The Demand Effects of Price Reductions in Urban Public Transport

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1. Executive summary

1.1. Executive summary - English

This report assesses the demand effects of lower public transport fares in Geneva, an urban area in Switzerland. Following a democratic vote, the regional tariff association in Geneva implemented a sharp price reduction in December 2014. While various ticket categories were discounted, the fares annual season tickets and tickets valid for one hour were reduced the most. In a comparative case study, we identify the causal demand effect of this price reduction for 2015 to 2019. We estimate a causal effect amounting to, on average, 10.6%. Moreover, we define a lower causal demand effect's bound of, on average, 3.7%.

First, and being the main investigation in our study, we analyze the effect on the demand of the transport company TPG, the main operator in the canton of Geneva. Additionally, we analyze the effect on the demand of the regional tariff association unireso. However, instead of just comparing the demand of the affected unit (by the price decrease) to comparable units one after the other, we create a respective synthetic counterfactual out of a weighted subset of unaffected units. This counterfactual mimics how the public transport demand in Geneva would have evolved in the absence of the price intervention. To define the suitable combination of unaffected units, we apply the so-called synthetic control method of Abadie et al. (2010) and Abadie and Gardeazabal (2003) and the synthetic difference in differences method of Arkhangelsky et al. (2019). To the best of our knowledge, we are the first to show how these methods can be used to assess such (for policy-makers) important price reduction effects in public transport. Finally, note that a so-called natural experiment like ours relies on underlying assumptions about how the world, here the world of public transportation, works. In our case, that is, e.g., the pre-price-reduction outcome variable of TPG (and unireso) must not be too extreme compared to the control units, which is fulfilled.

Moreover, we challenge our results by performing robustness investigations. First, we run placebo studies. Second, we randomly draw control units with replacement 2,000 times to create different control samples. With every sample, we construct a synthetic Geneva and estimate the average gap between Geneva and its counterfactual. Therefore, we can calculate a so-called 95% bootstrap confidence interval for our estimated effect. Third, we substantially expand our study period and our pool of control units and again construct a synthetic Geneva to estimate the effect of interest. Overall, we conclude that our results are robust.

However, the results depend crucially on whether we consider the influence of the vehicle kilometres. We propose using an aggregate metric, “passenger trips per vehicle kilometer,” that tackles the effect of supply changes on demand, therefore isolating our mechanism of interest, the effect of the price reduction on public transport demand. Moreover, this variable also serves as a proxy for an average passenger load rate. Considering CO_2 emissions, this is also important, as the average emissions of each passenger decrease when the metric increases. When we ignore the number of vehicle kilometres and instead solely use the number of passenger trips as variables of interest, we get the previously mentioned results serving as a potentially lower bound. In these estimations, we do not mitigate the effects of vehicle kilometres on passenger trips, which, in our case, likely leads to an underestimation of the price reduction effect. In addition, note that all values of the corresponding 95% bootstrap confidence intervals are higher than zero. We, therefore, also conclude that the lower causal demand effect's bound is above zero, that is, that the price reduction positively affected the demand for public transport.

As a word of caution concerning our estimates, we emphasize that we investigated a price reduction's effect in Geneva, a canton with a lot of cross-country traffic. On the other hand, in our control pool, we included Swiss areas with only BVB (Basel) and TPL (Lugano) operating in a comparable situation. Moreover, Geneva had – for Swiss relations – a relatively moderate share of public transportation. Therefore, we could also have observed a "catch-up-effect". Furthermore, in this study, we also set out to learn something about public transport price reductions in general. Therefore, regarding the external validity of our result, it is also important to mention that we analyze a price discount introduction in an economically well-developed country. Finally, it is also important to note that we provide a point estimate of demand changes. Therefore, in simple words, similar aggregate price reductions on a different price level would probably not lead to a similar effect.

Summing up, our study presents novel evidence on how reducing urban transport fares affects demand in the Swiss public transport setting. Our results may provide helpful insights for future designs of public transport fares for policy-makers.

1.2. Résumé exécutif - Français

Ce rapport évalue les effets sur la demande de la baisse des tarifs des transports publics à Genève, une région urbaine en Suisse. Suite à un vote démocratique, la communauté tarifaire genevoise a mis en œuvre une réduction des prix en décembre 2014. Alors que diverses catégories de billets ont été réduites, les tarifs des abonnements annuels et des billets valables une heure sont ceux qui ont subi la réduction la plus forte. Dans la présente étude de cas comparative, nous identifions l'effet causal sur la demande de cette réduction de prix pour les années 2015 à 2019. Nous estimons un effet causal s'élevant, en moyenne, à 10,6%. En outre, nous définissons une limite inférieure de l'effet causal sur la demande à 3,7% en moyenne.

En premier lieu, nous analysons l'effet sur la demande de l'entreprise de transport TPG, le principal opérateur dans le périmètre d'intérêt. De plus, nous analysons l'effet sur la demande de la communauté tarifaire genevoise unireso. Cependant, au lieu de simplement comparer la demande de TPG (et unireso) à des unités comparables l'une après l'autre, nous créons un contrefactuel synthétique respectif à partir d'un sous-ensemble pondéré d'unités non affectées (par la baisse de prix). Ce contrefactuel imite la façon dont la demande de transport public à Genève aurait évolué en l'absence de l'intervention tarifaire. Pour définir la combinaison appropriée d'unités non affectées, nous appliquons la méthode dite de « synthetic control » d'Abadie et al. (2010) et Abadie et Gardeazabal (2003) et la méthode de « synthetic difference in differences » d'Arkhangelsky et al. (2019). À notre connaissance, nous sommes les premiers à montrer, comment ces méthodes peuvent être utilisées pour évaluer des effets de réduction des prix aussi importants (pour les décideurs politiques) dans le domaine des transports publics. Enfin, il faut noter qu'une expérience dite naturelle comme la nôtre, repose sur des hypothèses sur la façon dont le monde, ici celui des transports publics, fonctionne. Dans notre cas, c'est-à-dire, que par exemple, la variable d'intérêt de TPG (et unireso) ne doit pas être trop extrême par rapport aux unités de contrôle, ce qui est réalisé.

En outre, nous remettons en question nos résultats en effectuant des enquêtes de robustesse. Premièrement, nous effectuons des études placebo. Ensuite, nous faisons un tirage aléatoire des unités de contrôle avec remplacement 2 000 fois pour créer différents échantillons de contrôle. Avec chaque échantillon, nous construisons une Genève synthétique et estimons l'écart moyen entre Genève et son contrefactuel. Par conséquent, nous pouvons calculer un intervalle de confiance bootstrap de 95% pour notre effet estimé. Troisièmement, nous élargissons considérablement notre période d'étude et notre pool d'unités de contrôle

et construisons à nouveau une Genève synthétique pour estimer l'effet recherché. Dans l'ensemble, nous concluons que nos résultats sont robustes.

Cependant, les résultats dépendent de manière cruciale de la prise en compte de l'influence des véhicules-kilomètres. Nous proposons donc d'utiliser une métrique agrégée, " voyages par véhicule-kilomètre ", qui aborde l'effet des changements de l'offre sur la demande, isolant ainsi notre mécanisme d'intérêt, l'effet de la réduction des prix sur la demande des transports publics. De plus, cette variable sert également de proxy pour un taux d'utilisation moyen des passagers. Si l'on considère les émissions de CO2, cette variable est également importante, car les émissions moyennes de chaque passager diminuent lorsque la métrique augmente. Lorsque nous ignorons le nombre de véhicules-kilomètres et que nous utilisons uniquement le nombre de voyages comme variables d'intérêt, nous obtenons les résultats mentionnés précédemment qui servent de limite inférieure potentielle. Dans ces estimations, nous n'atténuons pas les effets des véhicules-kilomètres sur les voyages, ce qui, dans notre cas, conduit probablement à une sous-estimation de l'effet de réduction des prix. En outre, il convient de noter que toutes les valeurs des intervalles de confiance bootstrap à 95 % correspondants sont supérieures à zéro. Nous concluons donc également que la limite inférieure de l'effet causal sur la demande est supérieure à zéro, c'est-à-dire que la réduction des prix a eu un effet positif sur la demande de transports publics.

En interprétant nos estimations, il faut tenir compte que nous avons étudié l'effet, nous soulignons que nous avons étudié l'effet d'une réduction de prix à Genève, un canton où le trafic transfrontalier est important. D'autre part, dans notre pool de contrôle, nous avons inclus des régions suisses où seules BVB (Bâle) et TPL (Lugano) se trouvent dans une situation comparable. De plus, Genève avait - pour les relations suisses - une part relativement modérée de transports publics. Par conséquent, nous aurions également pu observer un "effet de rattrapage". En outre, dans cette étude, nous avons également cherché à apprendre quelque chose sur les réductions de prix des transports publics en général. Par conséquent, en ce qui concerne la validité externe de notre résultat, il est également important de mentionner que nous analysons l'introduction d'une réduction de prix dans un pays économiquement bien développé. Enfin, il est également important de noter que nous fournissons une estimation ponctuelle des changements de la demande. Par conséquent, en termes simples, des réductions de prix globales similaires sur un niveau de prix différent n'entraîneraient probablement pas un effet similaire.

En résumé, notre étude présente des nouvelles évidences sur la manière dont la réduction des tarifs des transports urbains affecte la demande dans le contexte des transports publics suisses. Nos résultats peuvent fournir aux décideurs politiques des indications utiles pour la conception future des tarifs des transports publics.

2. Introduction

The transport sector is a pivotal contributor to air pollution. Globally, approximately 27% of CO_2 emissions and energy consumption are caused by the transport sector; in the European Union, the figure amounts to about a third (Batty et al., 2015). The transport sector, therefore, causes negative externalities, which means a situation in which the action of a person imposes a cost on another person who is not a party to the transaction. Another important example is noise pollution. Private car use will lead to even greater levels of such negative externalities, which a shift in transport mode towards public transport could help reduce. Lower fares are frequently discussed intervention to motivate individuals to use public transport (see, e.g., Redman et al., 2013).

Policy-makers must know how existing and potential customers respond to such lower fares. However, it is generally challenging to identify the causal effect of lower fares on public transport demand, as transport supply change over time. Therefore, we propose and discuss an aggregate metric that inherits a transport company's supply in public transport demand in this context. The metric is composed of passenger trips per vehicle kilometre. Moreover, considering CO_2 emissions, an increase in the metric points to an average emission decrease of each passenger.

In our comparative case study, we use this metric as the outcome variable to analyze lower fares empirically in the case of Geneva, an urban area in Switzerland. There, the electorate decided to reduce the price of state-owned public transport, which Geneva then introduced in December 2014. The reduction amounted to up to 29% for annual season tickets, 6% for day tickets and 20% for tickets valid for one hour. The case of Geneva is interesting for several reasons. First, Geneva is densely populated. Second, Switzerland has a high per-capita income, as does Geneva. Based on the first and second reasons, we resolve the puzzle of how lower fares cause demand when density and incomes are high, which is the case for many cities worldwide. Furthermore, the public transportation sector in Switzerland is known for its high quality of service. Conclusions can thus also be drawn as to whether price reductions increase the demand for public transport in areas where the quality of the public transport sector is high.

To illustrate the price reduction effect, we analyze TPG, the main operator in the city of Geneva and its agglomeration belt, and unireso, the regional tariff association in the canton of Geneva. To this end, we apply the synthetic control method (Abadie and Gardeazabal, 2003) to construct a synthetic TPG, a counterfactual that mimics the demand the company would have experienced in the absence of the price reduction. The methodology uses a data-driven procedure to create the synthetic TPG from comparable Swiss transport operators and regional tariff associations respectively. Comparing the demand of TPG and its synthetic counterpart, the main analysis in our report, we find that, on average, the price reduction increased the demand for public transport by 10.6% during the period 2015 to 2019, compared to 2014.

Furthermore, we set out to block off alternate reasons leading to our estimate through various robustness checks. For example, we find that the results are similar when increasing the length of the pre-treatment period or increasing the number of other operators to construct the synthetic TPG. Moreover, applying the recent difference in differences method of Arkhangelsky et al. (2019) does not question our findings. However, when we set out to assess the effect of our mechanism of interest, the effect of a price reduction on demand, using the total amount of passenger trips instead of the proposed metric, we cannot construct a suitable synthetic TPG. The thing to notice is that when we re-estimate the effect with the, for this case, more appropriate synthetic difference in differences method, we only get an effect of 3.7%. However, a corresponding 95% bootstrap interval amounts to [2%,12.4%], with all values higher than zero. Moreover, this estimate relies mainly on control units with an upwards demand trend. Therefore, we conclude that this estimate serves as a lower bound of the effect. Summing up, our paper provides the first empirical evidence, at least for Geneva, that a fare-reduction policy can help increase passenger demand. Finally, note that such quasi-experimental evidence is crucial, as price elasticities are often based on Stated Preference or experimental surveys (in Switzerland, see, e.g., Weis et al. (2016), Axhausen et al. (2021))

This report proceeds as follows.[1] Section 3 discusses the existing literature on pricing policies in public transportation. Section 4 describes the institutional background of the Geneva case study. In Section 5, we discuss our unique data set. Section 6 describes and visualizes the collected data. In Section 7, we discuss the methodology and our strategy to identify the estimate of interest. Section 8 applies the synthetic control and the synthetic difference in differences method to our case study and checks the robustness of our results. Finally, Section 9 discusses the results and Section 10 concludes.

3. Literature review

Our study fits into the literature on fare-policy interventions in urban public transport systems. Bresson et al. (2003) suggest that demand is less sensitive to fare changes in France's urban areas than in non-urban areas of England. Moreover, Bresson et al. (2004) analyze French urban areas in greater depth and show that the effects of changing fares vary across areas. This heterogeneity is mainly explained by car ownership, urban sprawl, and the aging of the population. Recently, Kholodov et al. (2021) estimate the effect of a new fare policy in Stockholm and find varying effects across socioeconomic groups and different modes of public transport. Many other studies have examined fare policies in Europe and cities by simulating fare changes (e.g., Parry and Small (2009) for London or Matas et al. (2020) for Barcelona) or by analyzing transport policy bundles (e.g., Buehler et al. (2017) for Vienna). We add to such studies by calculating the causal effect of fare-policy intervention in the interesting case in Geneva.

In the literature, causal analysis has mainly been conducted on fare-free policies rather than fare reductions, as in our case. In Europe, Cats et al. (2017) suggest that free fares increased public transport use by 14% in Tallinn. In addition, De Witte et al. (2006) and Rotaris and Danielis (2014) investigate free-fare policies in Brussel and Trieste. The settings of Lee and Yeh (2019) in Taichung (Taiwan) and Shin (2021) in Seoul (South Korea) are the closest to ours. In Taichung, bus network and schedule improvements gradually increased bus use, which then grew further due to free-fare policies, leading to further adjustments on the supply side. Shin (2021) estimates a 16% increase in subway use by older adults after a fare-free policy was introduced for this age group in Seoul.

Our study is also related to the rich literature on price elasticities in public transport. Price elasticities show the percentage change in demand due to a one percentage price change. For example, Holmgren (2007) exposes a short-run price elasticity of -0.75 and a long-run price elasticity of -0.91 in Europe. In line with Holmgren (2007), Brechan (2017) finds that increasing frequencies have a higher elasticity than reducing fares for public transport. Wardman et al. (2018) show that the effects of price changes in the public transport on car demand – the so-called cross-elasticities – are relatively low. Liu et al. (2019) add that changes to fare policy in Australia mostly increased the number of trips of existing users rather than attracting new users. That is also why Litman (2004) suggests a relatively large fare reduction is crucial for car-users to switch to public transport. (Redman et al., 2013) show that price can encourage car-users

[1] The main investigation of this report has already been published as a working paper, see (Wallimann et al., 2021). This report includes further analysis and materials compared to the working paper.

to use public transport. However, public transport's reliability, frequency, and speed will determine whether their intentions are implemented and maintained. In Switzerland, where our case study of Geneva is located, price elasticities regarding the demand for public transport are typically low, according to Citec Ingénieurs SA (2021). In a recent experimental study, Axhausen et al. (2021) estimate a price elasticity of -0.31 in Switzerland.

More broadly, our study adds to the literature on price policies, inter alia, with the goal of making mobility more sustainable. For instance, (Kilani et al., 2014) show that road-pricing combined with higher public transport fares in peak periods or discounts on off-peak tickets work in a complementary fashion in Paris. Moreover, the effect of road pricing (e.g., Percoco (2015), for Milan) or peak-pricing (off-peak discounts) in public transportation alone is also analyzed in recent literature (see, e.g., Rantzien and Rude (2014) for Stockholm and Huber et al. (2021) for Switzerland). Gkritza et al. (2011) assess the multimodal context of the urban public transport system with varying fare structures in Athens. For a review of public transport policies, see also Hörcher and Tirachini (2021).

Finally, we add to transportation studies applying the synthetic control method, according to Athey and Imbens, 2017 ”the most important innovation in the policy evaluation literature in the last 15 years” (p. 9). For instance, Percoco (2015), also previously mentioned, investigates the effect of road pricing on traffic flows. Another example is Tveter et al. (2017), who evaluate which transportation projects affect settlement patterns. Doerr et al. (2020) estimate how new airport infrastructure promotes tourism. Studying ski-lift companies, Wallimann (2020) discusses the effect of radically discounting prices, while Xin et al. (2021) investigate the impact of COVID-19 on urban rail transit ridership.

4. Background

This study investigates a price reduction's effect in Geneva, a Swiss urban area. In the following, we shortly introduce the geographical and mobility framework of our case and define the point of departure of our study.

4.1. Geography

Switzerland is organized into 26 federal states, the so-called cantons. Our canton of interest is Geneva. Geneva is in the southwest of Switzerland and a large part borders France (see. The canton of Geneva is composed of the city of Geneva and its agglomeration belt. The entire cantonal territory is classified as urban.[2]

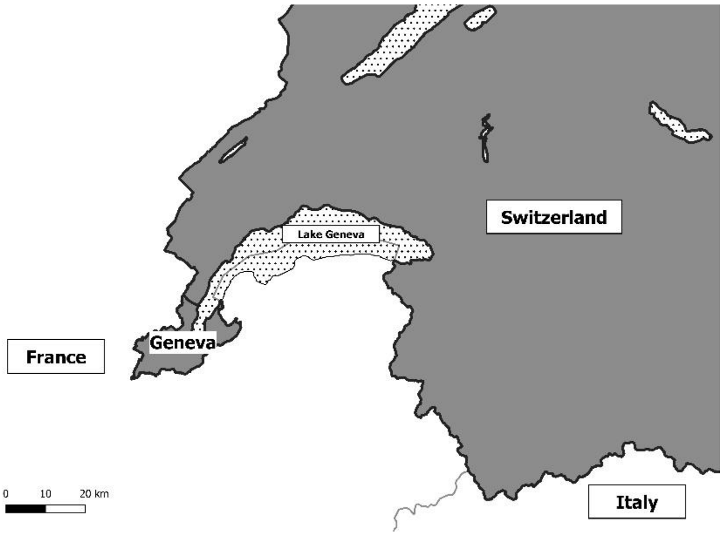

Figure 1 Map of the canton of Geneva and neighboring regions

4.2. Mobility

Switzerland is densely populated and has one of the highest GDP per capita in the world.[3] The road and rail infrastructures are well maintained, and public transport is reliable and frequent. The mixture of short distances, high incomes and good quality drives the demand for mobility in Switzerland. For these reasons, the countries' residents are highly mobile. On the one hand, 1,000 residents own, on average, about 500 individual motorized vehicles.[4] Apart from a yearly fee of 40 Swiss francs to use the highways, roads are free of charge. On the other hand, every second resident owns a public transport pass.[5] For example, about 2.7 million individuals (roughly 32% of the population) held a half-fare travel ticket in

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[2] https://www.bfs.admin.ch/bfs/de/home/statistiken/regionalstatistik/regionale-portraets-kennzahlen/kantone/genf.html

[3] See https://data.worldbank.org/indicator/NY.GDP.PCAP.CD (accessed on February 9, 2022).

[4] See https://www.bfs.admin.ch/bfs/en/home/statistics/mobility-transport.html (accessed on February 9, 2022).

[5] See https://www.bfs.admin.ch/bfs/en/home/statistics/mobility-transport.html (accessed on February 9, 2022).

2019.[6] With such a half-fare travel ticket, a person can buy Swiss-wide public transport tickets on a reduced tariff. Furthermore, Swiss residents bought more than one million subscriptions from regional tariff associations in 2019 (VöV, 2020).

In Geneva, 27.6% of the residents own a Swiss-wide public transport subscription. That is relatively low compared to other Swiss agglomerations. On the other hand, the proportion with a subscription from the regional tariff association is in Geneva relatively large with 25.4% (Federal Statistical Office and Federal Office for Spatial Development, 2012). That is probably because of the urbanity and the location of the canton of Geneva. For example, most journeys related to work are made within the canton (Federal Statistical Office and Federal Office for Spatial Development, 2012).

4.3. Point of departure

The Swiss political system is a direct democracy. Therefore, electorates can decide on political issues at the communal, cantonal, and state levels. In this political framework, the electorates of the canton of Geneva voted in 2013 that the public transport fares must be reduced. The initiative originated from a senior citizens' association. The regional tariff association – called unireso – implemented the price reduction in December 2014. This price reduction in Geneva is the point of departure for the underlying project. Mainly, we aim to answer whether the sharp price intervention increased urban public transport usage. Supplementary, we aim to answer how the purchasing behavior regarding the demanded ticket categories changed and if the COVID-19 outbreak influenced the effect of the price intervention.

[6] See https://reporting.sbb.ch/verkehr (accessed on November 9, 2021). Moreover, all under 16 years old (roughly 16% of the population) also travel with a price reduction of 50% and therefore do not need half-fare travel tickets.

5. Data

We analyze the effect of the price reduction on Geneva's public transport demand, the aforementioned point of departure, on two different levels. First, and being the main investigation in our study, we analyze the effect on the demand indicators of the transport company TPG. TPG operates the tram and buses in the city of Geneva and its agglomeration belt. Second, we analyze the demand indicators of the regional tariff association unireso.[7] Within a tariff association, passengers can use one ticket for various transport modes in the region. In Geneva, a ticket from unireso allows riding with the buses and trams from TPG, the trains from the Swiss Federal Railways and the ferries on the Lake Geneva provided by the company Mouettes.

5.1. Transport companies

To examine the demand effect on the level of transport companies, we use the annual reports of Swiss transport companies, which the Swiss National Library systematically archives.[8] In these annual reports, the companies publish financial and non-financial performance indicators. First, we collected the number of passenger trips, which are standardized in Switzerland. The number of passenger trips counts how many passengers enter a company's vehicle per year. Today, companies mainly count passengers automatically, but this was often done by hand in the past. From 2015 to 2016, Geneva's counting system was further digitalized and changed. Therefore, we adjust our data from 2016 to 2020 based on the observed growth rate of the passenger trips to have a uniform panel dataset.[9] Second, we also gathered the number of vehicle kilometres. The number of vehicle kilometres counts how many kilometres a company's vehicles travel per year. Due to data limitations, the variables "passenger-kilometres" and "revenue" are not analyzed on the level of transport companies.

Additionally, we gathered aggregate data about the share of public transport and individual motorized vehicles in Swiss agglomerations from the Swiss Mobility and Transport Microcensus for 2010 and 2015. Finally, we collected variables about the population growth and population density of Swiss cities yearly provided by the association of cities.

5.2. Tariff associations

To examine the demand effect on the level of tariff associations, we use data provided by the Swiss tariff associations. First, again, we collected the number of passenger trips. Second, we gathered the number of passenger-kilometres. The number of passenger-kilometres results from the number of passenger trips per line multiplied by the average travel distance on that line. On the level of tariff associations, no data about the supply-side (e.g., "vehicle kilometres") is available. Unfortunately, Swiss tariff associations do typically not collect data about the supply of the associated transport companies.

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[7] We also analyzed the regional passenger transport. However, the results are useless because construction works confound the results too much. Furthermore, we did not analyze long-distance passenger transport since there exists only one train line and most costumers do not travel with a ticket from the regional tariff association on that line.

[8] See https://www.nb.admin.ch/snl/de/home.html (accessed on November 9, 2021).

[9] We have verified our adjustments with the transport company TPG.

Additionally, we gathered aggregate data about the share of public transport and individual motorized vehicles in Switzerland's seven major regions[10] from the Swiss Mobility and Transport Microcensus for 2010 and 2015. Finally, we collected variables about the population growth and population density of Swiss cantons yearly provided by the Swiss Federal Statistical Office.[11]

Finally, we collected data about the prices, the quantity sold and the revenue for each ticket category. This data we apply to describe and visualize the possible changes in the purchasing behavior between different ticket categories.

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[10] The definition of the seven major regions is also used by EUROSTAT and the OECD.

[11] See https://www.bfs.admin.ch/bfs/de/home/statistiken/regionalstatistik/regionale-portraets-kennzahlen/kantone/genf.html (accessed on February 11, 2022)

6. Descriptive statistics and data visualization

In the following, we describe and visualize the collected data. First, in section 6.1, we outline the sharp price intervention in detail. Then, in section 6.2, we answer how the purchasing behavior regarding the demanded ticket categories changed. Finally, in sections 6.3 to 6.6, we describe the variables we use for our comparative case study.

6.1. Price intervention

At the request of Geneva's population, the tariff association unireso implemented a sharp price reduction in December 2014 (see Section 4.3). First, the full-fare hourly tickets were reduced by 14.3%[12] and the corresponding half-fare tickets by 20%. Second, the full-fare daily tickets were discounted by 5.7% and the corresponding half-fare tickets by 3.9%. Third, adults benefited from a price reduction of 28.6% on annual season tickets and seniors (women older than 64 and men older than 65 years) and juniors (people between 6 and 24 years) from a price reduction of 20% and 11%, respectively. Fourth, seniors additionally received a 10% discount on monthly season tickets, whereas adults and juniors received no discounts on monthly season tickets. (unireso, 2016) In 2014, The ticket categories who received a discount made up 65% of the total traffic revenue for 2nd class tickets[13] (see Figure 2).

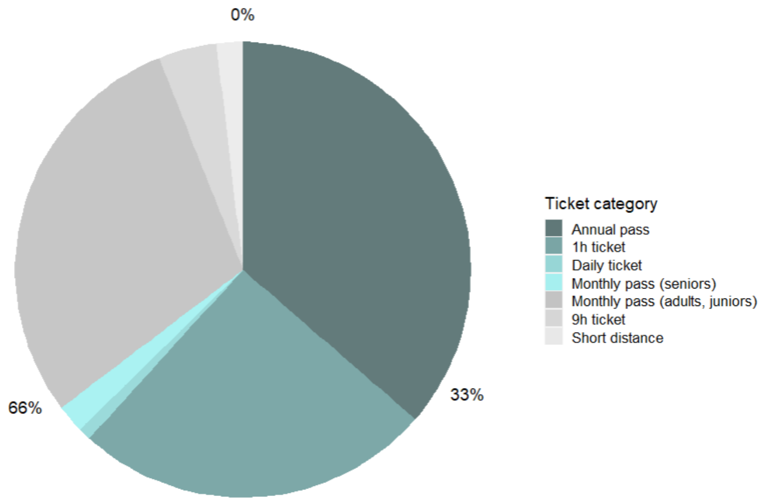

Figure 2 Unireso's revenue share per ticket category in 2014

This price intervention was a shift away from the typical Swiss price level for public transport. For instance, the annual season ticket in Geneva now costs 500 Swiss francs for adults (previously 700 Swiss francs) and 400 Swiss francs for seniors and juniors (previously 500 and 450 Swiss francs respectively). These prices are more than 200 Swiss francs less than those charged by other Swiss cities. For instance, annual season tickets in Lausanne, Berne, Basel, and Zurich cost 740, 790, 800 and 782 Swiss francs,

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[12] In Switzerland, rail cabins are split into two classes, a 1st, and a 2nd class. All prices are quoted for 2nd class tickets.

[13] In Switzerland, rail cabins are split into two classes, a 1st, and a 2nd class. Due to data limitations, we assume that all tickets are sold for 2nd class. However, this seems reasonable as the total traffic revenue of 1st class tickets amounts to only 1.5% of the total traffic revenue.

respectively. The same is the case for hourly tickets amounting to 3 Swiss francs in Geneva (2 Swiss francs for half-fare travel ticket owners).

6.2. Sales and revenue

Figure 3 shows that the price intervention led to changes in purchasing decisions regarding the demanded ticket category. While the quantities sold for hourly and annual season tickets, the two ticket categories with the highest discounts increased, the quantities sold of most other ticket categories decreased. For example, while the relative prices of annual season tickets for adults (-29%) and juniors (-11%) decreased, the quantity sold of monthly season tickets decreased by -31%, respectively -26%. Leaving aside the option that monthly season tickets buyer switched to hourly tickets instead of annual season tickets, these changes would result in a cross-elasticity between annual and monthly season tickets of 1.1 for adults and 2.4 for juniors over three years.[14] Therefore, it is likely that these ticket categories are close substitutes.

Figure 3: Price and quantity change per ticket category from 2014 to 2017

Due to the fact that the overall price level has dropped, and customers switched to relatively cheaper ticket alternatives, unireso's traffic revenue fell from 2014 to 2015 (unireso, 2016). While the ticket categories with the highest discounts reached their pre-intervention level, the revenue for the other ticket categories decreased. Hence, the overall traffic revenue remained below the initial value (see Figure 4).

[14] Calculations are based on the formulas proposed in Section 7.4

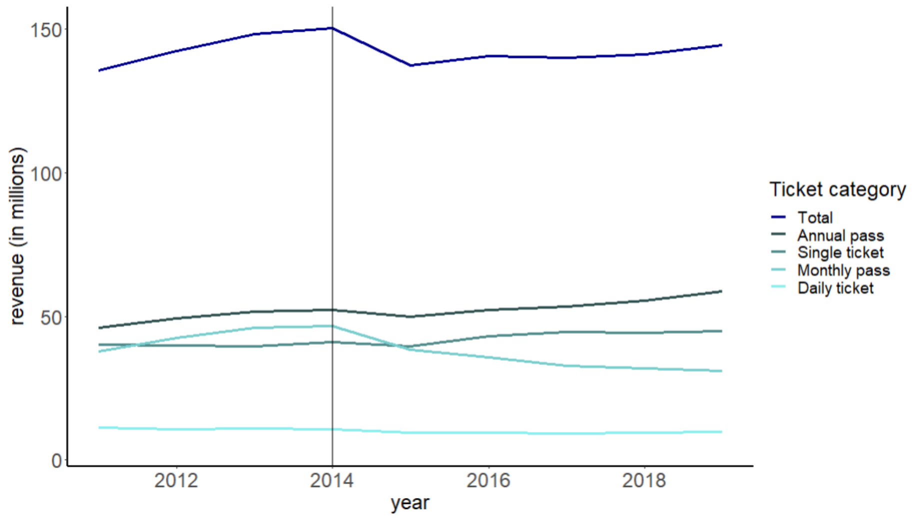

Figure 4 Traffic revenue development from 2011 to 2019

6.3. Passenger trips

In 2014, the transport company TPG counted 197 million passenger trips (TPG, 2015). That amounts to approximately 97% of the passenger trips within the regional tariff association unireso. The remaining 3% stem about two-thirds from the two train lines of the Swiss Federal Railways and one-third from the ferries on Lake Geneva. Therefore, the evolution of the number of passenger trips from TPG and unireso can be considered equivalent (see Figure 5). From 2010 to 2019, the numbers of passenger trips of TPG and unireso increased by 27% respectively, 28%.

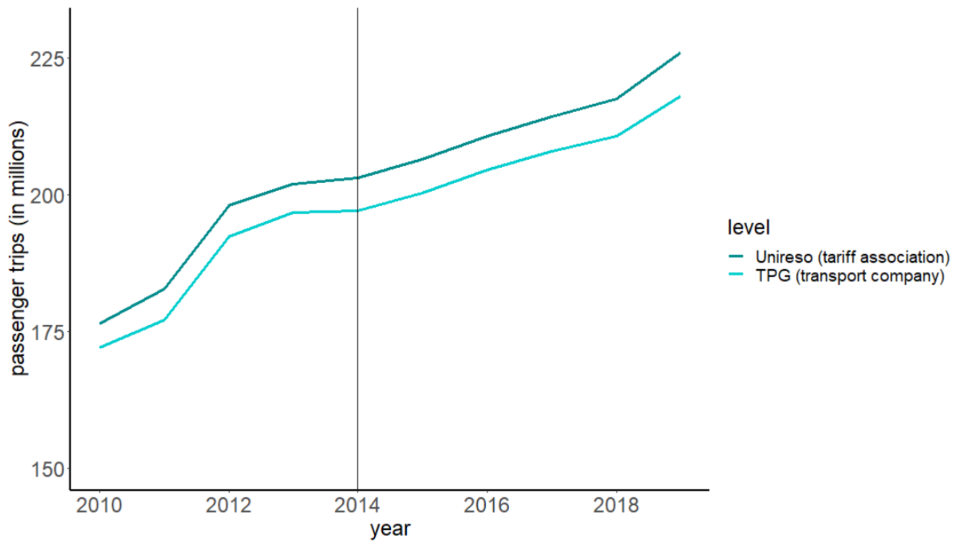

Figure 5 passenger trip development from 2010 to 2019

Table 1 shows the evolution of TPG's passenger trips divided into the tram, trolleybus, and autobus networks. One can observe that the evolution of the tram network differs from the evolution of the two bus networks. This difference results mainly from the variation of the number of vehicle kilometres between 2010 to 2019, which we discuss in the following Section.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Tram	6.7%	22.5%	-1.7%	-0.4%	-0.4%	0.2%	1.3%	2.5%	4.3%
Trolleybus	1.4%	-7.2%	5.1%	-1%	3.1%	3.3%	1.5%	-1.9%	0.0%
Autobus	2.6%	3%	5.5%	1.6%	2.9%	3.6%	2.3%	1.8%	4.7%
Total	3.3%	8.6%	2.2%	0.3%	1.5%	2.1%	1.7%	1.4%	3.7%

Table 1 TPG's Passenger trips development per public transport mode (in percentage change to the previous year)

6.4. Vehicle kilometres

In 2012, TPG finalized a tram network extension and the frequency along the tram lines was increased (TPG, 2013). Because of this frequency increase, the number of vehicle kilometres on the tram lines increased by 19.5% in 2012. The number of passenger trips on the tram lines matched this increase and grew by 22.5% in 2012 (see Table 1). Figure 6 shows that this frequency increase also significantly influenced TPG's aggregate number of vehicle kilometres and passenger trips. The number of vehicle kilometres increased by 7% and the number of passengers increased accordingly by 8% in 2012.[15]

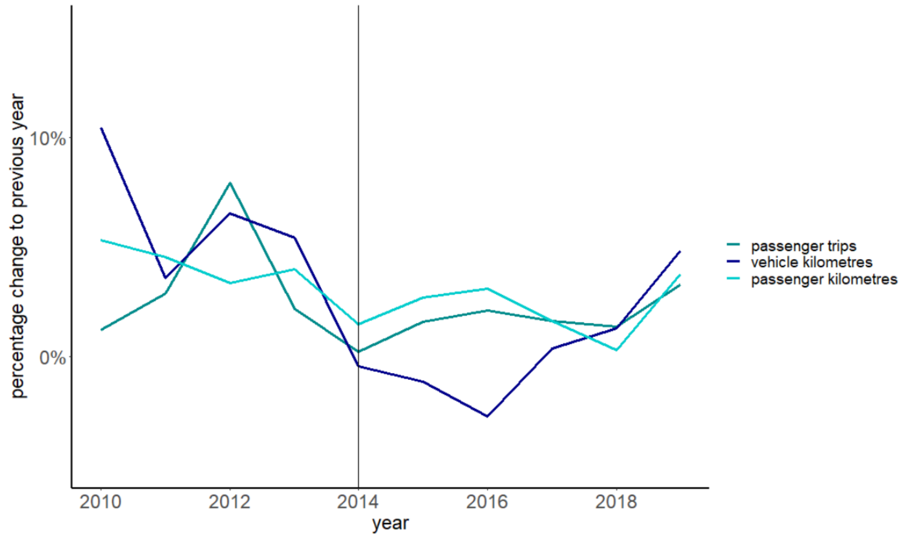

Figure 6 TPG's increase of different KPIs from 2010 to 2019

In December 2014, the price reductions were implemented. From 2014 to 2015, the number of passenger trips of TPG and unireso increased by 1.6% and 1.5%, respectively. Then from 2015 to 2016, the number of passenger trips of TPG and unireso both increased by 2.1%. Table 1 suggests that the passenger trips on the bus network increased more than on the tram network in those years. However, this is most likely a fallacy since vehicle kilometres decreased on the tram network. These changes in vehicle kilometres

[15] Figure 7 shows that the number of passenger passenger-kilometres reacted less to the increase in vehicle-kilometres in 2012. Remember, this number results from the number of passenger trips per line multiplied by the average travel distance on that line. Because the affected lines operate in the city center of Geneva, where the average travel distance is relatively short, this multiplication shifts the focus to the lines in the agglomerations with a longer average travel distance. Since these lines were not affected by the frequency increase, the number of passenger-kilometres reacted less.

occurred in similar subareas as in 2012 (see paragraph above) and 2019 (see paragraph below), where the number of passenger trips reacted accordingly to the changes in vehicle kilometres. Therefore, we assume that this was also the case in 2015 and 2016. Therefore, estimating the increase in passenger trips without considering the decrease of vehicle kilometres would underestimate the demand effect due to the price intervention.

At the end of 2019, the Swiss Federal Railways linked one train line within the regional tariff association unireso to the French public transport system. That was a milestone since a large part of the canton of Geneva borders France. In mid-2018, the frequency on the cross-country train line increased, and accordingly, the number of unireso's passenger trips increased (unireso, 2019). Additionally, the vehicle kilometres on TPG's tram and bus lines connected to the train line also increased. That again increased the number of TPG's passenger trips. With the urban tram and train network extensions in 2012 and 2019, Geneva regained ground compared to other agglomerations in Switzerland - such as Zurich - that are ahead of Geneva regarding urban tram and train developments.[16]

6.5. Share of public transport

Switzerland has four language regions. Geneva, the area of interest, is in the French-speaking part of Switzerland. Overall, the French-speaking part has a lower share of public transport than the German-speaking part. Among Swiss agglomerations with one of the ten most populated cities, Geneva had a relatively moderate share of public transport in 2010. The agglomeration of Geneva had a similar share of public transport as Lausanne, another city in the French-speaking part and Biel/Bienne, a city on the border of the French-speaking and German-speaking part. Lugano, a city in the Italian-speaking part, had the lowest share of public transport among these agglomerations (see Figure 7).

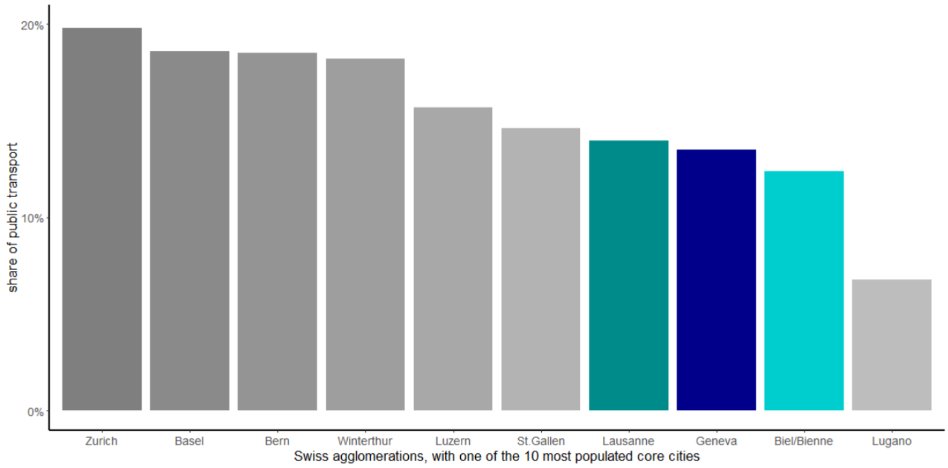

Figure 7: Mode Share of public transportation in 2010

Interestingly, the three transport companies TPG (Geneva), TL (Lausanne) and VB (Biel/Bienne) from the French-speaking agglomerations have experienced the highest increase in passenger trips from 2010 to 2019 (see Figure 8). It seems like the French-speaking agglomerations caught up a bit to the German-

[16] See also https://www.srf.ch/news/schweiz/leman-express-jahrhundertprojekt-soll-genfer-strassen-entlasten (accessed on February 9, 2022).

speaking agglomerations since 2010, probably not least because of supply improvements such as those described in Section 6.4.

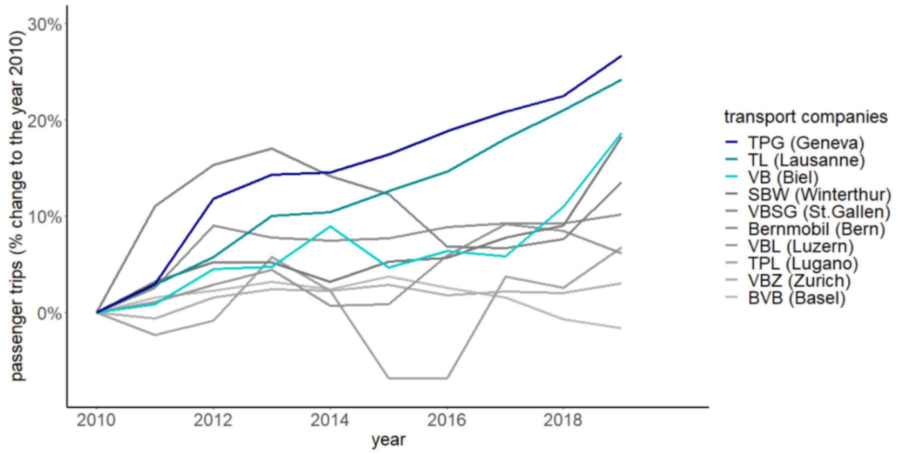

Figure 8 Passenger trips increase of the main transport companies in the ten biggest Swiss cities

6.6. Population size, density, and growth

The canton of Geneva is composed of the city of Geneva and its agglomeration belt. The entire cantonal territory is classified as urban. With 391’359 inhabitants in 2014, Zurich is by far the biggest Swiss city, followed by Geneva with 194’565, Basel with 168’620, Lausanne with 133’897, Bern with 130’015 and Winterthur with 106’778 inhabitants. Additionally, the city of Geneva is by far the densest populated city with 123 persons per hectare, followed by Basel with 70, Zurich with 45 and Lausanne with 32 persons per hectare.

From 2009 to 2019, the population of the city of Geneva grew by 10%. This is like the population growth in Biel/Bienne (+10%), Bern (+9%) and Lausanne (+11%). On the other hand, the population in the cities Zurich (+14%) and Winterthur (+14%) grew more. The population in the cities Luzern (+7%), St. Gallen (+5%), and Basel (+ 4%) and Lugano (+ 3%) grew less. Additionally, cross-border commuters from France to Switzerland increased by 53% from 2009 to 2019[17]. At the same time, cross-border commuters from Italy (+60%) grew more, the number of cross-border commuters from Germany (+38) and Austria (+27) grew less.

[17] https://www.bfs.admin.ch/bfs/en/home/statistics/work-income/employment-working-hours/economically-active-population/cross-border-commuters.html (accessed on February 9, 2022)

7. Methodology

In this Section, we outline the methodological approach to estimate the causal demand effect and discuss the underlying assumptions of our analysis. Then, we present the implementation and identification strategy. Finally, we explain how we calculate the price elasticity. This measurement, which we use in the discussion section, shows the change in the consumption of a product (here, public transportation) in relation to a price change.

7.1. The treatment effect of the price reduction

Let D denote the binary treatment 'price reduction' and Y the outcome of interest 'public transport demand'. The treatment D, the result of the initiative in Geneva, affects TPG.[18] All the other units (transport companies in Switzerland) in our data are not exposed to the price reduction and thus constitute the control group. We can define the observed outcome of TPG, our unit of interest, as

$$Y_t = Y_t^N + \alpha_t D_t.$$

Y_t denotes the observed outcome, Y_t^N the outcome without the treatment, and α_t the treatment effect at time t. It is important to note that the treatment D takes the value 0 for all units during the period $t < T_0$, with T_0 indicating the introduction of the treatment. This is because also TPG was not exposed to the price reduction during the pre-treatment period. Only looking at the post-treatment period permits to define the treatment effect as

$$\alpha_t = Y_t - Y_t^N.$$

As we observe Y_t, we merely need to estimate Y_t^N, the public transport demand of TPG without the policy intervention. Using statistical parlance, Y_t^N is a counterfactual. That is the outcome one would expect if the intervention had not been implemented.

However, instead of just comparing the demand of the affected unit to the comparable units one after the other, we create a respective synthetic counterfactual out of a combination of unaffected units. Therefore, we apply the synthetic control method of Abadie et al. (2010) and Abadie and Gardeazabal (2003). Moreover, we use the synthetic difference in differences method by Arkhangelsky et al. (2019).

To define the suitable combination, both methods assign (in a data-driven way) weights to each unaffected unit in the so-called donor pool, the pool of the respective comparable units. The methods choose the

[18] For simplification, we only talk about TPG as the treated unit and not the tariff association unireso.

weights such that unaffected units that are similar to TPG get a high weight and unaffected units that are different to Geneva get a low or zero weight.

The open question is how similarity should be defined. The synthetic control method weights unaffected units based on the demand level and predictors for similar mobility conditions. The synthetic difference in differences method weights unaffected units based on the demand level and the demand trend.

In the following, we explain the two approaches in more detail. Moreover, as we present the underlying assumptions for our natural experiment in Section 7.1.3.

7.1.1. Synthetic control method

The synthetic control method proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010) is ideal for settings where we have one treated unit and comparable multiple nontreated units. The method assigns the weights to the unaffected units such that the characteristics of interest are comparable to the affected unit (also called selection-on-observables assumption). More formally, the goal of the weighting process is to minimize the difference between the demand outcome variables of TPG and the demand outcomes of interest of synthetic TPG in the period before the intervention happened (the so-called pre-intervention period). To discuss the success of this goal, we calculate the mean squared prediction error (MSPE) of the outcome variables between TPG and the synthetic TPG.

7.1.2. Synthetic difference in differences

The synthetic difference in differences proposed by Arkhangelsky et al. (2019) is an extension of the synthetic control method. Compared to the synthetic control method, the synthetic difference in differences includes unit-specific fixed effects and time weights for different pre-intervention periods. The unit-specific fixed effects control for constant differences in the demand level among the affected unit and the synthetic counterfactual. Hence, the demand level can vary by a constant. Therefore, it might be sufficient that the affected unit and the synthetic counterpart match each other in terms of changes or trends (rather than levels).

Additionally, the synthetic differences in differences method includes time weights. By weighting each period before the intervention, the synthetic difference in differences method is more sensitive to what is happening in the periods just before the price intervention. Remember, the synthetic control method minimizes the difference between the outcome variables of TPG and its synthetic counterpart across all periods before the intervention. In other words, the synthetic control method assigns equal weights to each period before the intervention.

7.1.3. Assumptions

Identification requires statistical procedures, as explained in the previous section. However, on the other hand, ensuring that our calculation identifies the effect of the price reduction also relies on assumptions about how the world, here the world of public transportation, works (see, e.g., Huntington-Klein, 2021). Therefore, in this section, we discuss the assumptions underlying our analysis.

Assumption 1 (no anticipation):

Assumption 1 is satisfied when the public transport demand in Geneva did not change due to forward-looking customers reacting in advance to the policy intervention. To this end, the price reduction effect would be biased if travelers already use public transport before the intervention because they know that prices will fall later.

Assumption 2 (availability of a comparison group):

By Assumption 2, there exists a donor pool. The assumption is satisfied when we have a control group with characteristics that are, by assumption, comparable to the treated unit. That implies that other public transport companies do not sharply lower fares in our natural experiment. with characteristics comparable to the treated unit.

Assumption 3 (convex hull condition):

Assumption 3 is satisfied when pre-treatment outcomes of the synthetic counterfactual can approximate the outcomes of the treated unit. Using statistical parlance, the pre-treatment outcomes of the treated unit are not 'too extreme' (too high or low) compared to the outcomes of the donor pool.

Assumption 4 (no spillover effects):

Assumption 4 is fulfilled when the price reduction has no spillover effects, eighter positive or negative, on other transport companies in the donor pool. We conclude that this is the case in our study, as, for instance, other cities cannot switch to public transport in Geneva.

Assumption 5 (no external shocks):

Applying our methods, we assume that no shocks occur to the outcome of interest during the study period (see, e.g., Abadie, 2021). In our case this condition is challenging, since public transport companies improve their supply and offers from time to time, which typically affects the demand for public transport.

7.2. Implementation

7.2.1. Donor pool

To apply the synthetic control and the synthetic difference in differences method, we construct a synthetic counterfactual out of a combination of unaffected units in the so-called donor pool, the pool of the comparable units. In the following, we describe the donor pool for the synthetic TPG and the synthetic unireso and if they fulfill the assumptions outlined in section 7.1.3.

7.2.1.1. Transport companies (synthetic TPG)

On the level of transport companies, we compare the evolution of the demand from TPG with the demand from other Swiss transport companies. TPG, our transport company of interest, operates buses and trams in the city of Geneva, the densest and second largest city in Switzerland, and its agglomeration belt. Therefore, we focus on transport companies that operate trams and buses primarily in cities with more than 50,000 inhabitants. These are Bernmobil (Berne), BVB (Basel), SBW (Winterthur), TL (Lausanne), TPL (Lugano), VB (Biel), VBL (Lucerne), VBSG (St Gallen) and VBZ (Zurich). However, as the design of our donor pool might influence our results, we expand the donor pool in a robustness check with transport companies from smaller cities that also primarily operate trams and buses and for which the necessary data are available. These are BBA (Aarau), BSU (Solothurn), MBC (Morges), STI (Thun), TPN (Nyon), Travys (Yverdon), VBG (Zurich agglomeration), VZO (Zurich agglomeration) and ZVB (Zug).

7.2.1.2. Tariff associations (synthetic unireso)

On the level of tariff associations, we compare the evolution of the demand from unireso with the demand from other Swiss tariff associations. Tariff associations aim to integrate new areas into their network to enlarge their areas, such that customers can ride with the same ticket in a wider area. The tariff associations Libero (Canton of Berne and Solothurn) and Ostwind (Northeast Switzerland) experienced an association enlargement in 2015 and 2018, respectively. Additionally, TVZ (Zug) changed their counting system and TNW (Northwest Switzerland) experienced major growth on the railway network in 2018. Because of assumption 5 “no external shocks”, we drop Libero (Bern) from our donor pool and restrict the study period to the years 2011[19] and 2017 so that we can keep the other three tariff associations in our donor pool. The remaining donor pool from the available data then consists of the tariff associations A-Welle (mostly canton of Aargau and Solothurn), Onde Verte (West Switzerland)[20] Ostwind (Northeast Switzerland), Passepartout (Central Switzerland), TNW (Northwest Switzerland)[21], TVZ (canton of Zug), ZVV (canton Zurich). However, unireso is, after all (compared to the other tariff associations in Switzerland) mainly composed of a city public transport company. Therefore, we conclude that the first level analysis with TPG is the more reliable one.

[19] We only have sufficient data available from the year 2011 onwards.

[20] For Onde Verte, we have only data available for the revenue side.

[21] For TNW, we have only data available for the demand side.

7.2.2. Outcome variables

As just mentioned, we assume that no shocks occur to the outcome of interest during the study period. In our study, this condition is challenging since public transport companies expand their supply from time to time, which typically affects the demand (see, e.g., Brechan, 2017, Holmgren, 2007). To mitigate the effect of these increasing and decreasing frequencies, we propose the aggregate metric of passenger trips per vehicle kilometre as a possible outcome variable. Looking at Figure 9, TPG's metric "passenger trips per vehicle kilometre" is mainly robust against the frequency increases of TPG's buses and trams in 2012 and 2019, which we described in section 6.4.

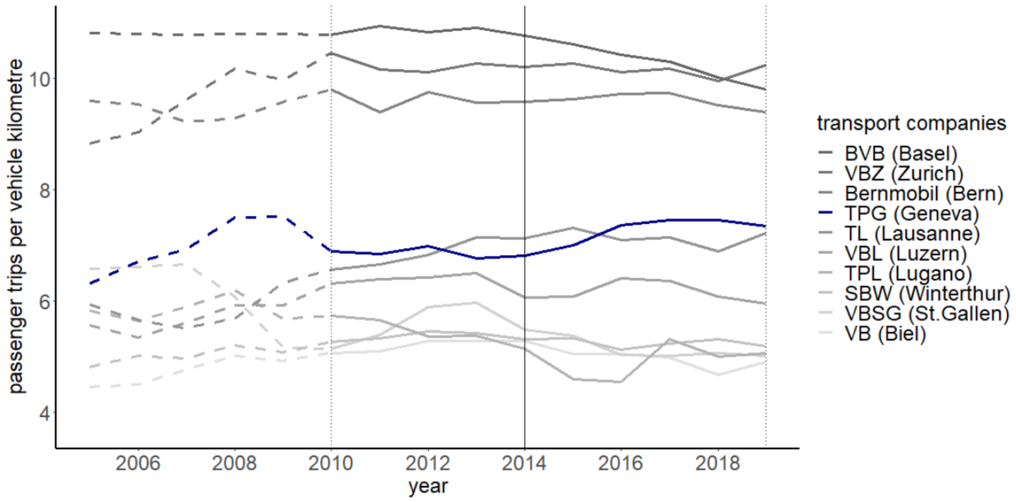

Figure 9 TPG's passenger trips per vehicle kilometre

Controlling for supply changes and therefore blocking off increasing and decreasing frequencies as an alternate explanation of demand-effects also makes sense because several studies show considerable effects of vehicle kilometers on demand (see, for instance, Holmgren 2007). In other words, and as a word of caution, we assume a considerable supply elasticity when applying the ratio. Therefore, and also a thing to notice in Figure 9 by looking at the period with the dotted lines, due to a substantial increase in vehicle kilometers plied by bus lines in Geneva's agglomeration belt from 2008 to 2010, the ratio in Geneva declined. This is because the aggregate change in TPG's supply occurred in the subarea where public transport is relatively poorly utilized. Therefore, we restrict our pre-treatment period to the years 2010 to 2014. However, collecting several observations on the unit of interest (TPG) and the donor pool is crucial before the price reduction (Abadie, 2021). Therefore, we also perform a robustness check with a more extended pre-treatment period. Moreover, we also oppose our results to estimations without the metric and thus use only passenger trips as the outcome variable. This robustness check is crucial, as unexpected low (or high) supply elasticities could be an alternate explanation of the treatment effect. Unfortunately, tariff associations do not typically gather information about their associated companies' supply (e.g., vehicle kilometres). Hence, we cannot mitigate the influence of supply on demand as just proposed on the level of tariff associations. However, Figure 6 suggests that, by chance, passenger-kilometres reacted less than passenger trips to the finalization of the tram network in 2012. Therefore, we also include the number of passenger-kilometres in our analysis.

Levels	Urban transport companies (TPG)		Regional tariff associations (unireso)	
Analyzed outcome variables	Passenger trips per vehicle kilometre	Passenger trips	Passenger-kilometres	Passenger trips

Table 2 Overview of analyzed outcome variables

7.2.3. Predictors

Whereas the synthetic difference in differences method solely relies on the pre-treatment period's previously discussed outcome variables, we include additional predictors when using the synthetic control method. On the level of transport companies, we construct the synthetic counterfactual such that it matches the affected unit in terms of the outcome variable and the predictors “share of public transport”, “share of individual motorized vehicles” (both on the agglomeration level), “population growth” and “population density” (both on the city level). On the level of regional tariff associations, we construct the synthetic counterfactual such that it matches the affected unit in terms of the outcome variable and the predictors “share of public transport”, “share of individual motorized vehicles” (both on the major region level), “population growth” and “population density” (both on the cantonal level).

7.3. Robustness checks

Moreover, we challenge our assumptions and our study design by performing robustness investigations for our main transport company-level results, the causal effect on TPG’s demand.

7.3.1. Placebo tests

To evaluate the significance of the results, we run placebo studies. To this end, we apply the synthetic control method to one transport company after another in the control group, all known to be untreated, using the remaining control companies as the donor pool. More precisely, we iteratively estimate placebo estimates of each unit with no price reduction considering it to be ’pseudo-treated’. If the estimated effect for TPG is similar to the placebo estimates, our result could have happened by chance. However, suppose the placebo investigations show that the effect estimated for Geneva is enormous relative to the transport companies in the control group. In that case, like Abadie, Diamond, and Hainmueller (2010), we interpret our analysis as providing significant estimates of the treatment effect α_t.

7.3.2. Bootstrap confidence interval

To challenge the weight assignment of our methods, we randomly draw 2,000 times nine control units with a replacement from our donor pool. In every sample, we construct a synthetic TPG and estimate the average gap between TPG and its counterfactual. Then, we calculate the corresponding 95% bootstrap confidence intervals to the treatment effect.

7.4. Price elasticities

Taking the causal demand change and the price change together, we can estimate the price elasticity of demand:

$$\text{Price elasticity of demand} = \frac{Demand\ change\ in\ \%}{Price\ change\ in\ \%}$$

To define the price change on an aggregate level, we consider the revenue share of each ticket category and their price change. Then, we calculate the price change on the aggregate level based on the revenue share before the price intervention.

$$Relative\ price\ change = \sum_{i=1}^{n} revenue\ share_{i,2014} * \frac{price_{i,2015} - price_{i,2014}}{price_{i,2014}} * 100\ ,$$

where i denotes the ticket categories. 1 stays for the first and n for the last category. Section 6.2 suggests a large substitution within tickets categories after the price intervention. Therefore, we likely underestimate the relative price change as we do not account for this substitution. That means we overestimate the price elasticities of demand.

8. Results

In the following, we apply the synthetic control and the synthetic difference in differences method to estimate the causal demand effect of the price intervention. In section 8.1, we analyze the effect on the demand of the transport company TPG. That is the main investigation in our study; therefore, we only apply the robustness checks in this section. In Section 8.2, we analyze the demand of the regional tariff association unireso. Finally, Section 8.3 discusses the effect of the Covid-19 pandemic in 2020.

8.1. Transport companies

8.1.1. Outcome variable: passenger trips per vehicle kilometre

First, we apply the synthetic control method with the outcome variable "passenger trips per vehicle kilometre". To construct the synthetic TPG, the synthetic control method assigns weights among the control group companies. VB (Biel) receives the highest weight with 0.400, while BVB (Basel) has the second-highest weight with 0.162, and the VBSG (St Gallen) has a zero weight. In the pre-intervention period, VB's (Biel) and BVB's (Basel) outcome variable, being passenger trips per vehicle kilometre, evolve similar to TPG's outcome variable. Additionally, VB's (Biel) and BVB's (Basel) predictors match the ones from TPG closely. E.g., the agglomeration Biel has a similar share of public transport as Geneva, and Basel is the second densest city after Geneva. For these reasons, VB (Biel) and BVB (Basel) have a sizeable predictive power for TPG outcome in the absence of price intervention.

Figure 10 plots the outcome variable of TPG and the synthetic TPG from 2010 to 2019. We can easily observe that the two trajectories track each other close in the period before TPG experienced the price intervention. The mean squared prediction error (MSPE) of the outcome variable between TPG and the synthetic TPG is small. Therefore, our synthetic TPG is a sensible counterfactual of our expected outcome if the intervention had not been implemented. After the price intervention, the two lines diverge. While demand from customers of the synthetic TPG continued its slightly downward trend, the demand for TPG increased.

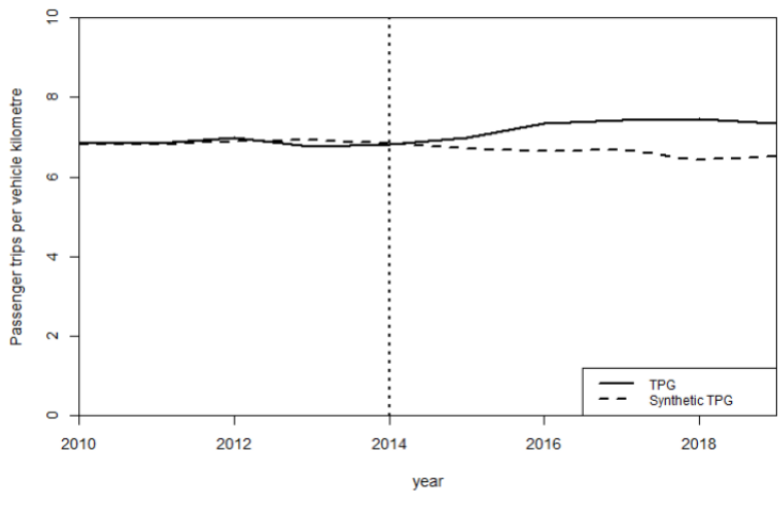

Figure 10 Transport companies: Synthetic control method with the outcome variable "passenger trips per vehicle kilometre"

The estimate of our analysis indicates the effect of the policy intervention on demand in passenger trips per vehicle kilometre. More precisely, this effect represents the yearly differences (gaps) between TPG and its synthetic counterfactual. In 2014, this gap was close to zero and the metric "passenger trips per vehicle kilometre" of TPG and the synthetic TPG amounted to approximately 6.8. One year after the intervention, the gap between TPG and its synthetic counterpart accounts for 0.3 (+ 4.4% compared to 2014). Three and five years later, the gap increased by 0.75 (+ 11.0%) and 0.83 (+12.2%) respectively. Therefore, the gap increased on average by 0.72 across all post-treatment periods from 2015 to 2019. This is a 10.6% increase compared to the year 2014.

Second, we apply the synthetic difference in differences. In comparison to the synthetic control method, the synthetic difference in differences includes unit fixed effects. This permits the outcome of TPG and the synthetic TPG to differ. Therefore, it might be sufficient that TPG and the synthetic counterfactual have a parallel trend. In this estimation, Bernmobil (Bern) receives the highest weight with 0.178, while most other companies also receive weights in the range between 0.075 and 0.150. Figure 11 shows that the metric "passenger trips per vehicle kilometre" for TPG and the synthetic TPG have a slight downwards trend in the pre-treatment period. Hence, they have a parallel trend. While the trend of the synthetic TPG continues to slightly decrease after the price intervention, the trend for TPG increases (as with the synthetic control method). The synthetic difference in differences estimation considers the upwards jump of TPG (see blue line) and the slightly downwards trend from the synthetic TPG (see red line) and calculates the gap (see black arrow). Almost identical to the synthetic control estimate, the ratio increases on average by 0.68 across all post-treatment periods from 2015 to 2019. That is a 10.0% increase compared to 2014.

Additionally, the synthetic difference in differences includes time weights. By weighting each period before the intervention, the synthetic difference in differences method is more sensitive to what is happening in the periods just before the price intervention. The thing to notice is that red triangles in Figure 11 show that the year 2014 receives the highest weight with 0.953.

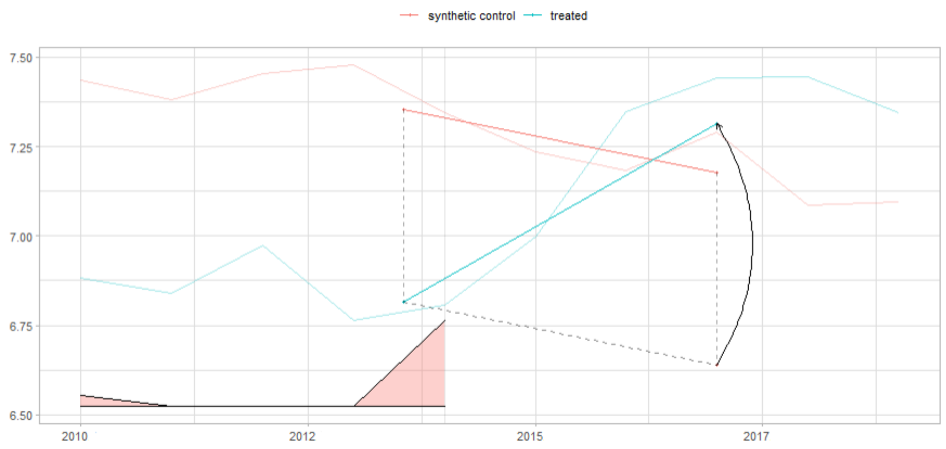

Figure 11 Transport companies: Synthetic Difference in Differences with the outcome variable "passenger trips per vehicle kilometre"

8.1.2. Outcome variable: passenger trips

We replace our metric with the original number of passenger trips in a second analysis. Remember, due to the finalization of the tram network extension and the corresponding demand shock, the analysis solely on passenger trips is challenging (as we cannot isolate the price shock). Hence, the trajectories of TPG and the synthetic TPG do not fit each other closely in the period before the intervention (see Figure 12). VBZ (Zurich) receives the highest weight with 0.479, while VBSG (St. Gallen) receives the second-highest weight with 0.101. In 2014, the passenger trips amounted to 197 million and due to the imperfect fit, this number was approximately 7.5 million (gap) higher than the number for the synthetic TPG. This already existing gap increased by 2.1 million (+ 1%) one year, 10.2 million (+ 5.2%) three years and 18.3% (+ 9.3%) five years after the price intervention.[22] The gap increased on average by 10.3 million across all post-treatment periods from 2015 to 2019. This is a 5.2% increase compared to the year 2014.

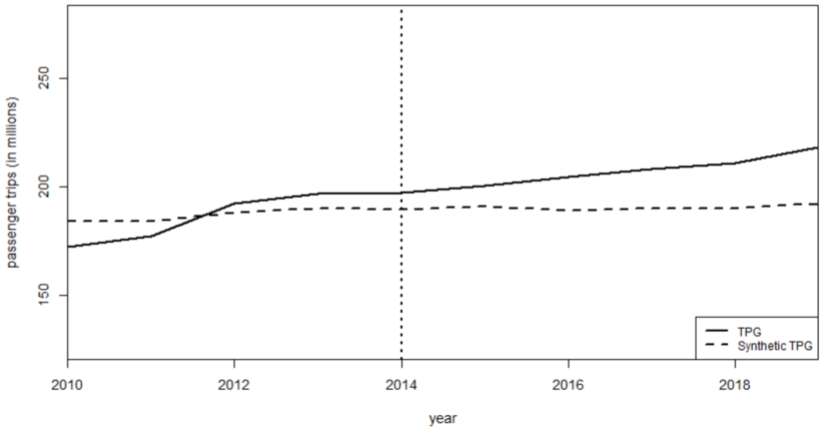

Figure 12 Transport companies: Synthetic Control Method with the outcome variable "passenger trips"

Second, we apply the synthetic difference in differences approach. TL (Lausanne) receives the highest weight with 0.506 and VBZ (Zurich) receives the second-highest weight with 0.446. Figure 13 shows that TPG and the synthetic TPG have a common upwards trend in the pre-treatment period. The estimation considers the upwards jump of TPG (see blue line) and the slightly upwards trend from the synthetic TPG (see red line) and calculates the gap (see black arrow). Similar to our result from the synthetic control method, the passenger trips increased on average by 7.3 million across all post-treatment periods from 2015 to 2019. That is a 3.7% increase compared to 2014. Additionally, the synthetic difference in differences method includes time weights. Note that red triangles in Figure 13 indicate that the year 2014 receives all the weights in this estimation. Therefore, the years before the finalization of the tram network have zero weights.

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[22] The measured gaps without correction are 9.5 and 17,5 million for the years 2015 and 2017.

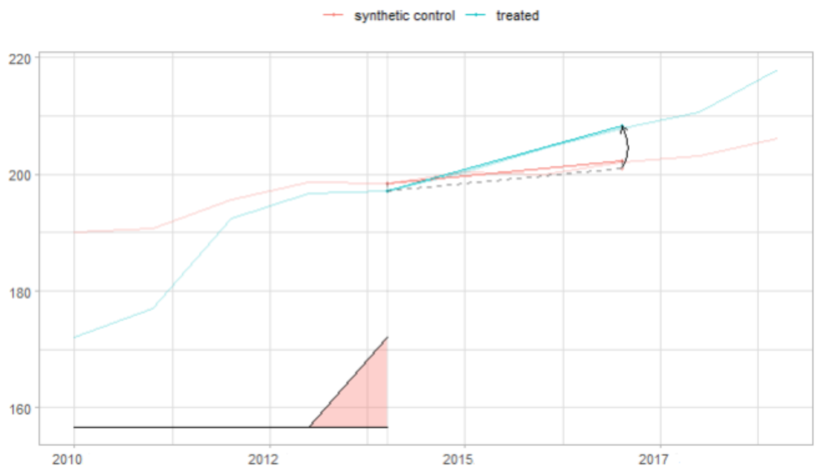

Figure 13 Transport companies: Synthetic Difference in Differences with the outcome variable "passenger trips"

8.1.3. Robustness investigations

We challenge our results by performing robustness investigations. First, we run placebo studies. If the estimated effect for TPG is similar to the placebo estimates, our result could have happened by chance. Second, we randomly draw control units with replacement 2,000 times to create different control samples. We construct a synthetic Geneva and estimate the average gap between Geneva and its counterfactual in every sample. With this procedure, we can calculate a so-called 95% bootstrap confidence interval to the causal demand effect. Third, we substantially expand our study period and our pool of control units and again construct a synthetic Geneva and estimate the causal demand effect.

8.1.3.1. Placebo tests

To evaluate the significance of the results, we run placebo studies. To this end, we apply the synthetic control method to one transport company after another in the control group, all known to be untreated, using the remaining control companies as the donor pool. More precisely, we iteratively estimate placebo effects of each unit with no price reduction considering it to be 'pseudo-treated'.

First, we run the placebo tests with the outcome variable “passenger trips per vehicle kilometre”. The black line in Figure 14 illustrates the gap between the trajectories of TPG and the synthetic TPG. As we know from the results in section 8.1.1, the MSPE of the outcome variable between TPG and the synthetic TPG is small. Hence the gap between the two lines is small in the pre-treatment period. However, they separate in the post-treatment period, and therefore we observe a causal effect of the treatment (price reduction) on the metric “passenger trips per vehicle kilometre”. We can now construct a synthetic counterfactual for all companies in our control group and compare these trajectories to the actual company's development. Suppose the trajectories from the 'pseudo-treated' companies and their synthetic counterpart fit well in the pre-treatment period and separate in the post-treatment period (even though they have not introduced a price reduction). Then, our effects calculated for TPG may be caused by chance rather than by the treatment (the price reduction).

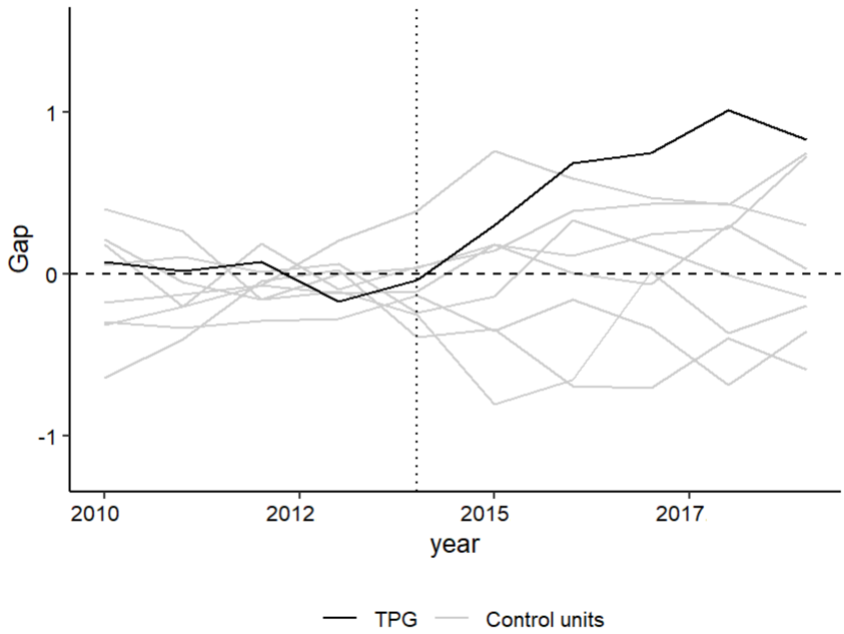

Figure 14 Transport companies: Placebo Tests with the outcome variable "passenger trips per vehicle kilometre"

The grey lines in Figure 14 summarize the results of iteratively applying our method to one transport company after the other by illustrating the gaps between the actual and the synthetic trajectories. The trajectories track each other closely in the pre-treatment period. In other words, the methodology also provides suitable counterfactuals for most companies in the control group. However, there remain a few lines that still deviate substantially from a zero-gap. From 2015 to 2017, the black line, the gap between TPG and its synthetic counterfactual, is further apart than all the grey lines. Hence, the difference between the post-treatment MSPE and the pre-treatment MSPE is the greatest among the companies. The ratio "post-treatment MSPE/ pre-treatment MSPE" for TPG amounts to 66.0, while the company with the second highest ratio is VBZ (Zurich) and TL (Lausanne) with 9.7 and 5.5 respectively. Therefore, we conclude that the increase of TPG's aggregate metric due to the price reduction is not driven by chance.

Second, we also run placebo tests with the "passenger trips" outcome variable. As we already saw above, the synthetic TPG does not mimic TPG well. Therefore, we present these results in Appendix B.

8.1.3.2. Bootstrap confidence interval

To challenge the weighting of our control units, we randomly draw nine control units with a replacement from our donor pool to calculate bootstrap confidence intervals. First, we apply the bootstrap confidence interval to our main estimate, resulting from the synthetic control method with the outcome variable "passenger trips per vehicle kilometre". Remember, this estimation resulted in an average effect of 0.72 (+ 10.6%) from 2015 to 2019. The corresponding 95% bootstrap confidence interval of the average estimated effect is [0.42;0.87]. The lower bound would amount to a 4.3% change and the upper bound to an 11.3% change. The distribution of the means of 2,000 samples is presented in Figure 15. Our estimate lies within the bootstrap confidence interval. Hence, the estimate is robust over different compositions of the synthetic TPG.

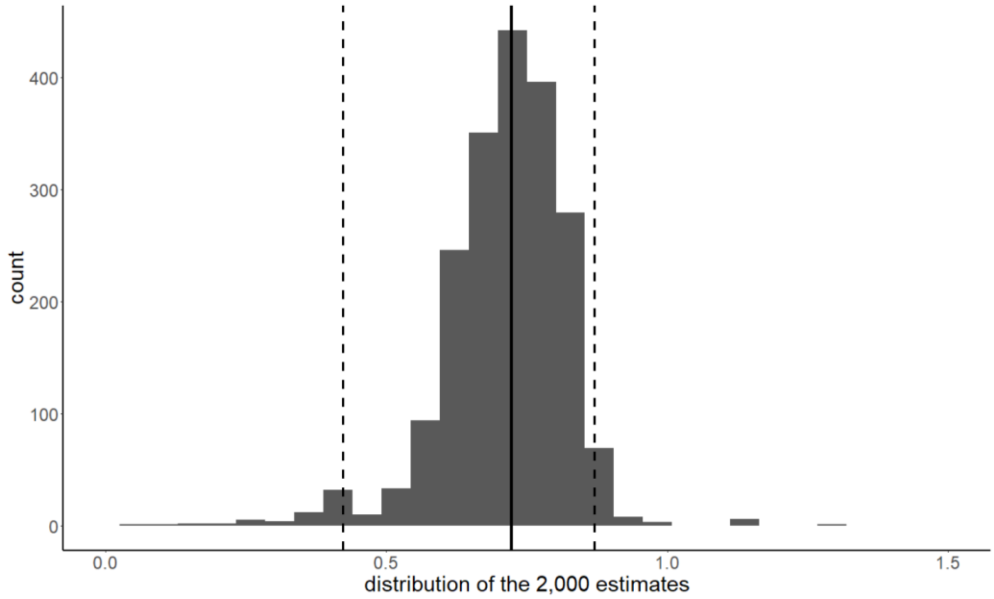

Figure 15 Synthetic control method: Bootstrap confidence interval

When applying the synthetic control method, we do not construct a bootstrap confidence interval for the outcome variable "passenger trips". In this estimation, the pre-treatment fit is not decent, and TPG already starts (in 2014) at a higher value than the synthetic TPG. Hence, we overestimate the effect, and so would the bootstrap confidence interval. Therefore, we use the synthetic difference in differences here to construct a bootstrap confidence interval. Remember, this estimation resulted in an average effect of 7.3 million passengers (+ 3.7%) from 2015 to 2019. The corresponding 95% bootstrap confidence interval of the average estimated effect is [3.9 million;24.5 million]. The lower bound would amount to a 2.0% change and the upper bound to a 12.4% change. The distribution of the means of 2,000 samples is presented in Figure 16. Our estimate lies within the bootstrap confidence interval. Hence, the estimate is robust over different compositions of the synthetic TPG.

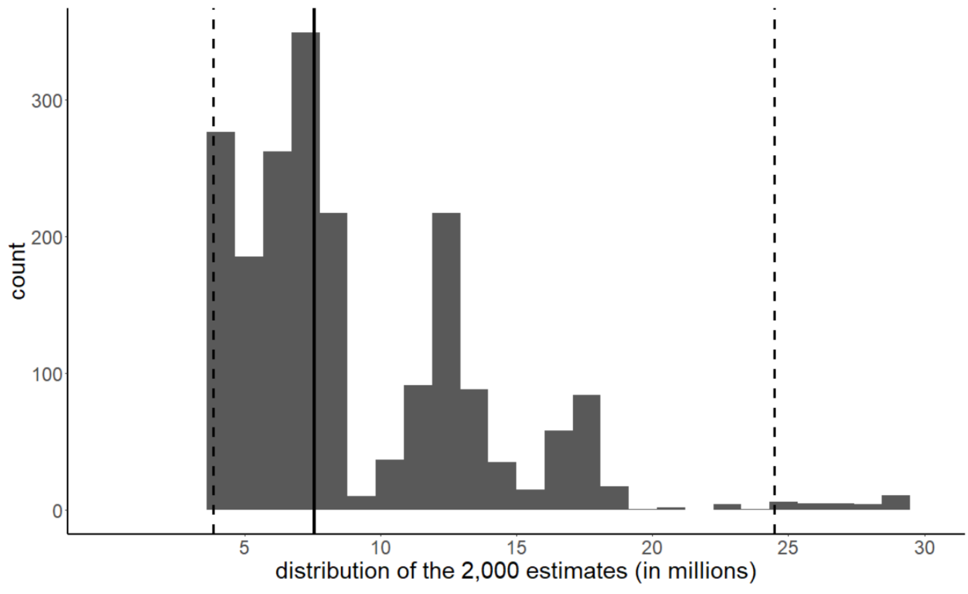

Figure 16 Synthetic difference in differences: Bootstrap confidence interval

8.1.3.3. Extension of the pre-treatment period and the donor pool

In a further robustness investigation, we substantially expand our pre-treatment period to 2005 to 2014. Due to a significant increase in the vehicle kilometres of bus lines in Geneva's agglomeration belt from 2008 to 2010, we restricted our pre-treatment period to 2010 to 2014. However, it is crucial when applying the synthetic control method not to have a pre-intervention window that is too small. Applying the synthetic control method and the synthetic difference in differences with the expanded pre-treatment period yields similar results as the ones already proposed.

Due to the risk of over-fitting, we only include transport companies operating in cities with more than 50,000 inhabitants in the control group. However, as the design of our donor pool might influence our results, we expand the donor pool in a third robustness check with transport companies from smaller cities that also primarily operate trams and buses and for which the necessary data are available. These are BBA (Aarau), BSU (Solothurn), MBC (Morges), STI (Thun), TPN (Nyon), Travys (Yverdon), VBG (Zurich agglomeration), VZO (Zurich agglomeration) and ZVB (Zug). Applying the synthetic control method and the synthetic difference in differences with the expanded pre-treatment period yields again similar results as the ones already proposed.

8.1.4. Conclusion

We created a unique data set from Swiss transport companies to identify the effect of the price reduction on the demand of TPG, by far the biggest transport operator in Geneva's tariff association unireso. In addition, we proposed a metric for aggregate demand to account for the effect of extended vehicle kilometres on passenger trips. This metric breaks down the demand for public transport per company's supply. We found that the lower fares caused an increase in the metric of 10.6% from 2015 to 2019. The effect lowers when solely using passenger trips as the outcome variable. However, our metric passenger trips per vehicle kilometres is more reliable as we can block off increasing or decreasing networks as an alternate explanation of demand-effects, being in the context of public transport of crucial importance.

Outcome Variable	**Passenger trips per vehicle kilometre**		**Passenger trips**	
Method	SCM	SDID	SCM	SDID
Unit with highest weights	VB (Biel/Bienne)	Bernmobil (Bern)	VBZ (Zurich)	TL (Lausanne)
Highest weight in donor pool	0.400	0.178	0.446	0.506
Treatment effect from 2015 to 2019 (in %)	10.6%	10.0%	5.2%	3.7%

Table 3 Transport companies: Estimation summary

8.2. Tariff association

8.2.1. Outcome variable: passenger-kilometres

First, we apply the synthetic control method. To construct the synthetic unireso, the method assigns weights among the control group associations. TVZ (Canton of Zug) receives the highest weight with

0.421, while Passepartout (Central Switzerland) receives the second-highest weight with 0.142. In the pre-intervention period, TVZ's (Canton of Zug) and Passepartout's (Central Switzerland) passenger-kilometres evolve similar to unireso's passenger-kilometres. Additionally, TVZ's (Canton of Zug) and Passepartout's (Central Switzerland) predictors match the ones from unireso in terms of share of public transport and individual motorized vehicles as well as population growth closely. Out of these reasons, TVZ's (Canton of Zug) and Passepartout's (Central Switzerland) have a sizeable predictive power for TPG outcome in the absence of the price intervention.

Figure 17 plots the outcome variable of unireso and the synthetic unireso from 2011 to 2017. We can observe that the two trajectories track each other close in the pre-intervention period and diverge in the post-intervention period.

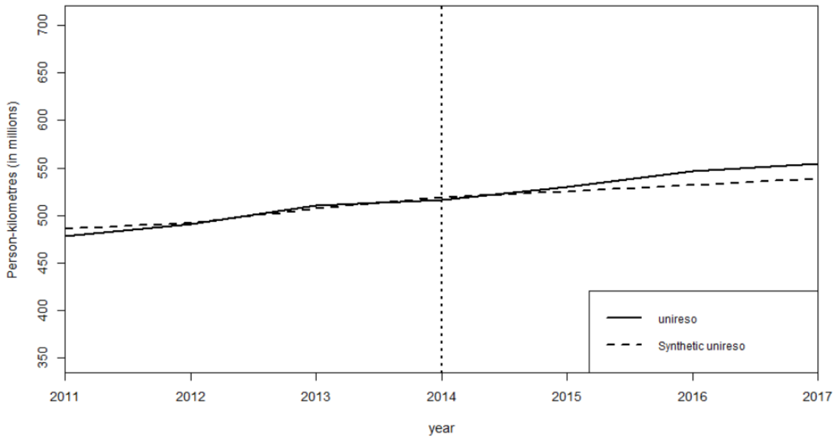

Figure 17 Tariff associations: Synthetic Control Method with the outcome variable "passenger-kilometres"

The causal demand effect represents the yearly differences (gaps) between unireso and its synthetic counterfactual. In 2014, the number of passenger-kilometres from unireso amounted to 516.5. One year after the intervention, the gap between unireso and its synthetic counterpart increased by 7.0 million (+ 1.4%) and three years later, the gap increased by approximately 17.1 million (+3.3%).[23] Therefore, the gap increased on average by 13.6 million across all post-treatment periods from 2015 to 2017. That is a 2.6% increase compared to the year 2014.

Second, we apply the synthetic difference in differences method. All companies receive weights in the range between 0.1 and 0.2. Figure 18 shows that unireso and the synthetic counterfactual have slightly upward trends before and after the price intervention. The estimation considers the upwards trend of unireso (see blue line) and its synthetic counterpart (see red line) and calculates the gap (see black arrow). The increase of the passenger-kilometres amounts to only 4.75 million across all post-treatment periods from 2015 to 2017, an 0.9% increase compared to 2014.

Additionally, the synthetic difference in differences method includes time weights. The red triangles in Figure 18 show that the year 2012 receives the highest weight with 0.559, while the year 2014 receives the remaining weight with 0.441.

[23] The measured gaps for the years 2015 and 2017 are 4.8 and 14,9 million, respectively.

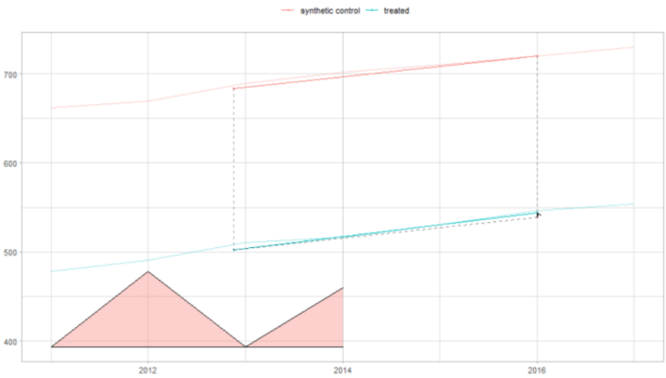

Figure 18 Tariff associations: Synthetic Difference in Differences with the outcome variable "passenger-kilometres"

8.2.2. Outcome variable: passenger trips

In a second analysis, we replace the number of passenger-kilometres with the number of passenger trips. Remember, due to the positive demand shock in 2012 after the finalization of the tram network extension, the analysis with passenger trips is challenging. With the synthetic control method, Ostwind (Northeast Switzerland) receives the highest weight with 0.549 and ZVV (Zurich) receives the second-highest weight with 0.256. However, due to the positive demand shock, the trajectories of unireso and the synthetic unireso do not fit each other closely in the pre-intervention period (see Figure 19). In 2014, the passenger trips amounted to 203 million, and due to the imperfect fit, this number was approximately 1.6 million (gap) higher than the number for the synthetic unireso. This already existing gap increased by 1.0 million (+ 0.5%) one year and 7.5 million (+ 3.7%) three years after the price intervention.[24] The gap increased on average by 4.5 million across all post-treatment periods from 2015 to 2017. That is a 2.2% increase compared to the year 2014.

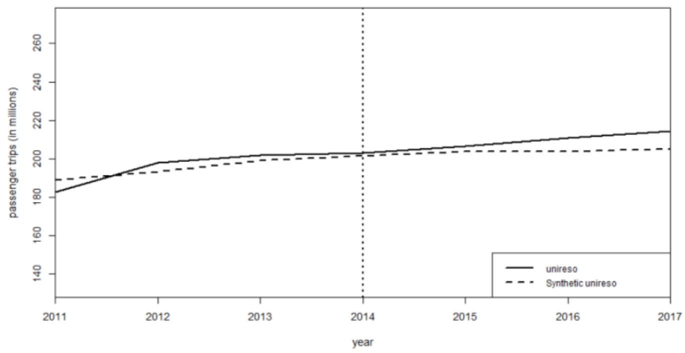

Figure 19 Tariff associations: Synthetic Control Method with the outcome variable "passenger trips"

Second, we apply the synthetic difference in differences method. In this estimation, ZVV(Zurich) receives the highest weight with 0.755, while Ostwind (Northeast Switzerland) receives the second-highest weight with 0.383. Figure 23 shows that unireso and the synthetic control have slightly upward trends before the

[24] The measured gaps for the years 2015 and 2017 are 2.6 and 9.1 million, respectively.

price intervention. After the price intervention, both lines continue their slightly upward trend. Hence, the increase of the passenger-kilometres amounts to only 0.17 million across all post-treatment periods from 2015 to 2017, a 0.1% increase compared to 2014.

Additionally, the synthetic difference in differences includes time weights. The red triangles in Figure 20 show that the year 2013 receives the highest weight with 0.617, while the year 2014 receives the remaining weight with 0.383. That is, the years before the finalization of the tram network have zero weights.

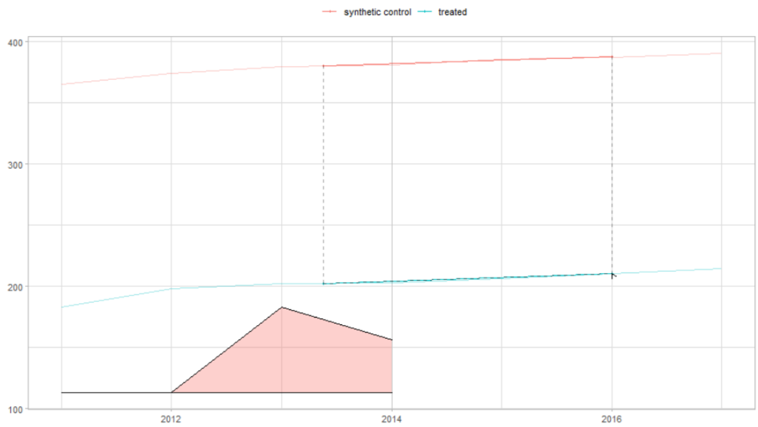

Figure 20 Tariff associations: Synthetic Difference in Differences with the outcome variable "passenger trips"

Tariff associations				
Outcome Variable	Passenger-kilometres		Passenger trips	
Method	SCM	SDID	SCM	SDID
Unit with highest weights	TVZ (Canton of Zug)	A Welle (Canton of Aargau and Solothurn)	Ostwind (Northeast Switzerland)	ZVV (Canton of Zurich)
Highest weight in donor pool	0.421	0.190	0.549	0.755
Treatment effect from 2015 to 2017 (in %)	2.6%	0.9%	2.2%	0.1%

Table 4 Tariff associations: Estimation summary

8.2.3. Conclusion

While we have appropriate data from the years 2010 to 2019 on the level of transport companies, we must restrict the study period to the years 2011 to 2017 on the level of tariff associations. To compare the results, we also restrict the post-treatment period on the level of transport companies to the years 2015 to 2017. When comparing the effects of the years 2015 to 2017, the estimated treatment effects are smaller on the level of the tariff associations than on the level of the transport companies. Since the demand for TPG and unireso can be considered almost equal (see Figure 5), the differences must stem from the synthetic counterfactual. In other words, the tariff association units that serve as a counterfactual have evolved in a more favorable way than the transport company ones.

Whereas we only include urban areas on the level of transport companies, we also include more rural areas on the level of the tariff associations. Therefore, one possible explanation for the differences is more favorable development in more rural areas. Concluding, due to the urban characteristics of Geneva, we assume that the donor pool on the level of transport companies satisfies assumption 2 “availability of a comparison group” more appropriately. On this level, we include all main tram and bus operators of the ten most populated cities in Switzerland.

8.3. Supplementary analysis: The effect of the Covid-19 pandemic

In March 2020, the Covid-19 pandemic hit Switzerland. In the following autumn 2020, the canton of Geneva counted the highest number of people infected with the Coronavirus among the Swiss cantons. Consequently, the canton Geneva introduced - compared to the Swiss federal government - more restrictive actions at the beginning of November 2020 to reduce the number of Covid-19 cases.[25] The higher number of cases and the more drastic restrictions might have reduced the movement of people more than in the rest of Switzerland. Hence, the demand for public transport might have been affected more negatively in Geneva than in other Swiss cantons. To analyze the demand indicators of 2020, we must keep in mind that the Swiss Federal Railways linked their regional trains to the French public transport system at the end of 2019, which could positively influence the number of passenger trips. Figure 21 shows that most of the gap between TPG and the synthetic counterpart vanished in 2020. That suggests that the collapse in demand in Geneva was bigger compared to its synthetic counterfactual. However, descriptive statistics show that the traffic revenue decline for season tickets was smaller than for single tickets during the Covid-19 pandemic. Hence, the cheap annual season tickets and the resulting higher proportion of people owning such a ticket might have made the public transport in Geneva more resistant against exogenous negative shocks, such as the Covid-19 pandemic.

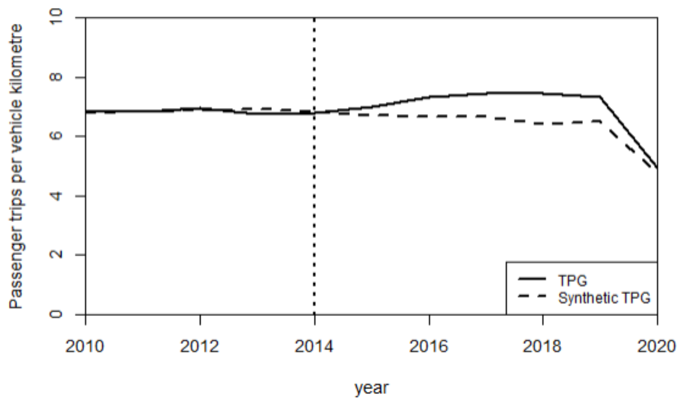

Figure 21 Transport companies: Synthetic control method with the outcome variable "passenger trips per vehicle kilometre" (including the years 2018 to 2020)

[25] See https://www.srf.ch/news/schweiz/neue-corona-massnahmen-wieder-shutdown-in-genf-schulen-bleiben-aber-offen (accessed on March 29, 2022)

9. Discussion

9.1. The causal demand effects

In Section 8, we have analyzed the demand of the transport company TPG and the demand of the tariff association unireso with two methodologies based on three different outcome variables. To sum up, we calculated eight different estimates for the causal demand effect of the price intervention. These estimates vary due to different donor pools, outcome variables and methodologies. However, some analyses are more appropriate than others.

First, assumption 2 is satisfied with a donor pool with characteristics comparable to the treated unit. Due to the urban characteristics of Geneva, the treated area, we assume that the donor pool on the level of transport companies is the more appropriate and valid donor pool. On this level, we include all main tram and bus operators of the ten most populated cities in Switzerland.

Second, assumption 5 is satisfied if no shocks occur to the outcome of interest during the study period. To isolate the effect of our mechanism of interest, the price reduction, we propose the aggregate metric "passenger trips per vehicle kilometre" inheriting supply changes of public transport networks. That makes sense as we can block off the effect of increasing and decreasing frequencies as an alternate explanation of demand-effects, being in the context of public transport of crucial importance. However, as a word of caution, we assume a considerable supply elasticity when applying the metric. E.g., in the years after the price intervention, the number of vehicle kilometres decreased, and we assume that passenger trips reacted to the same amount. This assumption likely holds since the change in vehicle kilometres occurred in similar subareas as the tram and train frequencies increased in 2012 and 2019. In those years, demand reacted elastically to changes in vehicle kilometres. More generally, the assumption of certain demand elasticity for supply changes must also hold for units in the donor pool. If this is not the case, the treatment effect of, on average, 10.6% would be confounded since part of the effect would stem from increasing or decreasing vehicle kilometres rather than changes in passenger trips. Therefore, we should oppose our main result to the estimates resulting from solely using the outcome variable "passenger trips".

Finally, we conclude that the synthetic difference in differences is more appropriate to analyze the outcome variable "passenger trips", because it includes unit-specific fixed effects and time weights. Due to the unit-specific fixed effects, the demand level can vary by a constant, which allows mimicking the positive demand trend of TPG better. Additionally, the period weights emphasize the year 2014, which is supposed to be unaffected by the demand shock of the tram network finalization in 2012. Therefore, TL (Lausanne) receives the highest weight in this estimation. Since TL (Lausanne) has the most favorable development among the unaffected transport companies in the donor pool, it is reasonable that the resulting estimate of, on average, 3.7% is a potential lower bound among the demand effect estimates.

9.2. Price elasticities

As the price change from 2014 to 2015 amounts to 12.6%, we can calculate the corresponding point elasticities of demand. In section 7.4, we describe how we assess the price elasticities. We get average elasticities of -0.84 and -0.29 of our main result and the lower bound, respectively. As discussed in the previous Section, the lower bound is appropriate since the approach focuses on the parallel trend between TPG and TL (Lausanne), the company with the most favorable demand development among the unaffected transport companies. Additionally, it is crucial to mention that we underestimate the price change and hence, overestimate the price elasticities as we do not account for the substitution between ticket categories (for details, see section 7.4). Therefore, our main elasticity of -0.84 could serve as an upper bound.

It is important to mention that this is a point elasticity of demand. That is, if unireso lowers the fares at the same amount on a different price level, we likely get different results. Our price elasticities are in line with the literature. In particular, Holgrem (2007) proposes that the often-stated rule of thumb of price elasticity of –0.3 only holds when vehicle kilometres treated exogenous but not when vehicle kilometres are treated endogenously. In the latter case, Holmgren (2007) suggests a short-run price elasticity of -0.75 and a long-run price elasticity of -0.91 in Europe. In Switzerland, where our case study of Geneva is located, price elasticities regarding the demand for public transport are typically low according to Citec Ingénieurs SA (2021). In a recent experimental study, Axhausen et al. (2021) estimate a price elasticity of -0.31 in Switzerland.

10. Conclusion

In this comparative case study, we answered the question of whether a public transport price discount leads to increasing demand. Therefore, we have applied the synthetic control method to assess the demand effects of lower fares in Geneva, a Swiss urban area. The methodology is ideal for such quasi-experimental settings of price reductions (in urban areas). It constructs a counterfactual that mimics the demand a treated unit would have experienced without the price reduction in a data-driven way. Following a democratic vote, the regional tariff association in Geneva introduced a price reduction of up to 28% for annual season tickets and of up to 20% for hourly tickets. To the best of our knowledge, our study is the first causal analysis of this case and of price reductions due to direct democracy in general. We created a unique data set of annual reports from Swiss transport companies to identify the increase in demand. In addition, we proposed a metric for aggregate demand to block off increasing networks as an alternate explanation of demand-effects, being in the context of public transport of crucial importance (Brechan (2017); Holmgren (2007)). This metric breaks down the demand for public transport per company's supply. We found that the lower fares caused an increase in demand of 10.6% from 2015 to 2019 for TPG, by far the biggest operator in the Geneva tariff association. The result remains robust when performing several robustness checks. However, when changing the study design by looking at the effect and applying the synthetic difference in differences method, we were able to provide a lower bound of the effect's estimate amounting to an increase of 3.7% additional passenger trips. With the aggregate price decrease of 12.6%, these demand estimates suggest a (point) price elasticity of demand of -0.84 and a lower bound (point) price elasticity of -0.29.

Summing up, our study provides the first empirical evidence for Geneva that a fare-reduction policy can help increase passenger demand. However, it is crucial to add some comments regarding public transport pricing. First, we only present a point estimate of demand changes. Therefore, any generalizations from our findings should consider this factor. Second, the substitution between ticket categories could not be considered adequately, and hence, our price elasticity is likely overestimated. Third, the price reduction was not the same for all age groups and ticket sentiments, and hence, the demand effect could vary across specific client groups (e.g., seniors). Fourth, the price intervention increased the share of annual season ticket owners, which might likely reduce the effect of further price interventions (e.g., discounts on off-peak tickets). All these comments lead to open questions that should be on the agenda for future research. Furthermore, future studies should aim at understanding whether a price reduction is a driver for a modal substitution, e.g., passengers switching from cars to public transport.

One additional limitation of the study is that we did not analyze the influence of the COVID-19 outbreak. Future studies should investigate a more extended period and also consider the impact of the pandemic. A thing to notice is that TPG is a company that operates on a cross-border territory. In Switzerland, and thus in the donor pool, we only have BVB (Basel) and TPL (Lugano) with a comparable situation. Therefore, we cannot completely exclude that the price reduction has a different effect on TPG's measures than on companies in the donor pool, which might lower the external validity of our result. Moreover, it is again essential to mention the extension of the tram network in Geneva, which, as a quality improvement, could still have had after-effects on demand. Thus, using statistical jargon, we do not know whether we completely isolated the effect of the supply increase, even when applying our metric.

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12. Appendix

A. Descriptive statistics

	TPG (mean)			Control group (mean)		
year	Metric	passengers	vehicle kilometres	Metric	passengers	vehicle kilometres
2010	6.9	172.1	25.0	7.2	84.4	9.8
2011	6.8	177.1	25.9	7.2	85.3	10.1
2012	7.0	192.3	27.6	7.3	87.6	10.2
2013	6.8	196.6	29.1	7.4	88.5	10.2
2014	6.8	197.1	28.9	7.2	88.1	10.3
2015	7.0	200.3	28.6	7.1	88.5	10.3
2016	7.3	204.5	27.8	7.1	88.5	10.5
2017	7.4	207.9	27.9	7.1	89.2	10.6
2018	7.4	210.7	28.3	6.9	89.2	10.9
2019	7.3	217.9	29.7	7.0	90.4	10.9

Table 5 Key figures of TPG and the control companies (in millions)

	unireso (mean)		Control group (mean)	
year	Passenger-kilometres	passenger trips	Passenger-kilometres	passenger trips
2011	477.8	182.7	698.8	154.2
2012	490.8	198.0	706.1	157.7
2013	510.8	201.9	729.8	161.4
2014	516.5	203.1	743.6	162.6
2015	530.3	206.4	750.5	164.8
2016	546.6	210.7	759.7	165.9
2017	554.2	214.2	768.5	167.4

Table 6 Key figures of unireso and the control tariff associations (in millions)

B. Further tables and figures

Company	Weight
Bernmobil (Bern)	0.055
BVB (Basel)	0.162
SBW (Winterthur)	0.080
TL (Lausanne)	0.079
TPL (Lugano)	0.091
VB (Biel)	0.400
VBL (Lucerne)	0.083
VBSG (St. Gallen)	0.000
VBZ (Zurich	0.049

Table 7 Company weights for the synthetic TPG of our main model (see Section 8.1.1)

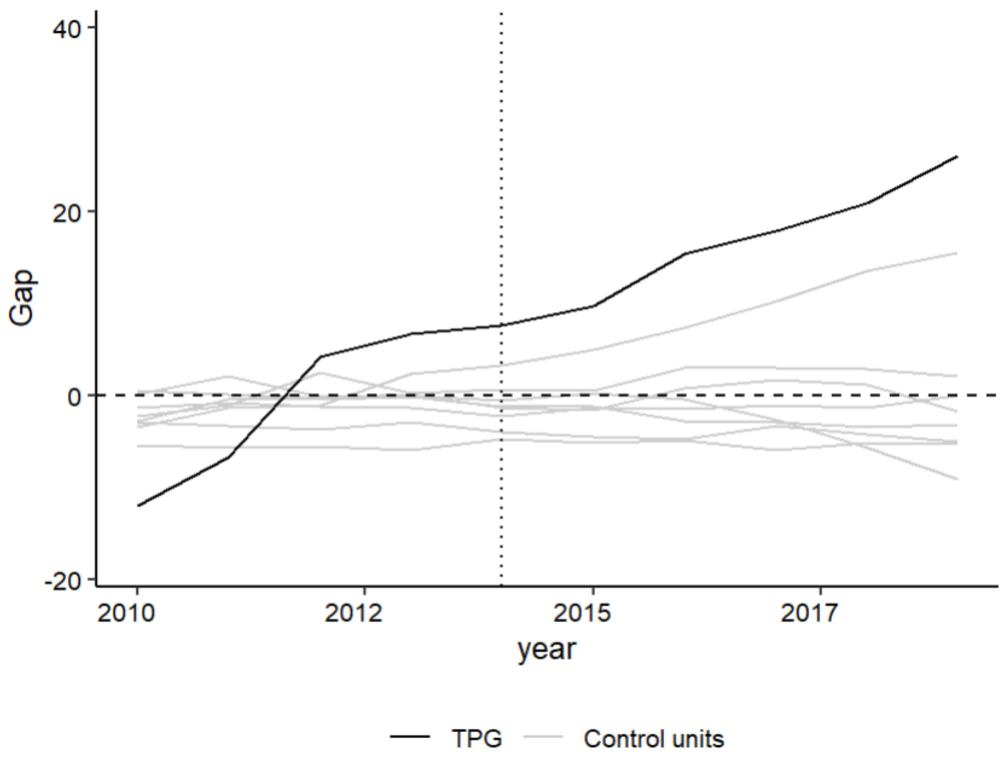

Figure 22 Transport companies: Placebo Tests with the outcome variable "passenger trips" (see Section 8.1.3.1)