic toll collection system AutoPASS, the former discount scheme was replaced. Road users having an AutoPASS agreement issued by the toll road operator Fjellinjen would get a 20 percent discount on crossings. AutoPASS agreements issued by other providers would give a 10 percent discount. Additionally, an hourly rule and a monthly cap was introduced provided you had an AutoPASS agreement. The driver only paid for one crossing per hour, even if crossing multiple toll gates. After 60 crossings within a month, the driver was not charged for further crossings. Later in 2008, the toll section *Bærumssnittet* on the boundary between Oslo and Bærum municipality west of Oslo was introduced. The rates in *Bærumssnittet* were half of the rates in the Oslo toll cordon.

As a result of a political decision, rates were revised in 2013. The rate was now set at NOK 30 and future adjustments would still follow general price increase. Also, the unique 20 percent discount for AutoPASS agreements issued by Fjellinjen was removed. At this time, everyone with an AutoPASS agreement would get a 10 percent rate discount on crossings.

In 2017, there were significant changes in the Oslo toll cordon. A congestion charge and environmental differentiation of rates were applied. The two former rate groups were divided into sub-groups. In rate group 1, diesel cars were differentiated from gasoline and rechargeable hybrids. In rate group 2, vehicles having the latest European emission standard for heavy-duty diesel engines (Euro VI), were differentiated from vehicles with lower classifications. An additional fee was charged for crossings during rush hour, in the timeframe between 06.30-09.00 and 15.00-17.00 on working days. Neither a congestion charge nor an environmental differentiation was applied in *Bærumssnittet*.

In 2019, the Oslo toll cordon was expanded into three rings. The existing ring *(Osloringen)* remained as before, while a new inner ring *(Indre ring)* was introduced. Toll sections equivalent with *Bærumssnittet* were applied at the borders between Oslo and Romerike in the northeast and Follo in the southeast, giving a city boundary ring *(Bygrensen).* At the two

inner rings (*Indre Ring* and *Osloringen*), two-way collection was introduced. At the outer-most ring *(Bygrensen)*, cars were still only charged in one direction; into the city centre. Compared to the former single toll cordon, the rates were reduced, but the number of crossings increased.

Furthermore, battery electric vehicles in rate group 1 were no longer completely exempt from tolls, but got a substantial reduced rate. The hourly rule and monthly cap was slightly changed. The two inner rings got a common hourly rule, where cars would be charged the highest rate recorded during that hour. Due to two-way collection in the two inner rings, the monthly cap increased from 60 to 120 crossings. The outermost ring, *Bygrensen*, has its own hourly rule and a monthly cap of 60 crossings. Furthermore, the AutoPASS discount increased from 10 to 20 percent on crossings for TG1 vehicles, while the discount for TG2 vehicles was removed. From January 1. 2021, light electric vehicles registered as vans are exempt from road tolls in the Oslo toll cordon. Figure 4.1 displays the toll gates associated with the three toll cordons around Oslo as of December 31st 2021. The western section of *Bygrensen* consist of the toll gates formerly known as *Bærumssnittet.*

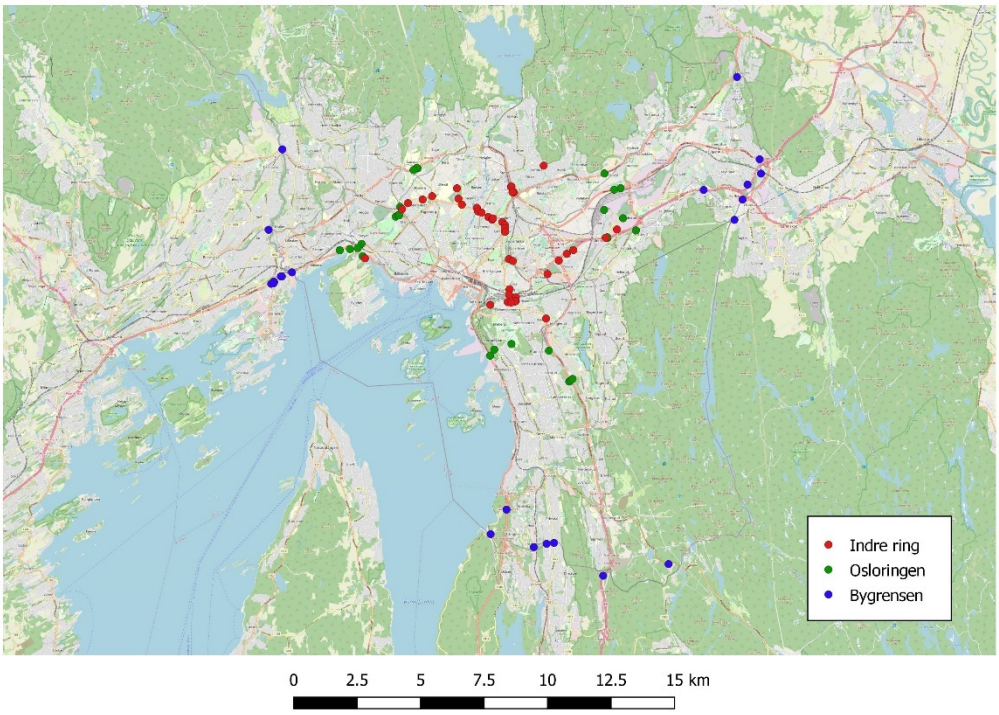


Figure 4.1: Toll sections in Oslo, 2021.

For more information on the Oslo toll cordon, see Statens vegvesen (2019a, 2019b), Fjellinjen (2011), Fjellinjen (2021), Samferdselsdepartementet (2015, 2018b), Visit Oslo (2020) and Wikipedia (2020).

4.1.2 Bergen

The toll cordon in Bergen opened on 2 January 1986, making it the first toll cordon in Norway and the second in the world after Singapore (Bekken and Osland, 2004). The Bergen toll cordon was from the beginning operated by the company *Bro & Tunnelselskapet* (later

BT Signaal). Initially, the cordon consisted of seven toll gates, collecting in one direction, towards the city centre as a main rule. Tolls were only collected on weekdays in the time period 06.00-22.00. The rates were 5 NOK for light vehicles and 10 NOK for heavy vehicles. With a prepaid punch card *(bompengekort)* you would get a discount.

On November 1st 1999, the rates were doubled and the punch card was replaced by a subscription scheme, with duration of one, three, six or twelve months. You could also buy a discount booklet for 20 crossings, which gave a 10 percent discount. In 2002, the Bergen Program for Transport, Urban Development and the Environment was introduced. Through road toll collection this political agreement would finance road and light rail investments.

On February 2nd 2004, the toll gates became fully automatic and a new toll gate at Straume was put into effect. The rates increased by 50 percent and toll collection was extended to 24 hours a day except on Sundays and during public holidays. An hourly rule and a monthly cap of 50 crossings were introduced. AutoPASS toll tags and a new discount scheme were introduced. With an AutoPASS agreement, you would get a 10 percent discount paying in arrears. Paying in advance would give up to 50 percent discount depending on number of crossings, with 350 crossings giving the maximum discount. On April 3rd 2006 the maximum discount when paying in advance was reduced to 40 percent for 175 crossings. Toll collecting on Sundays was also introduced. On July 11th 2007 the toll cordon was extended with five more gates at Fjøsangerveien, Storetveitveien, Natlandsveien, Michael-Krohnsgate and Ramsgårdsveien.

On July 1st 2013, the discount scheme changed. Paying in advance would give up to 20 percent discount, while paying in arrears would give a 10 percent discount. Also, the monthly cap increased to 60 crossings. Rates were increased from 15 to 25 NOK for light vehicles, and from 30 to 50 NOK for heavy vehicles.

On February 1st 2015, you could no longer sign and change toll agreements in selected gas stations.

On February 1st 2016, a congestion charge was introduced. The congestion charge was collected Monday through Friday in the time frame of 06.30-09.00 and 14.30-16.30. The rates outside rush hours dropped to 19 (45) NOK for light (heavy) vehicles, while the rates during rush were more than twice as high: 45 (90) NOK per crossing. In 2017 *BT Signaal* was acquired by and later merged into the toll company *Ferde*, which took over the operation of the Bergen toll cordon in 2018.

In 2018, the political agreement *Miljøløftet*, a continuation of the Bergen Program, was introduced. On June 1st 2018 environmental differentiation was introduced. In the light vehicles group, diesel cars now had to pay more than gasoline cars (5 additional NOK for light vehicles). In the heavy vehicles group, vehicles with Euro VI engines would pay less than vehicles with older emissions standards. The rates and discounts also changed. The possibility to pay in advance was discontinued. The discount when paying in arrears was increased to 20 percent for light vehicles, while the discount was removed for heavy vehicles.

On January 1st 2019, the rates were increased with consumer prices. On April 6th 2019 the toll cordon was extended with 15 new toll gates. The new gates did not charge a higher rate during rush hour, but the already existing 14 toll gates still did. As of this time, light electric vehicles also had to pay, but at a reduced rate (8 NOK as the standard rate, 16 NOK during

rush hours). Hydrogen powered cars were however still exempt from paying if having an AutoPASS agreement. This contradicts with the toll cordons in Oslo and at Nord-Jæren, where hydrogen vehicles are charged the same rate as electric vehicles.

On January 1st 2021, the rates for electric vehicles were cut in half due to government grants. In May 2021, the hourly rule in the toll cordon was modified. You were now charged for the highest rate instead of the first rate crossed within one hour.

Figure 4.2 displays the toll gates associated with the Bergen toll cordon in 2021, where the upper right corner zooms in on the city center. New and old toll gates are distinguished by color, where the old toll gates have congestion pricing implemented.

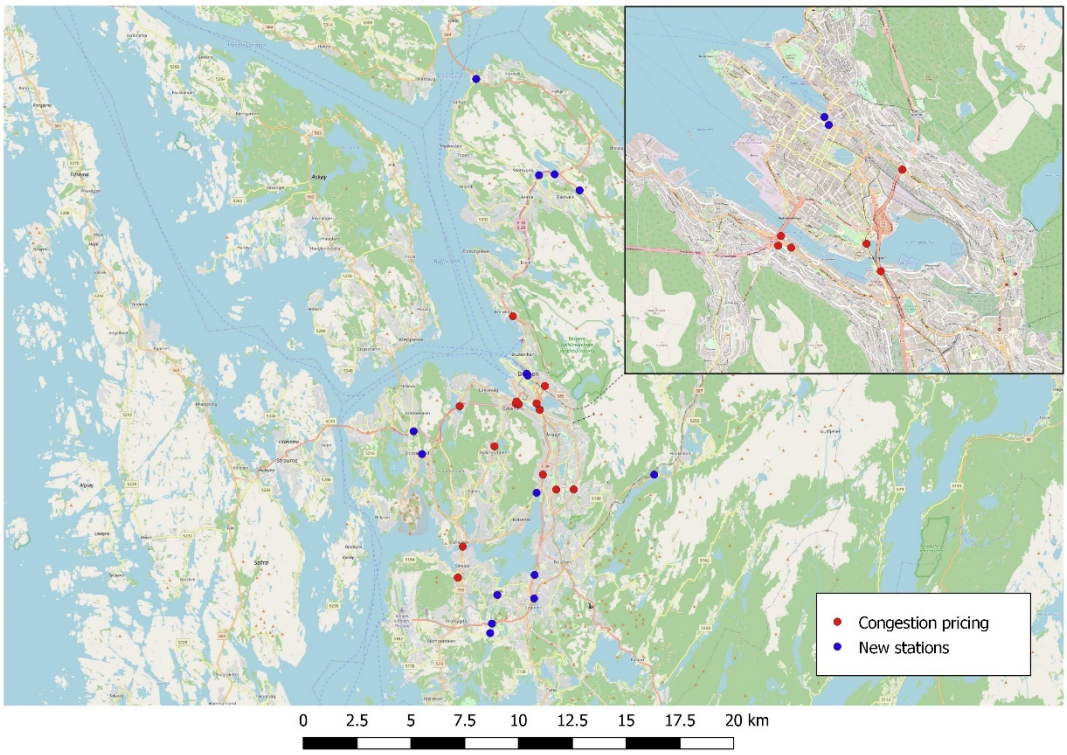


Figure 4.2: Toll sections in Bergen, 2021.

For more information, see Bro & Tunnelselskapet AS (2002, 2013), Ferde (2021a) and Murray and Riaz (2021).

4.1.3 Trondheim

The first toll cordon in Trondheim opened in October 1991 and was discontinued on 31 December 2005. Data from this ring has proved difficult to obtain, hence it has been omitted in this report.[6] The second toll cordon was initiated 31 March 2010, as part of the political agreement *Miljøpakken.* In the first phase, the ring consisted of three toll sections

[6] Some information on this toll cordon can be found at www.trondelag-bomveiselskap.no (from 2000) and www.trondelagveifinans.no (from July 1st, 2002) and in Skollerud et al. (2015).

(*Midtre, Søndre* and *Nordre*) with eight fully automatic toll gates charging in both directions. The toll cordon was operated by *Trøndelag bomveiselskap*, later renamed to *Vegamot*.

The rates were mainly 10 NOK for light vehicles and 20 NOK for heavy vehicles, with electric vehicles being exempt from paying. The toll cordon had an hourly rule, a monthly cap and congestion charge from the beginning, with some exemptions.

Regarding the hourly rule, you only pay for one crossing within a section each hour. The rule is internally in each section and you will always be charged for the first crossing, independently of differences in prices. Further, there was initially a cap of 90 crossings charged internally in each sections. You were not charged for additional crossings. The toll gates as Kroppan bridge were exempt from all discount schemes, including monthly cap and hourly rule.

The congestion charge was collected in the time periods 07.00-09.00 in the morning and 15.00-17.00 in the afternoon. Initially, the rates within rush hours were double the rates outside of rush hours, except for the gates at Kroppan bridge (*Kroppan bru*) which had flat rate all day. Congestion charge was not collected on Saturdays, Sundays, during public holidays or during Christmas Eve, New Year's Eve and the last Wednesday before Easter.

Phase two of *Miljøpakken* was introduced March 17th 2014. The cordon was expanded with 14 new gates and restructured into seven toll sections. The former *Midtre* section was disjoint into the sections *Omkjøringsveien* and *Sluppen*. The *Søndre* section was renamed to *Sør* and *Nordre* section was renamed to *Øst*. Three new sections at *Tonstad*, *Klæbu* and *Byåsen* were introduced. Further, the rates and discount schemes had some changes. Heavy vehicle rates were now the double, triple or fivefold of light vehicles rates, dependent on the section. The toll gates at Kroppan bru and Nedre Leirfoss had different rates for heavy vehicles than other toll gates within the same sections. The sections *Omkjøringsveien, Tonstad, Klæbu* and *Byåsen* were exempted from congestion charge. In the same sections, toll tag discounts during rush hours were abolished. Furthermore, the monthly cap was changed to a common cap of 110 crossing for all sections. This differed from before, where the cap was specific to each section. In 2016, rates were increased with consumer prices.

Phase three of *Miljøpakken* was introduced on June 1. 2018. Rates increased and a congestion charge was applied at the sections earlier exempt. The additional charge in these sections was about 30 percent during rush hours, as opposed to the other sections where the congestion charge was double the normal rate. Toll tag discounts for light vehicles were now a flat 20 percent discount for all sections, independent of toll tag issuer, while discounts for heavy vehicles lapsed. In 2020, rates increased further, except for at the *Sluppen* section, where the rate for heavy vehicles decreased.

With today's seven toll sections and even different rates within some of the sections, the cordon might be the most complex in Norway. In addition, there are some special occasions with exemption from toll collection. If you cross the two toll gates *Brøsetvegen* and *Jonsvannsveien* at Moholt within 30 seconds, you will not be charged. Also, crossing the gates in *Bøckmans veg* or at *Tonstad*, you will not be charged for crossing at *Sluppen* or *Bjørndalen*.

Note that there are also toll collection points in Trondheim municipality that are not a part of the toll cordon. The toll gate in eastern Trondheim at Ranheim is a part of the toll project

E6 Trondheim – Stjørdal. However, the more eastern toll gate at Være is a part of the Trondheim toll cordon. Also, there is toll collection at the ferry from Flakk to Rørvik.

For the time being, rates are not environmentally differentiated for heavy vehicles (except zero-emissions vehicles which are exempt). Gasoline and diesel vehicles in TG1 pay the same. Nor are Euro engine classes in TG2 differentiated.

Figure 4.3 displays toll gates belonging to the Trondheim toll cordon in 2021, with the current names of each section.

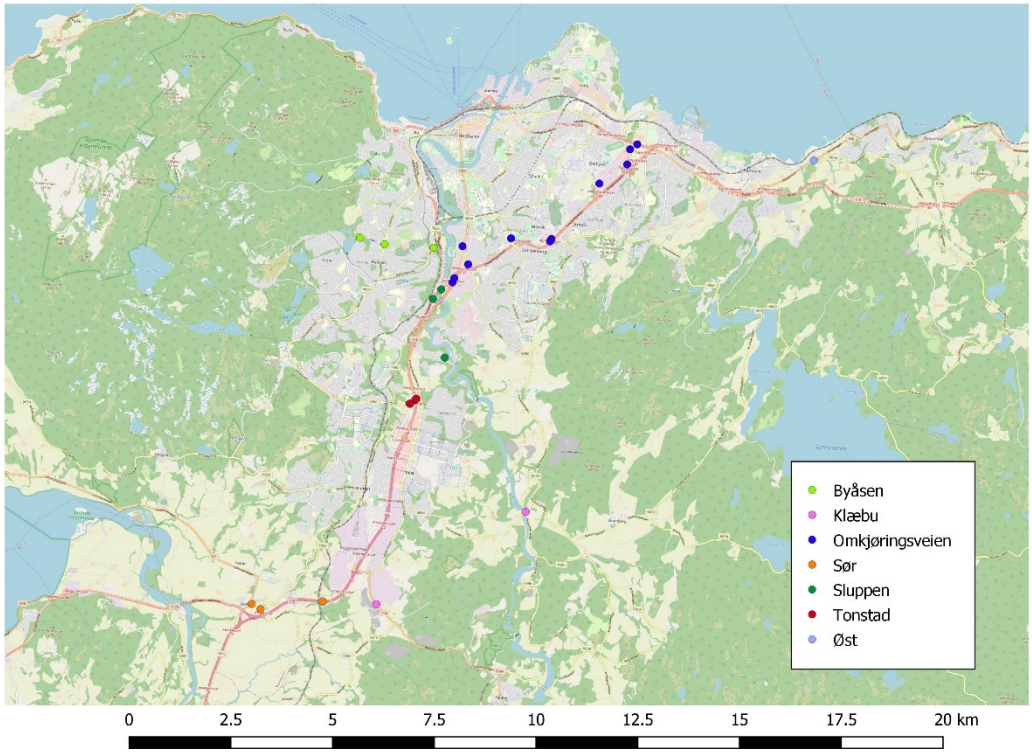


Figure 4.3: Toll sections in Trondheim, 2021.

Notes on dataset: The toll section *Omkjøringsveien* is denominated with the suffixes 1 and 2, where the latter refers to the toll gate at Kroppan bridge, which has some deviation in rates from the other gates in the section. Similarly, the toll section *Sluppen* is denominated with the suffixes 1 and 2, where the latter refers to the gate at Nedre Leirfoss which has some deviation in rates from the other gates in the section.

For more information, see Nedrebø (2015), Vegamot (2021) and Trøndelag Bomveiselskap (2010).

4.1.4 Nord-Jæren

The toll cordon at the Nord-Jæren region (the area around Stavanger) opened on April 20th 2001 and was operated by *Nord-Jæren bompengeselskap*. Initially it consisted of 21 toll gates collecting in one direction. From the beginning, the toll cordon had time differentiated rates. The normal rate was 5 NOK for light vehicles and 10 NOK for heavy vehicles, and twice as high during rush hours from 07.00-09.00 in the morning and 14.00-17.00 in the afternoon.

However, you were not charged on crossings from 18.00 in the evening and until 06.00 in the morning. Saturdays, Sundays and public holidays were free all day long.

Regarding the discount scheme, the toll cordon in Nord-Jæren had a monthly cap of 75 crossings, but no hourly rule. Having an AutoPASS agreement gave up to 50 percent discount paying in advance and up to 20 percent paying in arrears depending on number of crossings. In 2004, the operation of the toll cordon was taken over by *Bro & Tunnelselskapet.*

On January 1st 2005, the rates and payment structure changed. Now, road tolls were collected all day every day, at a rate of 13 NOK for light vehicles and 26 NOK for heavy vehicles. The rates were more than doubled, but the congestion charge was removed. A common hourly rule for the whole toll cordon was introduced, so you would only be charged for crossing one toll gate within an hour.

Further, in 2009 there was a raise in rates to 20 (50) NOK, and a reduction in the maximum discount for paying in advance to 40 percent. A rate exemption for tractors and agricultural machinery was introduced. Also, you could apply for a rate exemption for traffic between a private residence and the municipal center, schools and kindergartens.

On March 1st 2012, the toll tag discounts were changed to flat rates independent of number of crossings. The discounts were 20 percent for payments in advance and 10 percent for payments in arrears. However, corporate customers would get 20 percent for payments in arrears. Later that year, the operation of the toll cordon was transferred back to *Nord-Jæren bompengeselskap.*

On October 1st 2018, the new agreement *Bymiljøpakken* was initiated. The old toll gates were replaced by 38 new toll gates divided into the six toll sections *Stavanger, Sandnes, Forus, Risavika, Sola* and *Ytre bomsnitt*, as we know it today; the latter covering the area *Randaberg*. Rates were increased from 20 to 22 NOK for light vehicles and from 50 to 55 NOK for heavy vehicles. Cars were only charged in one direction, as a main rule on the way into a section. As a result of the road toll reform, the operation of the toll cordon was transferred to the regional toll company *Ferde* in 2018.

Regarding the discount scheme, there is still a common hourly rule and a common monthly cap of 75 crossings. Further, the option to pay the road tolls in advance was removed. The discounts for light vehicles increased to 20 percent while the discounts for heavy vehicles lapsed. The local scheme with rate exemption for some groups was discontinued.

With *Bymiljøpakken*, time differentiated rates were introduced again in the time periods 07.00-09.00 in the morning and 15.00-17.00 in the afternoon, with rush hour rates being twice as high as the normal rate. However, on December 10th 2018 it was discontinued with retroactive effect, reimbursing the congestion charge collected. This was due to a malfunction in the equipment at the toll gates, where cars had been charged the rush hour rate even though they passed the toll gate outside the time period where the congestion charge was active.

On March 25th 2019 congestion charge was reintroduced, with rates during rush hours twice the normal rates.

On February 10th 2020 further changes were implemented. The rates were increased with consumer prices and electric vehicles in TG1 lost the exemption from paying road tolls. Light electric vehicles with a toll tag are charged half the normal discounted rate, corresponding

to 9.20 NOK. Without a toll tag, electric cars are charged the normal rate. Further, congestion charge was once again discontinued. In 2020 the direction of toll collection was changed at the gates in the section *Risavika* and at the gate *Bybrua*. At *Risvika,* you pay on your way out of the section and at *Bybrua*, you pay in the northern direction. Also, at the *Ytre* section, you pay in direction Stavanger and not on your way to *Randaberg*.

Geographically today's sections form separate rings around the *Stavanger* city centre and *Sandnes* city centre, the suburban areas *Forus*, *Risavika*, *Randaberg* and *Stavanger Airport*. Even though the toll cordon consists of five sections, it works in practice as a single section, payment-wise. The rates are the same for all sections and both the monthly cap and hourly rule are common for all sections, with one exception: The *Hundvåg* tunnel opened in 2020 and has had toll collection since 1 February 2021. It is not a part of the Nord-Jæren toll cordon, but shares with the cordon a common hourly rule for TG1 and TG2 and a monthly cap for TG1. However, the rates for crossings in the tunnel are higher than for the toll cordon. This means that cars that cross both the tunnel and the toll cordon within an hour are charged for the first crossing independent of the rates.

Figure 4.4 displays the toll gates that are part of the Nord-Jæren toll cordon in 2021, where colors denote the six different sections.

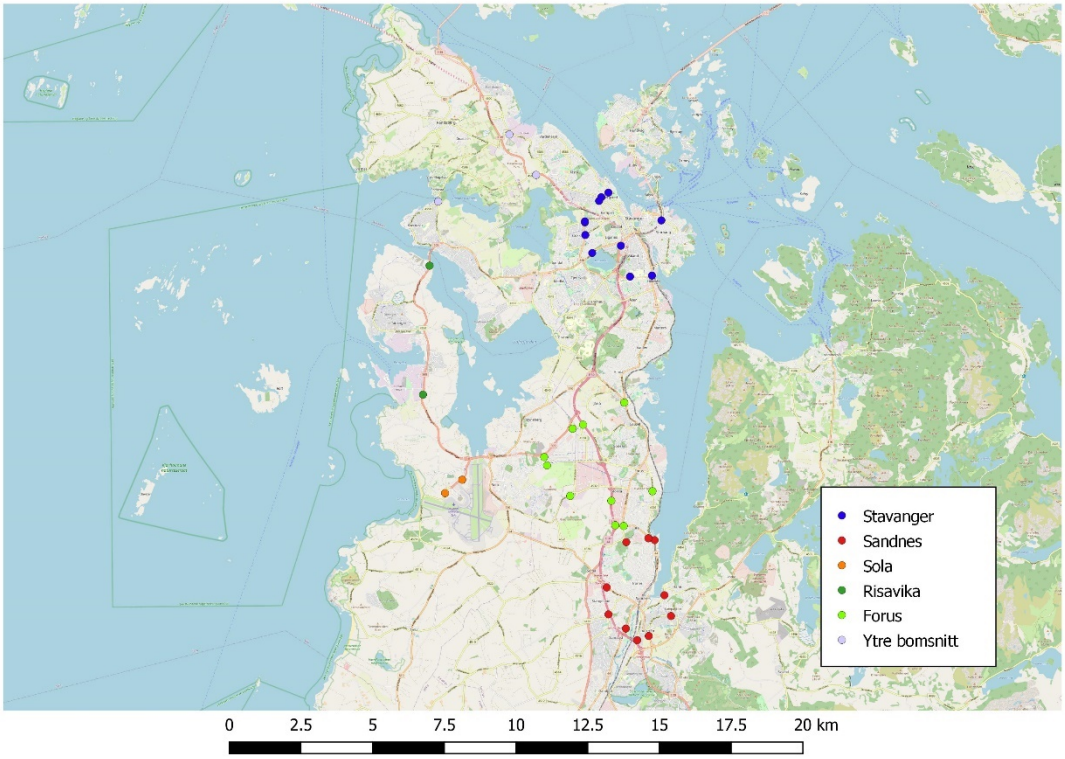


Figure 4.4: Toll sections in Nord-Jæren, 2021.

For more information, see Ferde (2021b, 2021c, 2021d), Statens vegvesen (2021), Bymiljøpakken (2021), Bro & Tunnelselskapet AS (2009) and Nord-Jæren Bompengeselskap AS (2000, 2013).

4.2 Other toll gates

The remaining data consists of toll gates that are or have been part of a single road project as well as the cordons in smaller Norwegian cities or areas, other than the four metropolitan areas described above. Toll cordons are still in operation in the following areas:

- Kristiansand *(Samferdselspakke for Kristiansandsregionen)*
- Haugalandet *(Haugalandspakken)*
- Askøy *(Askøypakken)*
- Bodø *(Bypakke Bodø)*
- Fredrikstad (and Sarpsborg from 2022) *(Bypakke Nedre Glomma)*
- Førde *(Førdepakken)*
- Grenland *(Bypakke Grenland)*
- Harstad *(Harstadpakken)*
- Nordhordland *(Nordhordlandspakken)*

In addition, two toll cordons have been discontinued:

- Tønsberg (Tønsbergpakken)
- Namsos (Namdalsprosjektet)

Discount schemes in road toll projects have varied a lot through the years, with peculiar local variants. Generally, you will have to sign an AutoPASS agreement and equip the vehicle with a toll tag to enjoy discounts, hourly rules and monthly caps. In 2017, a simplified discount scheme common for all toll road projects was introduced. Local discounts were mainly discontinued, being replaced by a discount of 20 percent for light vehicles when paying in arrears. The discount would apply to nearly all toll gates regardless of the toll tag issuer. Heavy vehicles would no more get a discount, on the basis of toll tags being mandatory for TG2 vehicles in 2015. Monthly caps and hourly rules however, are to a greater extent determined locally.

Before the discount scheme was changed, you would normally need to enter an agreement with the operator of each project to get a discount. Agreements paying in arrears was most prevalent, in the form of a punch card or a prepaid amount to an account. Those agreements would often give between 20 and 50 percent discount depending on number of crossings. Some projects had subscription models with unlimited crossings, typically for 1, 3, 6 or 12 months. Crossings in toll gates operated by another toll company than the one issued your toll tag, would normally give a 10 percent discount or no discount at all.

Some ferry connections charge road tolls in addition to the ferry ticket, but these projects are omitted from the dataset. The connections that have road toll collection include Mortavika–Arsvågen, Langevåg–Buavåg, Brekstad–Valset and Flakk–Rørvik, while the connections Gjermundshamn–Varalsøy–Årsnesm, Husavik–Sandvikvåg and Krokeide–Hufthamar have discontinued collection. See more information on Wikipedia (2021). Figure 4.5 displays other toll gates that were in effect in 2021, in relation to the four toll cordons described in Section 4.1.

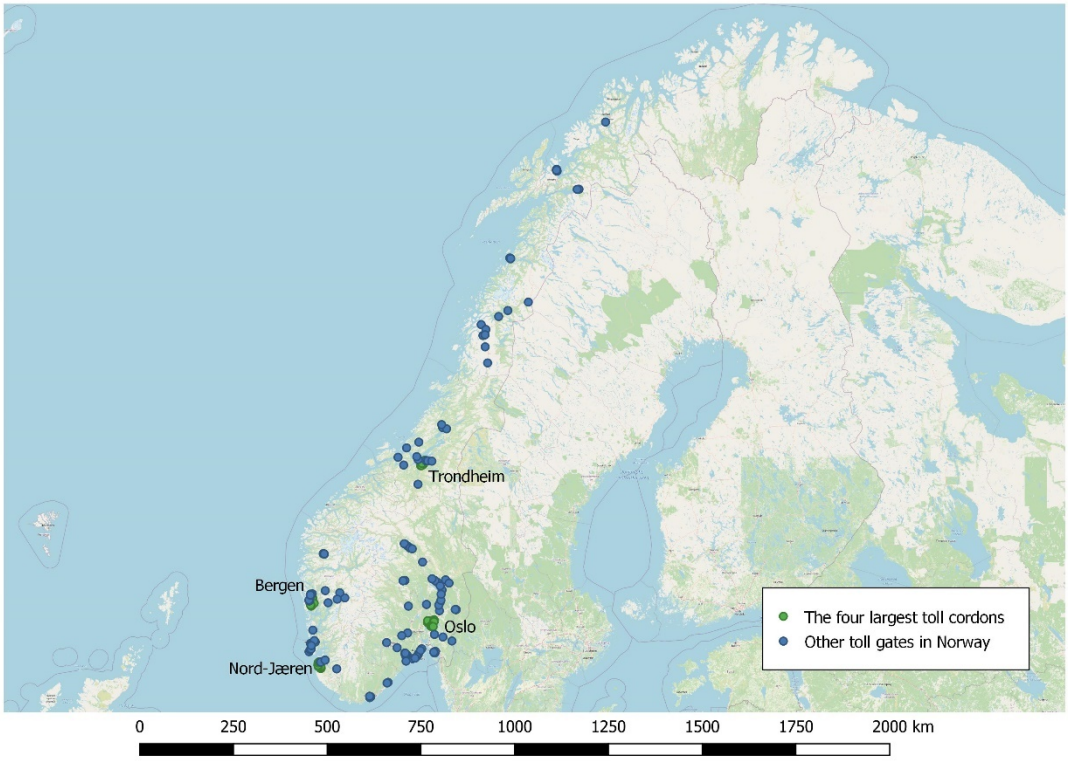


Figure 4.5: The four largest toll cordons and remaining toll gates in Norway, 2021.

For more information, see AutoPASS (2005, 2008, 2010, 2013, 2016), Nordvegfinans (2002, 2007, 2011), Oslofjordtunnelen (2000) Statens vegvesen (1998) and Tønsberg Hovedvegfinans (2015).

Next, we will list some of the major road toll projects that might be of special interest. The projects are listed chronologically, according to the time when road tolling was implemented.

Rennfast is the mainland connection for *Rennesøy* municipality, north of *Stavanger*. The project is a part of *Kyststamvegen*, the main connection from *Kristiansand* to *Trondheim* through the western part of Norway. The project consists of two tunnels (*Byfjordstunnelen* and *Mastrafjordtunnelen*), two bridges (*Asjesund bru* and *Åmøy bru*) and a ferry connection between *Mortavika* and *Arsvågen*. The project opened in 1992, and the price tag was 770 million kroners, financed solely through road tolls. The project was completely paid for March 15th 2006, but toll payments did not cease until July 28th the same year. Tolls collected between these dates went towards financing the *Finnfast* project. Rates were 90 NOK for passenger vehicles, 280 NOK for vans and 475 NOK for trucks.

Krifast is a project consisting of two bridges and a tunnel. The project connects *Kristiansund* and *Frei* to the mainland in the southern direction (while *Atlanterhavstunnelen* and *Atlanterhavsveien* connects *Kristiansund* to the mainland in the western direction). The project opened for traffic in 1992, and would be partly (61 percent) financed by road tolls through a 20 year period. The toll rates were similar to what the ferry rates had been. When the toll collection closed December 2nd 2012, the rates were 75 NOK for small vehicles and 425 NOK for large vehicles.

Imarsundet is a strait between *Stabblandet* and *Ertvågøya*. The strait was connected by a ferry until 2007, when a bridge along with new road connections opened. The rates were 95 NOK for small cars and 285 NOK for large cars, increasing by 10 and 30 NOK respectively in 2011. June 15th 2015, toll collection was abolished.

Eiksundsambandet consists of the bridge *Eiksundbrua* (405 meters), the tunnels *Eiksunds-tunnelen* (7765 meters), *Helgehorntunnelen* (1160 meters) and *Morkaåstunnelen* (630 meters) as well as 4.9 kilometres of new road. These links provide mainland connections for the island municipalities *Hareid*, *Herøy*, *Sande* and *Ulstein*. The connections opened February 23rd 2008, and 20 percent of the costs would be covered by road tolls. Rates were 76 NOK for small cars and 228 NOK for large cars. Toll collection was planned to last for a 15 year period; however, the project was completely financed in 2014 due to higher toll revenues than expected, and the toll gate closed at June 14th that year.

When ***Finnfast***, the mainland connection to *Finnøy* (an island north of *Stavanger*) opened in 2009, in the form of a subsea tunnel, light (heavy) cars were charged 200 (790) NOK in both directions. The rates were reduced in 2011 and again in 2019, to almost half of the initial rate (106 NOK for light vehicles, 35 NOK for heavy vehicles). In 2019, light electric cars were also charged 50% of the standard rate. Payments ceased in July, 2021. The reason for discontinuing the toll collection was a contribution from the Norwegian Parliament, that covered the down-payments on the tunnel about two years ahead of time.

Atlanterhavstunnelen is a subsea tunnel connecting *Averøy* to *Kristiansund*, about 5.8 kilometers long and 250 meters below sea level. The tunnel was scheduled to open in 2008, but the opening was delayed until December 19th 2009 due to delays in construction work. About 70 percent of the cost would be paid by road tolls. From day one, the rates were 85 NOK for light cars and 390 NOK for heavy cars, but 630 NOK for heavy cars above 12.4 meters. These rates were routinely increased every second year, by 2-5 NOK for small cars and 10-30 NOK for large cars. January 1st 2019 was the last time the rates increased, to 102/475/775 respectively. Moreover, the same date the cost for small electric cars increased from zero to 50 percent of the non-ZEV rate. The tunnel was scheduled to be completely financed in 2025; however, during government negotiations in 2020 it was decided that the tunnel should be paid with government funds and that road tolls should be removed. July 1st 2020 the toll gate closed, as the last existing manually operated toll gate in Norway.

Hardangerbrua is a bridge across *Eidsfjorden* between *Ulvik* and *Ullensvang* municipality that replaced a ferry connection in 2013. In case cars travelling between *Bergen* and *Oslo* choose to drive across *Hardangervidda*, which is the fastest route, they would go across this bridge. Toll collection started the same date the bridge opened to the public, August 17th 2013, with collection in both directions at the rate 150 (600) NOK for light (heavy) vehicles and full exemption for electric vehicles.

Hålogalandsbrua in *Narvik*, *Nordland* opened December 9th 2018, and toll collection started December 10th. The rates were 113/280 NOK for light/heavy vehicles. As part of the project *Trædalstunnelen* was built as well, to replace an older road where there was danger of landslides. In conjunction with the opening of *Trædalstunnelen*, a toll gate was established at E6/E10 *Leirvik* September 12th 2015, three years before *Hålogalandsbrua* was complete. The rates for this toll gate were 43/129 NOK for light/heavy vehicles. Due to additional public earmarked funding («*Tilskudd for reduserte bompenger utenfor byområdene*») the rates at

Hågalandsbrua were reduced by 20 percent, to 90/225 NOK in 2020, while the rates at *Trædalstunnelen* (E6/E10 *Leirvik*) were reduced by about 50 percent, to 22/50 NOK.

Ryfast is a subsea tunnel system with toll collection between the city of *Stavanger* and the area *Solbakk* in *Strand* municipality. The tunnel system, replacing ferry routes, consists of the *Ryfylke* tunnel from *Solbakk* to *Hundvåg* and the *Hundvåg* tunnel from *Hundvåg* to *Stavanger*. The *Ryfylke* tunnel opened officially to traffic December 30th 2019, as the longest (14.3 kilometre) and deepest (292 meters below sea level) subsea tunnel in the world. The opening of the *Hundvåg* tunnel was delayed until April 22nd 2020. Toll collection for the *Ryfast* project was delayed by 13 months due to technical difficulties, and did not start until February 1st 2021. The standard rate is 140 (420) NOK for light (heavy) vehicles in the *Ryfylke* tunnel, and 28 (76) NOK in the *Hundvåg* tunnel, with collection in both directions and a monthly cap of 40 and 75 crossings for *Ryfylke* and *Hundvåg*, respectively. The *Hundvåg* tunnel has an hourly rule, but the *Ryfylke* tunnel does not. For both tunnels, there is a standard 20 percent discount for cars with an AutoPASS tag, and light electric vehicles with a tag pay 50 percent of the discounted rate.

4.3 Descriptives: Development over time

This section attempts to illustrate how toll schemes have changed over time. All figures are over-simplified for the purpose of readability: for all details, see the dataset and additional information provided in sections 4.1-4.2. All figures relate to rates for small (i.e. passenger) cars; diesel cars in cases where rates for diesel and gasoline cars differ. All rates presented in this section are standard rates in current prices, before any discounts are deducted.

Figure 4.6 illustrates changes over time in rates for the four largest urban areas that were described more in detail in Section 4.1.

Rates in Figure 4.6 reflect non-discounted rates for small diesel cars (rates are slightly lower for gasoline cars in Oslo and Bergen for the most recent years). When comparing rate changes over time, there are several aspects to be mindful of:

First, the toll burden faced by households will not only be affected by the rates, but also the number of toll gates in each (section of each) toll cordon. The number of toll gates has increased over time, although a few toll gates have been decommissioned as well.

Second, the toll burden will depend on the direction of collection. In some cases, tolls are collected both ways, in other cases tolls are only collected to or from the city center. The direction of collection has changed over time, and is also often different between sections of the same toll cordon.

Third, the total toll burden associated with a trip will depend on hourly rules. Hourly rules are in place in all toll cordons; however, sometimes they are specific to certain sections or even certain toll gates within each section. This is also something that varies across cities and over time. See Section 4.1 for more information regarding changes in hourly rules.

For Oslo, the figure shows that rates for *Osloringen* were significantly reduced in 2019, to the same level as *Bygrensen*. However, a new section (*Indre ring*) was added, and two-way collection was introduced for *Osloringen*. Thus, it is difficult to say whether the changes increased or reduced the toll burden, without a certain route in mind.

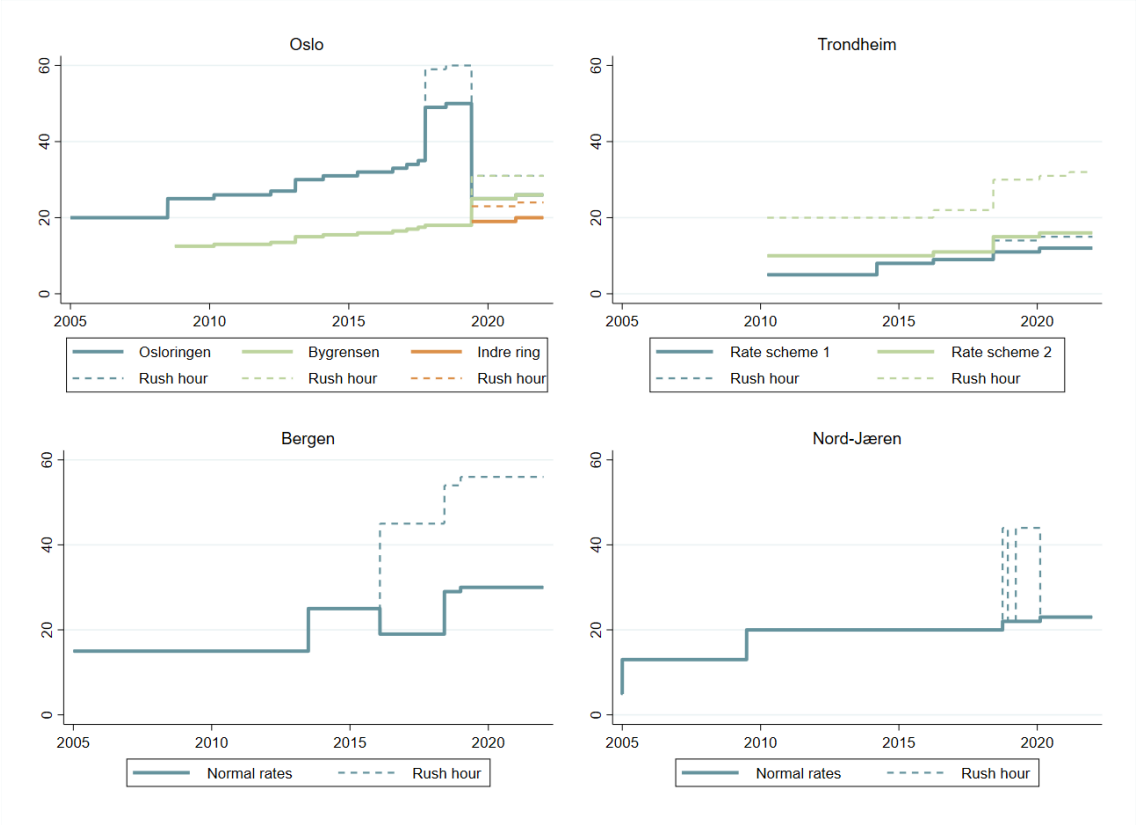


Figure 4.6: Changes in rates over time for the toll cordons in the four largest cities. Rates reflect the cost for small diesel cars. Current prices.

For Trondheim, the figure displays the two most common pricing schemes. Pricing scheme 1 (where a congestion charge was introduced in 2018) applies to the sections *Byåsen*, *Omkjøringsveien* and *Tonstad*, while pricing scheme 2 (where a congestion charge was in place since the beginning, i.e. 2010) applies to the sections *Klæbu*, *Sluppen*, *Sør* and *Øst* (see Figure 4.3). However, note that *Byåsen, Klæbu* and *Tonstad* were not opened until March 2014. Furthermore, the toll gates at *Kroppan bru* (labelled *Omkjøringsveien 1* in the dataset) followed pricing scheme 1 until March 2014. This means that the *Kroppan bru* toll gates had a congestion charge in place from 2010 until 2014, and again from 2018.

For Bergen, the figure displays the pricing scheme for the first section, labelled *Bergen 1* (see Figure 4.2). The toll gates that constitute *Bergen 2* follow the same pricing scheme as *Bergen 1* outside rush hours, but there is no congestion charge in place.

Nord-Jæren has the simplest toll cordon, as all sections share the same rates and hourly rules. What is special about the rates here is that those that paid during the first period of congestion charge, from October to December 2018, were retroactively reimbursed. Thus, whether the first period of congestion charge should be included in the data or not will depend on the scope of the analysis.

Figure 4.7 displays the remaining toll gates in Norway, outside the four aforementioned urban areas. The left panel illustrates the average rate per toll gate, while the right panel shows the overall number of toll gates.

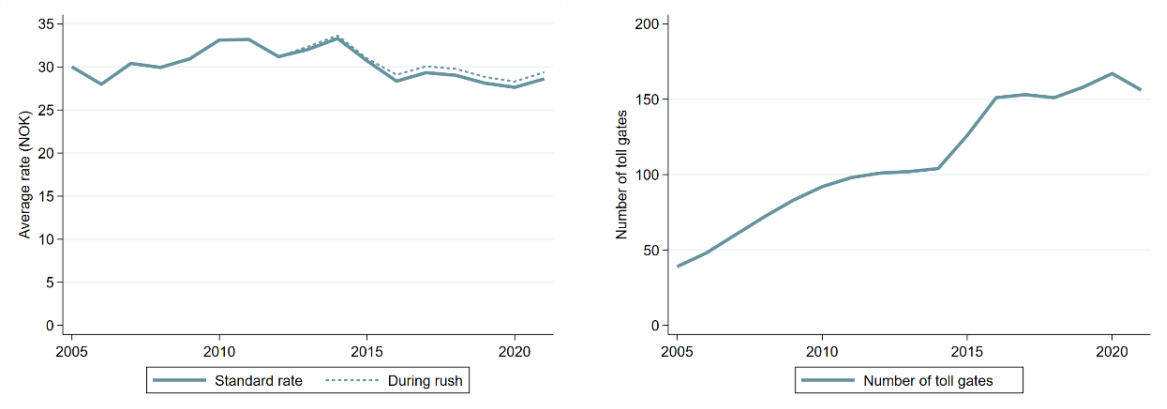


Figure 4.7: Toll gates outside the four major cities. Rates reflect annual averages for small, non-ZEV vehicles.

Both rates and number of toll gates are measured at the end of each year, at December 31st. The average rates as shown in the left panel reflect the cost, excluding discounts, for small, non-ZEV vehicles, and take neither direction of collection nor hourly rules into account. According to the right panel, the number of toll gates outside the major cities has increased gradually, from 39 in 2005 to 156 in 2021. The average rate per toll gate however has remained fairly constant, varying between 28 and 33 NOK. Rush hour rates were introduced in Kristiansand in 2013 and Grenland in 2016, with rates about 50 percent higher than the normal rates. However, as these toll gates constitute a small share of the total number of toll gates, the average difference between rush and non-rush rates is less than 1 NOK.

The average rates displayed in Figure 4.7 mask large differences across toll gates. Rates for small non-ZEVs can be as low as 5 NOK, and as high as 200 NOK (in the case of Finnfast). Some of the more expensive tolls have ceased collection, which is why the average toll rate has declined compared to 2014 levels. To better illustrate how rates have changed over time, Figure 4.8 displays histograms for selected years, with the number of toll gates along the y-axis and 10 NOK bins (rates excluding discounts for small non-ZEVs outside rush hour) along the x-axis.

The histograms illustrate that the increase in the number of toll gates over time is driven by the 0-50 NOK segments.

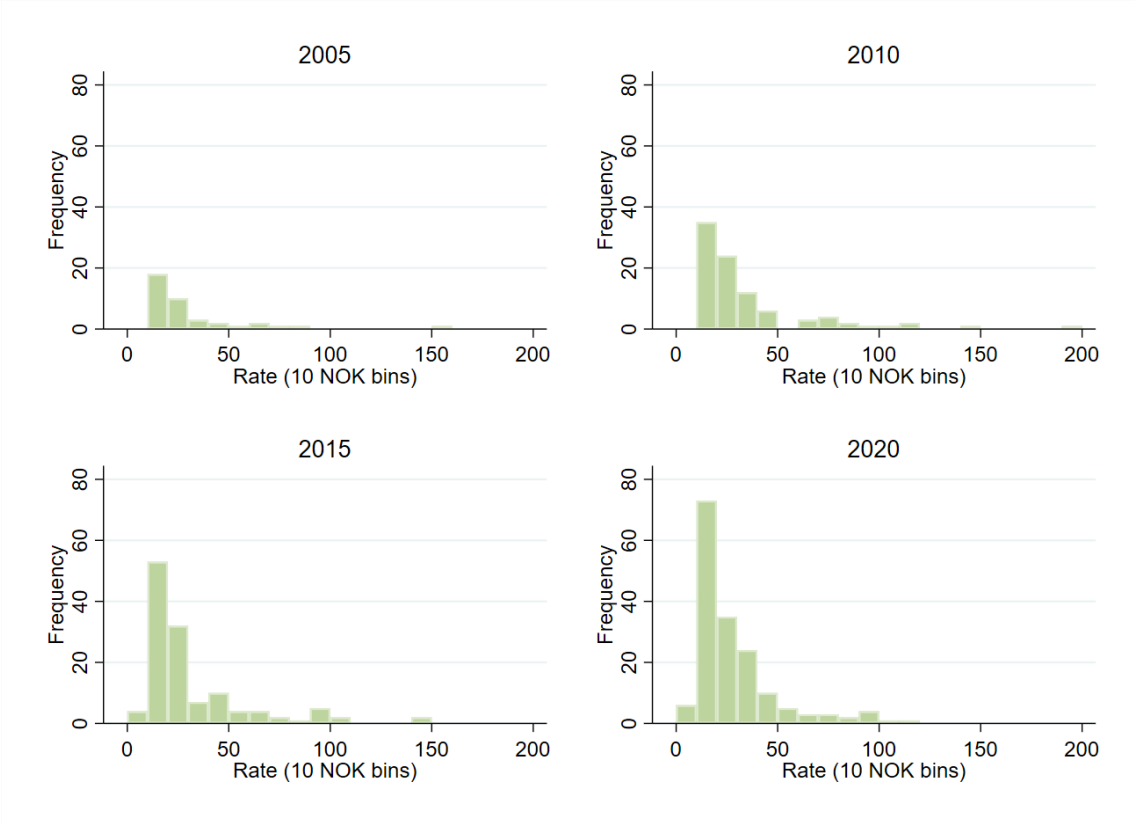


Figure 4.8: Histogram of number of toll gates outside the four largest cities by year and cost segment. Segments reflect the cost for small non-ZEVs outside rush hour.

5 Road toll on trips between neighborhoods in Norway

This chapter describes an application of the toll dataset. The application consists of using the toll data in conjunction with road network data, to create a new dataset with historical data on toll exposure at the origin-destination (OD) level.

Origins and destinations are centroids of Basic Statistical Units (*grunnkretser*), henceforth referred to as neighborhoods.[7] A "neighborhood" is the smallest geographical unit recorded in public statistics in Norway. There are about 14,000 of these neighborhoods, with an average of less than 400 individuals (less than 200 households) residing in each. The geographical area of each neighborhood varies, but they tend to be smaller in densely populated areas. Figure 5.1 displays the neighborhoods in and around Oslo as an illustration.

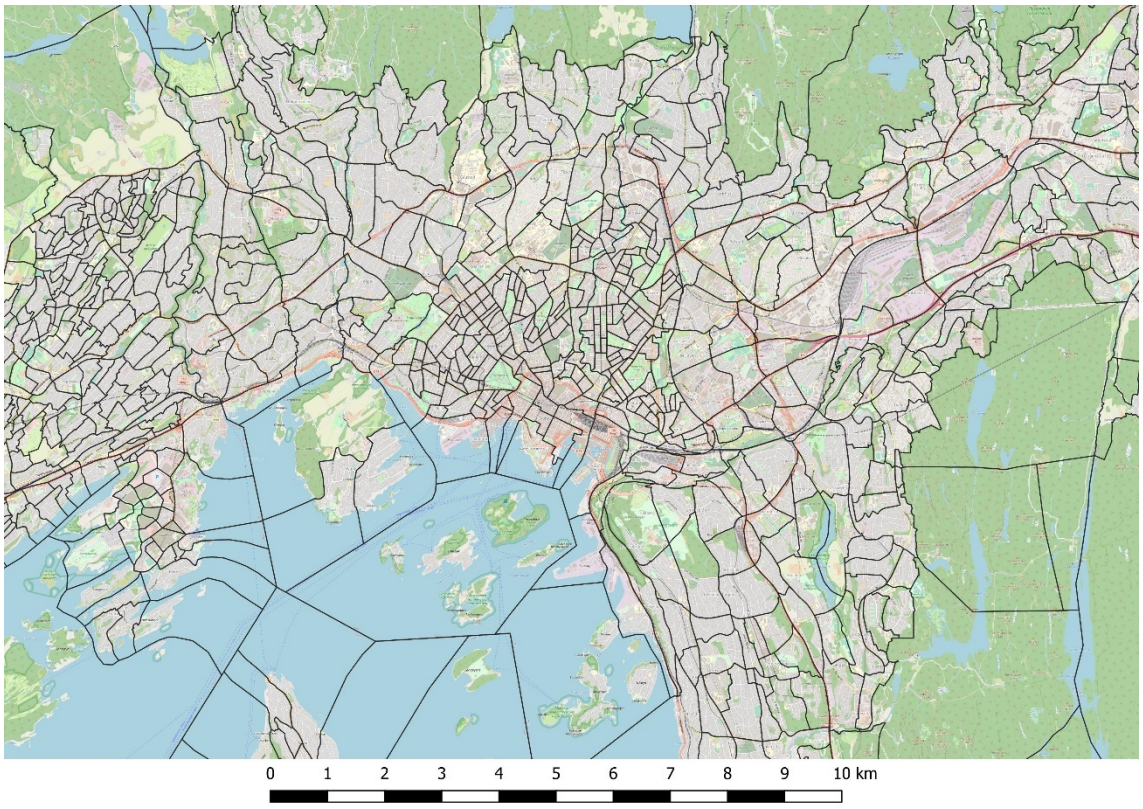


Figure 5.1: Neighborhood borders in and around Oslo.

For today's level of toll exposure, the same type of toll exposure data can be obtained from the regional transport models of Norway. Data from these models are most likely better suited than the dataset described here for many purposes, as they are continuously updated and quality checked by a large team of model operators. However, historical level-of-service

[7] See e.g. https://www.ssb.no/en/klass/klassifikasjoner/1/koder.

data has not been established, which implies that toll exposure from the regional transport models in previous years is not available.

Section 5.1 describes briefly the OD level data on toll exposure, including the main assumptions and limitations. Section 5.2 documents how the data is established, while Section 5.3 provides some descriptive analyses as an illustration of how these types of data can be used.

5.1 Description of dataset

The dataset contains toll exposure on car trips between all neighborhood pairs in Norway, i.e. almost 200,000,000 observations. Toll exposure is calculated as the sum of toll payments along the fastest route of a road network between centroids of neighborhood pairs. As pathing algorithms are computationally intensive, several simplifications has been made:

- Travel times are calculated according to the speed limit, hence they do not take congestion into account (this might or might not be desirable, depending on the scope of the analysis).
- The road network is fixed, and will therefore lack information about roads opening or closing. This means that the fastest route between two neighborhoods is the same for all years – changes over time in toll exposure can be solely attributed to changes in toll rates or the location of toll gates. It would have been possible to include changes in the road network over time, but with two main caveats: First, using year-specific road networks for 2005-2021 would imply a 17-fold increase in both the manual labor and the computational burden. Second, several of the changes made to the digital representation of the road network over time are improvements to the network data rather than changes to actual roads. Thus, some of the changes in calculated travel routes over time would be unrelated to actual changes in road infrastructure.
- The route is assumed to start and stop at the road link closest (in Euclidian distance) to the centroid of the neighborhood. This might not always be a good approximation. First, because the geographical centroid do not necessarily represent the center of activities. Second, if the closest road link is a particular lane of a major road with limited connectivity, a driver that is placed on that road link might be forced to continue in the 'wrong' direction for a significant distance before it is possible to turn around.
- Toll levels are recorded annually. The values used are the toll levels measured at December 31st each year for the period 2005-2021.
- The only toll-related variables we keep in the data are (a) toll exposure net of discounts for passenger non-ZEVs (diesel cars) during rush hour and (b) toll exposure net of discounts for passenger BEVs during rush hour. The reason for focusing on passenger vehicles and rush hour is that the dataset is created with commuting trips in mind.
- Since our focus has been solely on two-way trips, we have not kept track of the direction of collection. Toll payments are always allocated to road links in both directions, but rates are divided by two for toll gates where there is one-way collection (the only exception to this is when the road is a one-way road, meaning

that the toll gate can never be passed from two directions). This means that toll levels should be correct when considering the whole trip (both directions).

For the analyses we have had in mind when creating the data, the simplifications above are acceptable. For other applications however, they might not be. Even with the simplifications above, the data takes several days to construct, and the final dataset is about 20 GB.

The neighborhood division is from 2014,[8] while the road network used (Elveg) is from 2015. Geospatial data on both neighborhoods and road networks are publicly available and can be downloaded from the web page of The Norwegian Mapping Authority. Additionally, the same road network can be downloaded from NVDB, through the The Nowegian Public Roads Administration's web page.[9]

In addition to the annual toll variables, the dataset has information on travel time, travel distance, distance where the road has a bus lane and travel distance where the route is a ferry connection rather than a road (ferry charges are not included). All the additional variables are straightforward to extract from the road network as soon as the route is determined.

5.2 Construction of dataset

This section is meant as a technical documentation, and could be skipped by the casual reader.

5.2.1 Toll gate specific variables

The *most precise way* to calculate toll exposure between OD pairs would be to keep track of all individual toll gates you would need to pass on a certain route, and calculate the amount of tolls retroactively based on the combination and order of, and time between, each of these toll gates. This however is infeasible due to the high data requirements (one variable for each toll gate would need to be kept during the route calculations).

The method that would be *least computationally burdensome* would be to allocate certain toll rates to certain road links, and calculate the total toll exposure by summing over all rates for the links along the route (this would require one variable per year, e.g. "tolls in 2010"). This however would not allow us to capture interdependencies between toll gates (e.g. hourly rules).

[8] Neighborhoods have an 8-digit identifier, where the first two digits identify the county, while the first four digits identify the municipality. This means that the identifier will change whenever counties or municipalities change. Neighborhoods also tend to be split whenever their population increases significantly. There are fewer examples of neighborhoods being merged. See e.g. https://www.ssb.no/metadata/alle-endringer-i-de-regionale-inndelingene (Norwegian only) for more information on changes in neighborhood identifiers over time.

[9] See e.g. https://www.vegvesen.no/fag/teknologi/nasjonal-vegdatabank/ (Norwegian only). NVDB and Elveg are two separate databases, but the geospatial information on road networks is the same (Elveg is exported from NVDB). Elveg is maintained by The Norwegian Mapping Authority, while NVDB is maintained by The Nowegian Public Roads Administration.

We have gone for a hybrid approach, where the toll cordons around Oslo, Bergen, Trondheim and Nord-Jæren (henceforth referred to as OBST) are treated separately, while the remaining toll gates are lumped together. This means that we are able to take hourly rules into account for OBST, but not for the remaining toll gates.

For the **non-OBST toll gates**, we sample toll rates at Dec 31st each year, to get a finite set of rates for 2005-2021. In the period 2018-2021, we also include rates for zero-emission vehicles (before 2018, these rates were zero everywhere). As the main focus is on the commute, we assume that households are able to get the highest discount available (the highest discounts are typically meant for commuters), and multiply every rate by 1 minus the discount rate. As stated earlier we multiply the rates of all one-way toll gates by 0.5. The rates will be correct for all two-way trips – except for the few cases where completely different routes are chosen for each direction.

For the **OBST toll gates**, we want to count the number of toll gates that are passed on a certain route, such that the associated cost can be added later taking hourly rules into account. The toll gates are grouped into categories based on the rate scheme and the time period each gate was open. The 23 chosen categories are summarized in the table below.

Table 5.1: Selected categories for toll cordon sections.

City	Toll cordon section	Time period open	Variable name
Oslo	Osloringen	2005-2021	o_or_1
Oslo	Osloringen	2019-2021	o_or_2
Oslo	Indre ring	2019-2021	o_ir
Oslo	Bygrense	2008-2021	o_bg_1
Oslo	Bygrense	2019-2021	o_bg_2
Bergen	Bergen 1	2005-2021	b_1
Bergen	Bergen 2	2019-2021	b_2
Trondheim	Byåsen	2014-2021	t_b
Trondheim	Klæbu	2014-2021	t_k
Trondheim	Omkjøringsveien 1	2014-2021	t_o_1
Trondheim	Omkjøringsveien 2	2010-2021	t_o_2
Trondheim	Sluppen 1	2010-2021	t_s_1
Trondheim	Sluppen 2	2010-2021	t_s_2
Trondheim	Sør	2010-2021	t_s
Trondheim	Tonstad	2014-2021	t_t
Trondheim	Øst	2010-2021	t_o
Nord-Jæren	Opprinnelig	2005-2017	nj_o
Nord-Jæren	Stavanger	2018-2021	nj_st
Nord-Jæren	Sandnes	2018-2021	nj_sa
Nord-Jæren	Forus	2018-2021	nj_fo
Nord-Jæren	Sola	2018-2021	nj_so
Nord-Jæren	Risavika	2018-2021	nj_ri
Nord-Jæren	Ytre bomsnitt	2018-2021	nj_yb

Note that the time intervals above do not correspond perfectly to the actual data. In reality, there is variation between some toll gates within each category (e.g. one toll gate in Osloringen opened in 2017). However, these simplifications are necessary to reduce the number of variables, in order to speed up calculations.

The procedure above has produced two simplified datasets on the toll gate level: the non-OBST toll gates have variables for annual rates, while the OBST toll gates have 23 dummy variables for membership to the groups above.

5.2.2 Matching toll gates to road links

Next, toll gates are matched to the correct road links. This consists of two steps:

1. Load the road network and the toll gate coordinates into a GIS software, and match toll gates automatically to the nearest road link;
2. Go through each automatic merge manually and make necessary changes.

The main reason the second step is necessary, is because toll gates sometimes will have to be matched to multiple road links, as illustrated in Figure 5.2 (the road network is blue and the red circle in the middle is the coordinate of a toll gate). As the figure illustrates, the actual road where toll is collected is split in four road links, one for each lane.

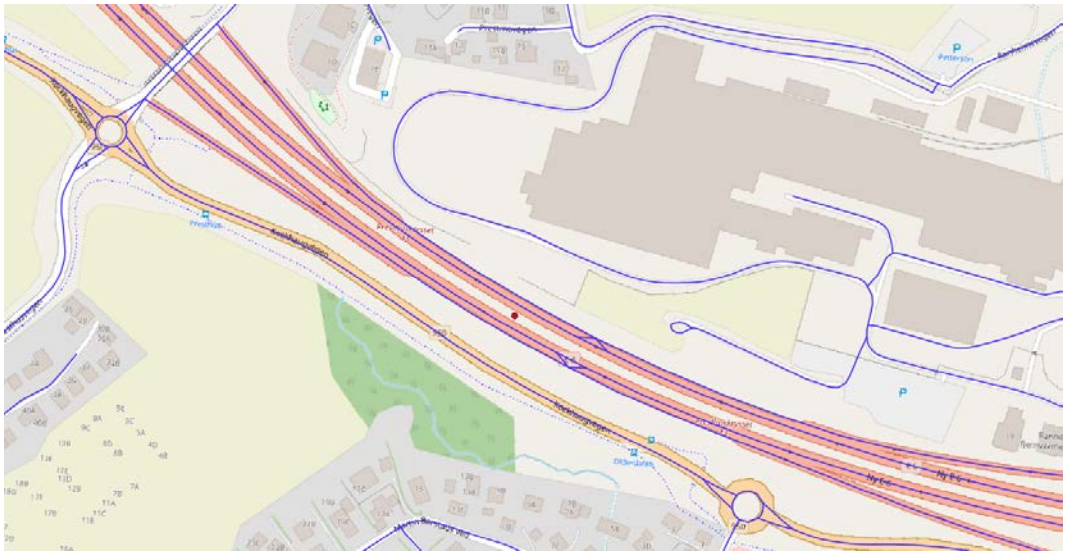


Figure 5.2: An illustration where one toll gate (red dot) should be matched to four separate road links (blue lines).

Some toll gates are also matched to the wrong road link, in particular in some cases where toll gates should be located on access ramps, or in tunnels/on bridges where different roads intersect at different altitudes.

Moreover, some toll gates appear on roads that are not part of the road network. This is because the road network is from April 2015, while the toll gate positions cover all years from 2005 to 2021 (this is not a major problem as there has been few large roads built in the time period we consider). Figure 5.3 provides an illustration, where the maps clearly illustrates that roads on the background map are not part of the road network (the blue lines). These toll gates are not included in the calculations of OD toll exposure, as they do not match the road network that is used.

Figure 5.3: Two illustrations of mismatches between the road network and the actual location of the road.

When this process is complete, the road network has a new set of variables: the annual rates for the non-OBST gates and the toll cordon section dummies for the OBST gates. These variables are zero for all road links that have not been matched to a toll gate.

Note that the data on toll gates include some information that would allow each toll gate to be merged to the correct placement on the correct road link automatically. This is in particular the variable “road_reference_system”. However, this variable is incomplete for older observations. Moreover, there has been changes in the road reference system used in NVDB over time. Hence, we felt that doing the whole process manually would produce a more reliable result.

5.2.3 Creating OD pairs from neighborhood borders

With the geometry of neighborhoods available, this step is straightforward with GIS software. We created the centroids of neighborhood polygons as coordinates in QGIS, and used the NNJoin plugin to match each coordinate to the nearest node of the road network. The dataset of neighborhoods with node IDs is then expanded to neighborhood-by-neighborhood, and rows where the two neighborhood-IDs are equal are removed.

5.2.4 Calculating the fastest route between OD pairs

The main (and most computationally heavy) step is to find the correct routes in the network graph. We have chosen to use the time-minimizing route along the network – this is likely to cover the main arterials which again are more likely be exposed to toll payments. Route attributes are obtained in the following way: first, the fastest route for each node pair is found. Then, the attributes we want to keep are summed over all road links contained in the fastest route. The only attribute the minimization problem takes into account is “time use”, but we also sum over “distance”, “distance by bus lane”, “distance by ferry”, the annual toll rates as well as the indicator variables for passing OBST toll gates.

We use Dijkstra’s algorithm for pathing. This works by looking through combinations of nodes for the quickest path (the path that minimizes the sum of the time variable), and storing that combination in memory in case the node pair in question is relevant for subsequent calculations. The advantage is that the computational speed per node pair improves drastically the more node pairs that are considered. The disadvantage however is that the internal memory of the computer fills up quickly (there are about 3.2 million road

links in the network, and more or less infinitely many ways in which these road links can be sequenced together). We are grateful to Simen Gaure at the Frisch Center for help setting up the calculations on a powerful computer with high internal memory storage, saving weeks of computation time. This step is done in *R* using a slightly modified version of the *findPath* package.[10]

5.2.5 Final formatting

From the previous step we have calculated the toll exposure per OD pair for the non-OBST toll gates. The final step is to add toll payments for OBST toll gates based on the sums of the 23 toll section dummies. This is straightforward if we assume that hourly rules always apply – i.e. no route through the same section of a toll cordon takes more than one hour. This means that an amount is added to the total toll exposure if the toll section dummy is greater than zero, independent of how many times that section is crossed.

Sometimes the combination of toll cordon sections also matter, in case hourly rules cover several sections. As an example, Table 5.2 illustrates the toll burden in Oslo in 2021 for a one-way trip for diesel cars during rush, depending on which toll cordon sections that are crossed. *Osloringen* and *Indre ring* (but not *Bygrensen*) has a common hourly rule.

Table 5.2: The average toll burden per trip, taking into account the hourly rule for small diesel cars during rush in Oslo 2021.

Bygrensen (31/12.4 NOK)	Osloringen (31/24.8 NOK)	Indre ring (24/19.2 NOK)	Total toll burden
X			31/12.4 NOK
	X		31/24.8 NOK
		X	24/19.2 NOK
X	X		62/37.2 NOK
	X	X	31/24.8 NOK
X		X	55/31.6 NOK
X	X	X	62/37.2 NOK

Each cell in the table has two numbers: the first number is the toll rate before taking into account discounts and the fact that *Bygrensen* only has one-way collection. The second number subtracts the 20 percent AutoPass discount and divides the *Bygrensen* rate by two. The table illustrates for instance that passing all three toll cordon sections with a diesel car and an AutoPass tag during rush costs on average 37.2 NOK one way (74.4 NOK when driving back and forth with more than one hour in between).

The same calculations are done for all toll cordons and all years, 2005 to 2021, taking into account changes in rates, discounts, hourly rules and one/two-way collection.

[10] See e.g. https://search.r-project.org/CRAN/refmans/ggm/html/findPath.html. An equally good alternative is the *pgr_dijkstra* command from *pgRouting*, an extension to *PostGIS/PostgreSQL* (see e.g. https://docs.pgrouting.org/3.1/en/pgr_dijkstra.html).

Finally, observations where the Dijkstra algorithm were unable to find a route through the road network are deleted. This happens rarely, but may occur in cases of “islands” of road links that are disconnected from the rest of the network.

5.3 Descriptives: differences across the population

In this section we provide descriptive evidence of toll exposure by matching the OD-level toll exposure above to register data on the universe of Norwegian households (annual observations for the years 2005, 2011, 2015 and 2019). From the registers, we observe the residence neighborhood of each household as well as the workplace neighborhood of each individual. This allows us to link toll exposure to household specific demographic and geographic traits. The measure of toll exposure is the sum of toll payments in both directions for the fastest route between the road links closest to the centroids of the residence and the working neighborhood. Since 2019 is the final year for which we have register data, we are not able to show this measure for subsequent years.

All figures in this section represent average daily toll exposure per working individual per household. This means that toll exposure for couples where both are working is the average of both spouses, while toll exposure for couples where one is working is the toll exposure for the working individual. To be included in the analysis, an individual must be over 18; be one of the heads of the household (young adults living with their parents are not included); earn more than 1G (through wages) annually; be registered as an employee at a firm located in Norway; and have a work distance (along the road network) of less than 150 kilometers. For individuals with several employers, the workplace location of the highest earning job is used.

According to this measure, the average daily toll exposure in Norway has increased from 4.4 NOK in 2005, to 7.6 NOK in 2011, 10.1 NOK in 2015 and 19.8 NOK in 2019. The shares of working households where toll exposure on the commute was non-zero were 28.0 percent in 2005, 34.9 percent in 2011, 36.7 percent in 2015 and 44.4 percent in 2019.

Figure 5.4 displays how average toll exposure on the commute for working adults vary across income deciles, and has varied over time. The figure displays toll exposure for singles and couples separately.

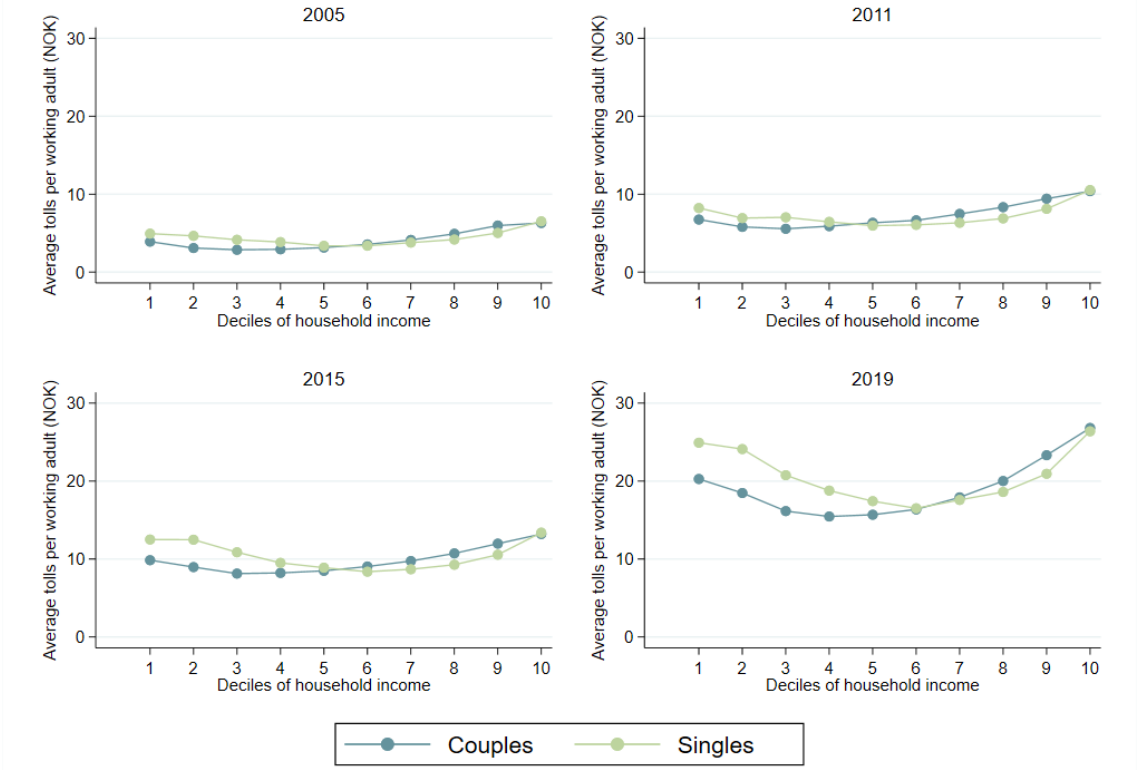


Figure 5.4: Daily toll exposure on work commute by year and income decile.

The figure illustrates how toll exposure has increased over time, and that exposure is increasingly u-shaped in income. The reason for this is a general increase in toll levels in and around cities: Major cities tend to have higher income levels in general, while also being inhabited by a large proportion of students and young adults that are typically located in the left of the income distribution. Young adults are more likely to live alone, which explains why toll exposure increases relatively more over time for singles in the left of the income distribution.

Note that there are several aspects relating to *actual* toll payments this measure does not capture. This includes (a) whether the individual can (partly) avoid tolls by having access to a BEV; (b) whether the individual drives to work at all;[11] (c) whether there exists an alternative route with zero or lower toll payments, and (d) how much longer this alternative route is. Importantly, this measure only considers commutes, and not any other trip types. The primary reason for focusing on commutes is that the residence-workplace combination is the only OD pair we have information about from micro data at the household level.

Figure 5.5 illustrates the same measure of toll exposure for the same years by averages within residence neighborhoods. For confidentiality reasons, neighborhoods with a small number of valid observations are given a value based on the average in the municipality that year. Average toll exposure is truncated at 100 NOK.

[11] In cities, where the toll exposure tends to be higher, car ownership is lower, public transport accessibility is better and distances are shorter. This means that individuals are more likely to live within walking or cycling distance of their workplace, and thus be unaffected by toll exposure on their commutes. Moreover BEV ownership is also higher in cities, and BEVs pay somewhere between zero and 50 percent of the standard rate.

Figure 5.5: Daily toll exposure (NOK) on work commute by year and neighborhood of residence.

The figure illustrates that the share of Norway that is exposed to tolls has increased over time, and that the level has increased over time in most areas. Toll exposure is most prominent around the major cities Oslo, Bergen, Trondheim and Stavanger. However, the map also shows several other areas where the toll burden has increased, such as the far south of Norway (around the city *Kristiansand*) and the county *Nordland* (e.g. the cities *Bodø* and *Mo i Rana*). Although this macro-view illustrates geographical differences, one should have in mind that the size of the areas do not correspond well to the number of households

affected. Neighborhoods with few households tend to be large, while densely populated neighborhoods in cities are too small to be visible on the maps.

As BEVs were completely exempt from paying tolls until 2018, and partly exempt in later years, we would expect households that are exposed to tolls to be more likely to purchase and own BEVs. We can examine whether this is the case by merging data on car ownership from the central motor vehicle register to each household by means of the person identifier.

Figure 5.6 displays the share of households that acquired a BEV in 2019 by income and whether they are exposed to tolls on their commute. There are about 2.6 million valid households in the dataset in 2019, and about half of them are couples. Setting toll exposure to zero for households where adult members are unemployed, about 23 percent of singles and 39 percent of couples are exposed to tolls.

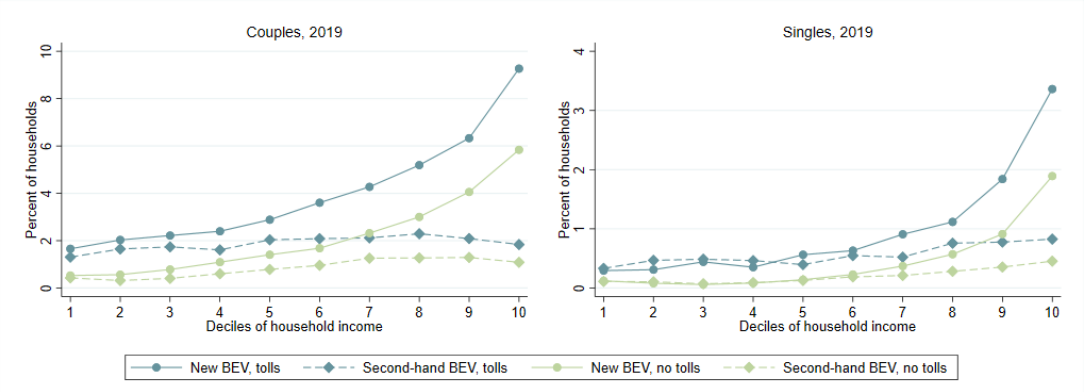


Figure 5.6: BEV acquisition by toll exposure and income decile.

We stress that these figures are purely descriptive, and not meant to depict any causal relationship. For instance, both toll exposure and BEV ownership tends to be higher in cities. For studies where this type of data is used to estimate the causal effect of toll exposure, see e.g. Isaksen and Johansen (2021) and Halse et al (2022). Although the share of households that acquired a new BEV in 2019 was less than 2 percent nationally, the figure illustrates that it was almost 6 percent for the richest decile of couples that were not exposed to tolls, and more than 9 percent for the richest decile of toll exposed couples. Second-hand BEV acquisition is more evenly distributed throughout the income distribution, but still much higher for toll exposed households. Figure 5.7 provides the same illustration, but of BEV ownership rather than acquisition.

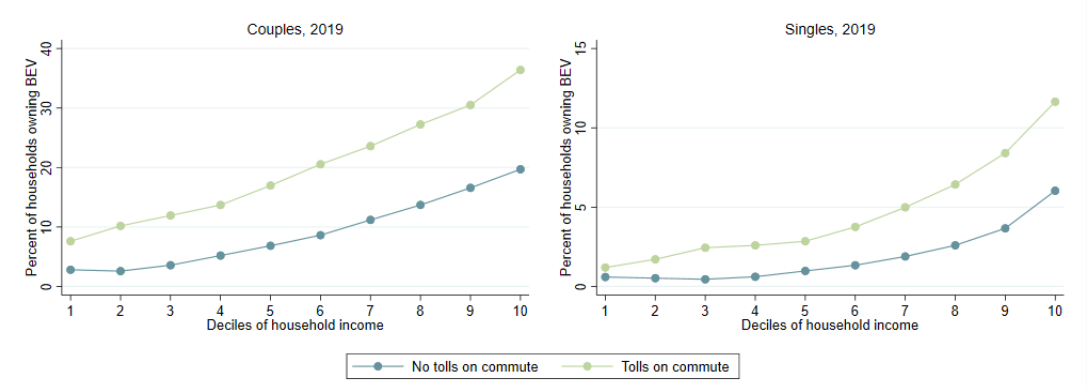


Figure 5.7. BEV ownership by toll exposure and income decile.

When it comes to car ownership the differences are even larger. The share of BEVs among toll exposed households is about twice as large as for the remaining households. This is as expected: since tolls for BEVs increased somewhat from 2018, it is likely that tolls played a larger role in car acquisition decisions prior to this.

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Appendix

A 1. Downloading historic toll data from NVDB

```
"""
----- RETRIEVE DATA FROM NVDB API USING PYTHON ------
API documentation: https://api.vegdata.no/
This script is based on a script from Jan Erik Jensen Norwegian Public
Roads Administration:
https://github.com/LtGlahn/workinprogress/blob/historisk-
riksveg/hentrv532.py
"""

# Measure the run time of the script
from datetime import datetime  # datetime is a module for manipulating
dates and times
t0 = datetime.now() # save the start time

# Make sure to have the following libraries installed:
import pandas as pd  # pandas is a data analysis and manipulation library
import nvdbapiv3

"""
nvdbapiv3 is a library for retrieving data from Nasjonal vegdatabank
(NVDB).
Documentation is available on GitHub: https://github.com/LtGlahn/nvdbapi-V3
For the library to work, create a json-file in the project directory named
'nvdbapi-clientinfo.json'
with the following content:
{ "X-Client" : "NVDB Rapporter",
 "X-Kontaktperson" : "ola@nordmann.no" }
Notepad++ is a convenient source code editor for creating json-files:
https://notepad-plus-plus.org/downloads/
"""

def date2int(date):
    """
    Function for converting the ISO date string to integer, '19861123' =>
19861123
    This makes filtering on dates more applicable. An open end date will be
represented as 99991231.
    """

    result = 99991231
    if isinstance(date, str) and '-' in date:
        result = int(date.replace('-', ''))

    return result


# Create an empty list to house the results
data = []

# Create an empty dictionary to house the desired response filters
data_filter = {}
```

```
"""
----- EXAMPLES OF CHARACTERISTICS THAT CAN BE USED AS FILTERS -----

Filter for incidents where "Takst stor bil" is greater than 80 NOK
data_filter['egenskap']= '1820>80'
The different egenskap IDs are found here:
https://datakatalogen.vegdata.no/45-Bomstasjon

Filter for desired kommune. Takes a list of kommune numbers.
data_filter['kommune']= [301,3020,3024,3029] #Oslo, Nordre Follo, Bærum and
Lørenskog
data_filter['kommune']= [5001] #Trondheim

Filter for objects within a squared region (bounding box), where the
coordinates form the diagonal corners
data_filter['kartutsnitt']= '-53074.72,6507486.16,-13880.70,6570928.63'

Multiple filters can be applied simultaneously.
Additional filters can be found here:
https://nvdbapiles-
v3.atlas.vegvesen.no/dokumentasjon/openapi/#/Vegobjekter/get_vegobjekter__v
egobjekttypeid_
"""


# Retrieve data for every year from 2004 until today
for year in range(2004, int(datetime.now().strftime('%Y')) + 1):
    print('Retrieving data for', year)
    # Retrieve vegobjekt data. ID specified in parentheses, where 45 is
bomstasjon.
    # Other objects can be found on: https://datakatalogen.vegdata.no/
    response = nvdbapiv3.nvdbFagdata(45)
    # Append a date filter for the desired years to the filter dictionary
    data_filter['tidspunkt'] = str(year) + '-01-01'
    # Apply the filters
    response.filter(data_filter)
    # Coordinates are now in lat/lon. Standard is ESPG: 32633
    #response.add_request_arguments({'srid': 4326})
    # Append the retrieved data to the empty list
    data.extend(response.to_records())

"""""
# Alternatively, retrieve data for every month every year from 2004 until
today.
# This method will takes longer, but will capture observations where there
are several changes within a year
for year in range(2004, int(datetime.now().strftime('%Y')) + 1):
    for month in range(1,12+1):
        print('Retrieving data for month number', month, 'in the year',
year)
        response = nvdbapiv3.nvdbFagdata(45)
        if len(str(month))==1: #January until September
            month_mm = '0' + str(month)
            data_filter['tidspunkt'] = str(year) + '-' + month_mm + '-01'
        else: # October until December
            data_filter['tidspunkt'] = str(year) + '-' + str(month) + '-01'
        response.filter(data_filter)
        #response.add_request_arguments({'srid': 4326})
        data.extend(response.to_records())
"""
```

```
"""
# Alternatively, retrieve data from a specific date
date_retrieve = '2009-05-10'
print('Retrieving data for', date_retrieve)
data_filter['tidspunkt']= date_retrieve
response = nvdbapiv3.nvdbFagdata(45)
response.filter(data_filter)
response.add_request_arguments({'srid': 4326})
data.extend(response.to_records())
"""

# Convert retrieved data to a Pandas dataframe (a two-dimensional data
structure)
data_df = pd.DataFrame(data)

# Convert start and end dates from strings to integers
data_df['startdato_num'] = data_df['startdato'].apply(lambda x:
date2int(x))
data_df['sluttdato_num'] = data_df['sluttdato'].apply(lambda x:
date2int(x))

"""
----- FILTER AWAY DUPLICATES -----
As we retrieve data for every year, unchanged objects will cause
duplicates.
Subset is a list of columns to consider for identifying duplicates. By
default, it considers all of the columns.
Also, it considers the first value as unique and rest of the same values as
duplicates by default."""
data_df_dropdup = data_df.drop_duplicates(subset=['nvdbId', 'geometri',
'startdato', 'sluttdato', 'Takst stor bil', 'Takst liten bil']).copy()

# Export data to Excel file format using Pandas
data_df.to_excel('TollStations_2004-2021.xlsx')
#data_df_dropdup.to_excel('TollStations_2004-2021_dropdup.xlsx')

# Alternatively, export data to csv format. Specify desired field delimiter
using sep. Specify encoding to support æ,ø,å
#data_df_dropdup.to_csv('TollStations_2004-2021_dropdup.csv', sep=';',
encoding="ISO-8859-1")

# Print the run time of the script
run_time = datetime.now() - t0
print("Script run time:", run_time.total_seconds(), "seconds")
```

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