ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Master's Thesis Policy Economics

Does subsidising rail transportation help to improve air quality and motivate people to move to cities with access to rail lines?
A case study from Slovakia.

Author: Estera Szakadatova

Student ID number: 452299

Supervisor: Prof. Dr. Olivier Marie

Second assessor: Dr. Aksel Erhabar

Date final version: 17th July 2020

Abstract

This master's thesis investigates the causal relationship between the introduction of rail transportation subsidy and air pollution as well as migration decisions of people to move to municipalities with access to rail transportation. The causal effect is derived from changes in pollution and migration patterns caused by the introduction of the subsidy scheme and it is estimated by using difference-in-differences method. This research explores the impact of the of the rail transportation subsidies introduced in Slovakia in 2014. The identification strategy relies on an exogenous variation in the date of introduction of rail transport subsidy.

Keywords: pollution, migration, transportation subsidies, difference-in-differences method, Slovakia

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I. Introduction

In the past decades, in Slovakia the increasing living standard led to the increasing use of automobiles, especially in more densely populated and affluent regions of the country. At the same time, increased car ownership leads to increased traffic and traffic congestion which contributes to negative externalities associated with automobile usage.

According to the data collected by the navigation technology company TomTom (2020), commuters in the capital city of the country Bratislava lose almost one hour in rush hour and the traffic has been worsening, e.g. in 2019, the level of congestion in Bratislava increased by 3 percent compared to 2018. According to this estimate, annually the time lost in traffic jams adds up to approximately 167 hours (almost 7 days). The opportunity cost of this time could be considered in terms of planting 168 trees (TomTom 2020), spending time on personal development or pursuing hobbies. One of the reasons for increasing congestion in Bratislava and the surrounding area can be the increased number of people moving to Bratislava's suburbs and satellite villages. The increasing traffic and congestion also negatively affect air quality, which on top of time lost in the traffic jams has an adverse effect on people's lives.

According to the European Environment Agency (2019) air pollution represents the largest risk to health in Europe. Cardiovascular diseases and stroke are among the most common causes of premature death that are attributed to poor air quality. Moreover, the measurements of air pollutant concentrations across the European Union suggest that Europeans are exposed to concentration of pollutants that exceed the EU legal standards and the guidelines of the World Health Organisation. The data points to improving air quality across the EU, thus, the effect of air pollution on the health of the European citizens is reduced. However, citizens are still exposed to air pollution, especially those living in urban areas, where the population density is much higher.

In the past decades there has been a call for a fight against climate change. Since air pollution is among the greatest concerns regarding global warming and climate change (European Commission, 2010), countries around the world have started to implement policies to fight these problems. In the EU, policies aiming to reduce air pollution are especially targeted at the transportation sector, which is one of the greatest pollutants in the EU (European Environment Agency, 2018).

In our study, we will analyse, whether subsidising public transportation, particularly rail transportation, which is perceived as more environmentally friendly, can contribute to the improvement of air quality. In the context of this study, we will look at the environmental impact of predominantly socially focused transportation subsidies in place in Slovakia. In addition, we will look into whether the introduction of rail transportation subsidies affects people's decision to move to cities and villages having access to the rail network. We will carry out this analysis based on the data from the Bratislava region in Slovakia and consider the policy change linked to the increased subsidies in rail transportation for selected groups of population, which was introduced in 2014.

The paper is structured as follows: first, we review relevant literature, then, we describe the details of the targeted policy intervention; subsequently, we discuss the data and a methodological approach. In the next section, we present and evaluate the results of the data analysis. Finally, we discuss the results and conclude the paper.

II. Review of relevant literature

Many societies use their public policies to ensure adequate minimum living standards for their inhabitants. Even though the tools used are similar across different countries, the extent to which individual policy instruments are used and how much intervention takes place varies widely across different countries. In this context, it has been recognized that access to transportation is important for people's lives, especially for poorer people, since it may provide them access to better jobs (or any jobs at all) and improve their standards of living and those of their families too (Todd, 2014). Also, access to education has been found a significant factor for social mobility and future life achievements of individuals (see e.g. the studies by the OECD[1]). Transportation subsidies can pursue different objectives, among the most important ones being the aim to facilitate mobility and to make transportation more affordable for the poor or reducing negative environmental externalities and promoting allocative efficiency through a reduction of private car use.

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[1] E.g. OECD (2018). A broken Social Elevator? How to Promote Social Mobility.
Available at: https://www.oecd.org/social/soc/Social-mobility-2018-Overview-MainFindings.pdf

The supply and demand side transportation subsidies reduce the cost of services to the final user. This can be done for example by lowering the proportion of costs that must be covered by the transportation provider. These subsidies are referred to *as supply side subsidies*. Alternatively, the subsidies may be targeted at lowering the outright monetary outlays of the users and thus, they are focused on the demand side and are referred to as *demand side subsidies*. Even though the goal of supply and demand side subsidies is to bring the benefits to the end users, frequently, the benefits are also shifted towards others, e.g. in case of the demand side subsidies, changes in equilibrium prices of goods and services and the labour market conditions indicate that the costs and benefits of subsidies may be shifted also towards other agents in an unintentional way (Seberinsky et al., 2009).

Seberinsky et al. (2009) suggest that the subsidies can also be classified based on the method used to reach target groups. For instance, demand side subsidies can be means tested, or targeted based on the socio-economic conditions of potential beneficiaries, or they can be provided to certain population groups based on their social status, such as to students or elderly. The demand side subsidies can have different forms, e.g. of concessionary fares, or transportation vouchers.

In addition, the authors point out that both in developed and developing countries, transport subsidies are implemented to increase the public transport usage and to reduce externalities, such as greenhouse gas emissions and congestion, and to make transport more affordable, particularly for the poorest. The research suggests that public transport subsidies can also be supported by economic efficiency arguments. However, many of the arguments are "second-best" in nature, since subsidies compensate for generated externalities in other parts of the economy, specifically in private transportation use (Elgar & Kennedy, 2005; Vassallo & Perez de Villar, 2007; Seberinsky et al., 2009).

Basso and Silva (2014) argue that under-pricing of negative externalities generated by automobile usage (e.g. air pollution, congestion, noise) points in favour of transport subsidies. As the automobile travel is a substitute to public transport travel, when the negative externalities of car usage are not priced, the second-best alternative is to reduce the cost of using public transportation, which implies the need for transport subsidies.

Basso and Silva (2014) also find that in absence of other policies, public transport subsidies help to reduce negative externalities produced by automobiles and increase marginal welfare. However, if other policies are in place, e.g. congestion pricing or bus lanes, the effect of public transport subsidies diminishes. There are no alternative policies in Slovakia aimed at reducing negative externalities of automobiles (such as congestion pricing). Thus, in our setting transport subsidies could be the best available approach to reducing the negative externalities and making public transport in suburban areas more attractive. Nevertheless, it should be noted that all subsidies have also a distributional effect on income.

On this subject, the allocative efficiency argument is based on two explanations. Firstly, it is related to under-pricing of certain means of transportation (mostly the ownership and usage of automobiles). This under-pricing implies that the users do not pay the full cost that they impose on the society – this can be related to the infrastructure usage, environmental externalities like pollution, congestion, etc. Because of this, providing public transport subsidies supports the equalisation of conditions for competition between car and train transportation and has the potential to improve the resource allocative efficiency (Seberinksy et al., 2009). Second, there exist economies of scale (i.e. increasing returns to scale in rail transportation) and they are known as the "Mohring Effect" (Mohring, 1972; Jara-Diáz & Guevara, 2003). The "Mohring Effect" arises because the total cost of a trip does not only comprise of the price directly paid for the given mean of transport, but it also includes the users' cost of time. Increased demand for rail transport leads to increased frequency of train services, decreased waiting times, therefore, it further triggers the increase of the demand for rail transport (Mohring, 1972). Furthermore, the "Mohring Effect" suggests that higher investment in rail transit infrastructure incentivises car users to switch to a different mode of transport, thus, reducing air pollution.

On the other hand, Vickrey (1969) argues that increased investment in transportation triggers the demand for travel, which causes a traffic creation effect. Since investment in rail transport supposedly makes people substitute away from car travel, but it also increases the demand for car travel, thus the net impact on car travel and air quality will be uncertain (Vickrey, 1969; Chen and Whalley, 2012).

The cost of fuel represents another factor affecting the choice between the rail travel and the private car travel. Based on the study of selected railway systems in the USA, Clifford & Vikram (2007) found that a decline in real gas prices during the sample period caused rail demand to increase. This finding is consistent with the notion that gas prices tend to affect the transit use by influencing the overall level of economic activity. Moreover, due to the fact that in the USA, the majority of suburban-based rail trips are combined with a car trip, lower gas prices could increase rail demand by expanding its catchment area (Baum-Snow & Kahn, 2005). They also found that the demand for the rail transport decreases as average commute time increases, but this effect diminishes as commutes get longer and travellers are more willing to shift to rail to avoid road congestion even if they have to drive to the railway stations.

Chen and Whalley (2012) focus on quantifying the effect of an opening of a new urban rail transit in Taipei on air quality. They estimate the effect of the opening of a new rail transit on the concentration of major tailpipe air pollutants in the air. The motivation for their study comes from the "Mohring Effect" explained above, which states that due to the increased investment in rail infrastructure, drivers should substitute away from using automobiles and move towards using rail transport. Consequently, this switch in the mode of transportation should reduce air pollution. They find that the opening of a new Taipei metro line led to between 5 to 15 percent reduction of concentration of carbon monoxide CO in the air. Moreover, the authors find similar impact on the concentration of nitrogen oxides (NO_x), but they also find these estimates to be less precise. However, their analysis does not reveal any significant effects on the reduction of the ground level ozone (O_3). This conclusion is also supported by the finding of Auffhammer and Kellog (2011), who studied the effect of the gasoline content regulations in the USA on the pollution by ground ozone. They found an improvement in air quality in California only, where the regulation was inflexible and carefully targeted.

With regard to the distributional impacts of transport subsidies Seberinsky et al. (2009) point out that available evidence from developing countries indicates that existing urban public transport subsidy policies do not make the poorest people better off.[2] They point out that the supply side subsidies were found for the most part neutral or regressive; while demand side subsidies performed better, but many of them still did not improve the income distribution.

However, transport subsidies have been used for years especially in developed countries. For example, in Canada, during the 1960s and 1970s, public transport systems were subsidised by between 5 – 30 percent of the transportation costs in urban areas. Subsidies were even higher and reached close to 50 percent for light railways (Frankena, 1973). Also, in

[2] However, they have not studied this impact for developed countries in more detail.

the USA, the public transit services received significant subsidies for their capital expenditures and operation costs (Pucher et al., 1983; Obeng et al., 1997). Parry & Small (2009) indicate that the cost recovery from fares was 29 percent for the US bus systems and 48 percent for the US commuter rail. They also looked at ten European nations and found that their public transportation systems could recover only between 25-29 percent of costs from fares. In the UK, about 1 billion GBP has been spent annually on subsidizing local bus services (DfT, 2002) and still, this figure excludes the Greater London Authority transport grant. In Spain, the travel subsidies in the Metropolitan Region of Madrid exceeded 1.1 billion USD in 2005 (Vassallo and Perez de Villar, 2007). These examples represent explicit subsidies on subsidising rail, or bus transportation. However, implicit subsidies such as the availability of free parking facilities, or the implementation of the infrastructure grants for transit enhancements are also frequently used and these are usually not considered when accounting for transportation subsidies.

Studies have shown (Frenkena, 1973; Asensio et al., 2003) that means tested public transport subsidies do not bring large benefit for the poor, also because urban transportation subsidies do not bring benefit to those living in rural areas, where poverty levels are usually higher than in urban areas. An example of Ukrainian urban households showed that, in some cases, the benefit from public transportation subsidies has been increasing even up to the highest income category (Seberinsky et al., 2009). This documents that even though subsidies provided in the form of untargeted fare reductions will benefit low income households to some extent, but they will bring larger benefit to middle and high-income households and will lead to the subsidy having regressive impact in most cases. However, it should be also noted that as income levels in a society increase and private automobile ownership becomes more widespread, the public transport (especially in case of bus transport) may be almost solely used by lower income individuals. In difference to what was mentioned above, this theory may explain, why we often find public transport subsidies to be progressive in developed countries (Frenkena, 1973; Asensio et al., 2003).

Economies are frequently disrupted by strikes in the transportation sector, the impact of which has also been studied in the literature. Bauernschuster et al. (2017) concluded that due to higher traffic volumes and longer travel times, total hours of car operation increase during strikes between 11 to 13 percent. They found this effect to be accompanied by 14 percent increase in vehicle crashes, 20 percent increase in accident-related injuries, 14 percent in particle pollution, and 11 percent increase in hospital admissions for respiratory diseases among young children and pointed out that two main externalities associated with an increase in the usage of private cars were traffic accidents and air pollution, and entire city populations, not only transit users, might be adversely affected in each of these areas, when the public transport shuts down. Since transport subsidies make travel more affordable, more people can be expected to move towards using this subsidised form of transportation and the impact of these externalities can be decreased.

The studies of the transportation systems and transport subsidies in Slovakia are limited. Michniak (2016) identifies the main trends in commuting in Slovakia based on the 2001-2011 censuses. This study points to an increasing number of out-commuters, an increasing number of cross-border commuters as well as an increasing number of commuters to Bratislava and to other commuting centres. Šveda and Barlík (2018) used mobile positioning data to identify the commuting patterns of more than 190,000 phone ID users during the period of selected fourteen days of 2017. Their analysis showed that the majority of people commuted to work from satellite villages and towns to central area of Bratislava, predominantly to the historical city centre and surrounding parts of the city. The fact that the central train station is located close to the historical centre of Bratislava, where parking is at premium, may explain why rail transportation has become more widely used by commuters to this area of Bratislava in recent years. Given the accessibility of the city centre by trains from some satellite settlements and existing subsides for commuters, this policy may also impact individual decisions to which village/town to move. Virtually all municipalities in the Bratislava area are accessible by regional buses, but some of them are also accessible by local/regional trains.[3]

III. Transportation subsidy policy measures in Slovakia

In Slovakia, both supply side as well as demand side subsidies are in place for public transportation, i.e. bus and train transportation. These are provided locally, by administrative regional units, or at the central level. In this paper, we will focus on centrally implemented demand side subsidies for rail travel.

[3] Thus, when analysing the impact of this policy on migration behaviour of people in identified districts, we might use the municipalities without rail connection as a control group.

In the past decade, the social-democratic party "Smer-SD" had a leading position in the government and introduced a variety of social policy measures, among them also the measures expanding travel subsidies for elderly and students.

A. Free of charge travel subsidy

On 22nd October 2014, the Slovak government passed a law which would allow certain groups of population, namely children, students and pensioners, to use trains as a mean of transport within the Slovak Republic free of charge. The governing party (Smer-SD) promoted this policy within its social package formulated before the 2012 parliamentary elections[4]. The political party Smer-SD won the elections having gained the support of more than 44 percent of voters and the majority in the parliament. This also opened up the opportunity for passing laws and regulations, which were opposed to by the opposition parties. New rail subsidy measures were one of them. Main proclaimed aims of this policy were to encourage the use of rail transportation, improve people's lives and help to alleviate parents' expenditure burden related to their children's commuting costs. On the 17th November 2014, which is also celebrated as a Students' day in Slovakia, the Amendment of the Act 513/2009 and the Act 514/2009 (Central Government Portal, 2014) granting free rail transportation to selected groups of population came to force.

The opponents of the policy claim that the provision of the rail travel free of charge to selected groups of population shifts the cost burden partially to people, who do not benefit from the rail subsidy. In addition, it is also pointed out that due to the lack of rail infrastructure in more remote locations of the country, in reality, up to two thirds of citizens eligible for the subsidy do not have access to free rail travel, even though they are eligible to use it free of charge. Even though the subsidy has also been widely criticised by analysts, mainly on the grounds, which pointed to poor quality of railway infrastructure, which is in need of financial resources for its updates instead of overcrowding the train services by free

[4] Apart from free rail subsidy, the government introduced other measures as a part of their social package. These interventions include the increase of the minimum wage, Christmas bonus for pensioners, lower regulated prices of gas, increased salaries for teaching assistants of disabled children, exemption from tax and social contribution levies on part time jobs of students (up to the earnings of 200 euro per month) and the subsidies for innovation activities and tax allowances on R&D for businesses and start-ups. We do think that these interventions impacted our treatment and control groups.

of charge travellers, it has been in place up to now and the new coalition government, which came to office in April 2020, does not plan to modify this existing policy.

The passengers eligible to travel free of charge can be divided into three groups:

- Children under the age of 16[5] and students,
- Students studying at higher education institutions under the age of 26 and students from other European Union member countries, if they are enrolled in a study programme at a Slovak higher education institution,
- Seniors above the age of 62 and others, if they receive a pension (in such a case also if they are under the age of 62 years).

Slovakia as a member of the European Union must prevent discrimination of other EU citizens, thus, European seniors and those receiving a pension are also eligible to travel by train free of charge in Slovakia.

However, in order to be able to travel for free, eligible individuals for the subsidy must register for a travel card (this does not apply to children under the age of 6). Before each trip, a traveller must get a ticket free of charge to their desired destination and identify themselves with the travel card. Nevertheless, there is the allocation of only a limited number of "free of charge" seats on each train, which represents a problem for these groups of travellers, especially if they want to travel during peak times as Friday or Sunday afternoons, or on the days before holidays. Then, they must make sure to reserve the tickets well in advance, or they need to buy alternative tickets, which would be still heavily discounted travel tickets. However, the number of "free of charge seats" is unlimited on regional trains (Os and REX).

There are only two firms providing rail transportation in the Slovak Republic, i.e. the state-owned *Slovak Railway Company* (*Železničná Spoločnosť Slovensko*) and privately owned *RegioJet*. RegioJet must also comply with this legislation and provide free rail

[5] In Slovakia, it is compulsory for children to attend school below the age of 16 (they can finish school attendance after completing the school year during which they turned 16 years old). Thus, those, who leave the formal schooling system, when they reach 16, loose the status of a student, and therefore, they are not eligible for railway travel free of charge anymore.

transport to people from the above-mentioned groups. It is important to note that the subsidy is not applicable on InterCity and EuroCity trains (IC), or services which are not financially subsidised by the Slovak government.

In 2014, in addition to the subsidies covering 100 percent of the train fare described above, the government introduced also a 30 percent discount on commuter fares. This discount is applied on the regular fare and also on weekly and monthly travel passes. Since 1st February 2015, the discount on fares and travel passes for commuters was increased to 50 percent of full fare. The government introduced this measure to further stimulate the demand for rail travel and to make commuting for employees less expensive, too (SITA, 2015).

It is also important to note that rail fares were subsidised by the government even before the law on free rail travel for selected groups was introduced in 2014. Compared to Western European countries, as Slovakia was part of the former Soviet Union communist block, subsidies were high in some sectors of the economy and in some cases, they persisted even after the collapse of the block. According to Sachs and Woo (1994) in ex-communist countries mainly the services provided by state owned firms and services linked to employment were especially subsidised by the governments, which is supported also by the subsidies on train travel in Slovakia.

Table 1. Train ticket pricing as of 15th June 2014.

		Fare with free of charge tickets not available		
Price category	*Distance [km]*	*Normal fare*	*Children under 15, students*	*Railcards: students under age 26, seniors under age 70**
A Second class	0-50	2.75€	1.37	1.65€
	0-150	7.26€	6.63	4.36€
	0-300	13.26€	6.62	7.96€
	0-450	18.96€	9.47	11.38€
EuroCity (EC) supplement		1.50€	1.00€	1.00€

Note: For every additional 1 km the price is increased by: regular fare: 0.04€; children under the age of 15, students and railcard holders fare: 0.02€.
Source: Železničná Spoločnosť Slovensko, 2014.

Table 1 and *table 2* provide an overview of the train fares before the introduction of the train subsidies for children, students and pensioners. As can be seen from *Table 2*, before the introduction of free of charge travel, the fares for seniors older than 70 years of age were very low. Maximum fare that seniors had to pay for travelling from one end of the country to another one was 1.45 euro (see *Table 2*).

Table 2. Train ticket pricing before the introduction of the "free of charge" travel for seniors above 70 years of age.

		Subsidised fares for seniors above the age of 70 before the introduction of free of charge tickets		
Price category	*Distance [km]*	*Price*	*Distance [km]*	*Price*
A Second class	0-50	0.15€	251-300	0.90€
	51-100	0.30€	301-350	1.05€
	101-150	0.45€	351-400	1.20€
	151-200	0.60€	401-450	1.35€
	201-250	0.75€	451-500	1.45€
For every additional 50 km				0.15€
EuroCity (EC) supplement				1.00€

Source: Železničná Spoločnosť Slovensko, 2014.

To put the price of train tickets into perspective, if one commuted daily in the zone between 0-50 kilometres, it would cost 5.50 euro per day, commuting cost of five days per week would cost 110 euro per month. The prices of the train tickets might seem relatively low by international standards but taking into account that in 2014 in Slovakia the gross minimum wage was 352 euro (Inštitút zamestnanosti, 2020), even these costs of commuting might be prohibitively high for people earning lower wages.

Table 3. Price of fare (we consider travelling distance up to 50 km) and average wage/ pension earned by an individual in a respective group.

Type of fare	*Price paid for commuting per month [€]*	*Average wage/pension [€]*
Students under age of 26	66	161.84
Normal fare	110	858.25
Seniors	66	399.70
Seniors above age of 70 (subsidised)	6	399.70

Note: Since the data on the earnings of students are not available, we use a proxy only. Students who work while studying can work for maximum of 20 hours per week. Thus, we assume that students would earn fraction of the minimum wage related to this duration of working time.
Source: Statistical Office of the Slovak Republic, 2020.

If they needed to cover full cost of their commuting to work from their earnings, they might not continue working, since they would have to allocate about one third of their gross wage to cover the cost of their commuting (*Table 3* provides an overview of the cost of the fares relative to earnings in selected groups affected by the policy).

According to the data provided by the Slovak Railway Company (ZSSK, 2020), since the introduction of the free of charge rail travel, the demand for this travel has significantly increased on annual basis. This documents that the subsidy has been widely used by eligible groups of population and it has fulfilled the goal to stimulate the demand for rail travel. As proclaimed by the authorities (Government Office of the Slovak Republic, 2014), on the day, when the policy came to force (17th Nov 2014), more than 200 thousand people had already registered for a "free travel card", and within the first ten hours of the policy being in force, more than 20 thousand people took advantage of the free of charge travel. But only approximately 10 percent of people, who registered for a "free travel card" used the free travel immediately after they were issued it. We can speculate that they just wanted to make sure that they are eligible and have the required travel document to use if they decided to travel.

Due to the high demand for rail travel after the introduction of free of charge rail subsidies, the frequency of the most heavily used services was increased to meet the increased demand of travellers. Within the first two years since the introduction of this policy measure, more than 900 thousand people registered for a "free of charge travel card". As can be seen from *table 4*, more than 50 percent of registered individuals are represented by pensioners. By the end of the year 2019, the total number of registrations for free travel document increased by approximately 33 percent compared to 2016.

Table 4. Composition of persons registered for the free of charge travel card

Eligible group	*Number of registrations*			
	2016		*2019*	
Children under the age of 16	180 127	470 499	245 617	618 686
Students	290 372		373 069	
Pensioners under the age of 62	40 076	520 082	75 172	707 583
Pensioners above the age of 62	480 006		632 411	
Total number of registrations		990 581		1 326 269

Source: Železničná spoločnosť Slovensko, 2016

According to the statistical data provided by the Slovak Railway Company, ZSSK, (2016, 2020), in 2016, around 26.5 million trips were travelled for free due to the free of charge subsidy. In 2019 the number of free of charge trips reached almost 30 million and 50 percent of the trips were made by students above the age of 16 and 31 percent of these trips were made by pensioners.

In addition, as of 2016 among 990,000 registered for free travel, more than 21,000 people were foreigners, out of them almost 86 percent were pensioners, followed by children under the age of 16 and students (ZSSK, 2016). Citizens of the Czech Republic represented the majority of registered foreign nationals, which is understandable, since it is a neighbouring country of Slovakia, both countries share their common past and have similar languages. Czech tourists represent the largest group from among foreign tourists in Slovakia, i.e. they comprised almost 31 percent of all foreign tourists, who visited Slovakia in 2016 (Statistical Office of the Slovak Republic, 2020).

The travel subsidy has been assessed differently by different interest groups. The supporters of this policy measure argue that the subsidy helped to increase the attractiveness of passenger rail transportation. The policy is popular especially among students and pensioners, which are the groups taking advantage of free transport the most. During the recent restrictions caused by the COVID-19 pandemic; the government temporarily suspended the free of charge travel for students to limit their mobility. As some schools opened in June 2020, the free of charge travel for students was reintroduced. There was the proposal to temporarily suspend also free travel for pensioners, who as a population group most threatened by COVID-19 are encouraged to isolate themselves at home, but such measure has not been introduced.

On the other hand, critics of the policy point out that free of charge train travel is actually not free as eventually the cost must be covered from taxpayers' money. According to the Ministry of Finance of the Slovak Republic (2018), in 2018, the government expenditures to compensate for the cost of free of charge rail travel to the Slovak Railway Company was 22.5 million euro. The Ministry of Transportation (SITA, 2018) estimated that out of it 13 million euro was covered from taxes. However, the precise data on the sources used to cover the cost of this policy are not available and they can also change on annual basis.

This policy has also been criticised because the subsidy is partially shifted to pensioners from other European countries (which might have higher GDP and average income/pensions than it is the case in Slovakia) and this cost is covered by Slovak taxpayers. Some Slovak youth organisations also protested and petitioned against the policy, pointing out that money used to cover its cost should be directed to another uses and provide higher value in those sectors, which have been underfunded for years such as research and development, or education. One of such petitions was signed by more than 40,000 people (Nová generácia, 2017).

Even though this policy has been opposed to, at the moment, there seems to be a political consensus not to change it. Politicians realise that it is a sensitive issue for pensioners, students and families, i.e. voters, who tend to have quite high electoral turn out. Moreover, to our knowledge, so far, the impacts of this policy have not been systematically analysed. We believe that such an analysis could shed the light on the efficiency and welfare impacts of the measure and provide arguments to those, who are interested to improve the quality and efficiency of the public sector functioning in Slovakia.

B. Commuter rail subsidies

The changes in the regulation of subsidies for rail transport in Slovakia also include commuter travel, when people can buy discounted weekly or monthly travel passes for the route of their choice without the need to meet any additional requirements. This policy intervention was introduced to decrease the travel cost for commuters. Even though the fares are relatively low by international standards in Slovakia as shown above, they can be prohibitively high for people earning lower wages and subsequently reduce their incentives to keep their jobs requiring them to commute and pay full fare.

Thus, in 2014, the government introduced subsidised rail travel for commuters on the same route targeted at employees providing them with up to 30 percent discount on the cost of basic fare. This applied to weekly and monthly subscription tickets (travel cards). In addition, since the 1st February 2015, the subsidy was further increased to up to 50 percent of the price of the basic fare (ZSSK, 2020).

The price of the travel cards depends on the distance one wants to travel. The discount for second class single travel ticket represents 50 percent of the basic fare and the discount for first class travel ticket is even higher (if we consider the price per single trip). Moreover, the discount becomes relatively even larger, if one purchases the travel card allowing for the unlimited number of trips on a given route within a given period of time and travels more frequently.[6] Furthermore, the travel card can be used on all kinds of trains, except for the intercity trains (ICs), on which a supplement must be paid to use their faster service.

The statistical data of the Slovak Rail Company (ZSSK, 2020) show that the number of those purchasing weekly and monthly travel passes has grown since 2015, when their price was lowered due to the increased subsidy (see Appendix *Table A1*), in particular, the demand for weekly travel cards increased most. For example, within the Bratislava region (BA) the number of purchased weekly travel cards increased by 63 percent between 2015 and 2019. Thus, as suggested by the literature, this shows that subsidising the rail travel incentivises people to use this mode of transport more, even among the paying customers, if they receive a price discount.

The largest number of weekly and monthly travel passes was purchased within the Bratislava region (BA) and for the travel from Trnava (TT) to Bratislava region. However, rather surprisingly, the statistical data of the Slovak Rail Company shows that most people purchasing weekly rail travel cards for travel within the Zilina (ZA) region (ZSSK, 2020).[7] This could be explained by the fact that the car producer Kia has a production plant near Zilina, where many people from the region commute to work. Moreover, as suggested by the data reflecting numbers of purchased weekly and monthly travel cards, many people also commute from the Bratislava region to the Trnava region. This could also be explained by the fact that PSA Peugeot Citroen automobile plant is located in Trnava and people commute to work there.

In general, the commuting patterns indicate that in Slovakia the commuting has been increasing especially around large cities such as the capital – Bratislava, also due to people moving to the satellite villages, where real estate prices have been lower than in large cities, and then, commuting back to work to large cities. This concerns e.g. the neighbouring districts of the capital city Bratislava - Senec, Pezinok, Malacky, or another two nearby districts, which have substantial commuter travel: Dunajská Streda and Trnava. In recent years, these districts have experienced dynamic growth of the residential development as many people moved from the capital city to the nearby countryside. However, the majority

[6] Since the price of the travel card is not limited to a specific number of trips that one can make. Thus, one can travel unlimited number of times on the route one purchased the travel card for.

[7] KIA car producer has their largest European plant located in the region,thus, one can speculate that this might be linked to people commuting to work from different areas of the region to this company and their suppliers, many of which are also located in the region.

of them still commute for work and study purposes to the capital Bratislava. Thus, the demand for transportation from these satellite municipalities to Bratislava grew (Šveda and Barlík, 2018). Šveda and Barlík (2018) point out that a significant number of people moved to the suburbs of Bratislava between 2000 - 2017, since from among 80,000 dwellings built in the Bratislava region during this period, almost 50 percent were built in the suburban areas. *Figure 1* shows a map of the Bratislava region, Dunajská Streda district and city Trnava and related moving patterns (the description of individual districts is shown in *Figure 1A* in the Appendix).

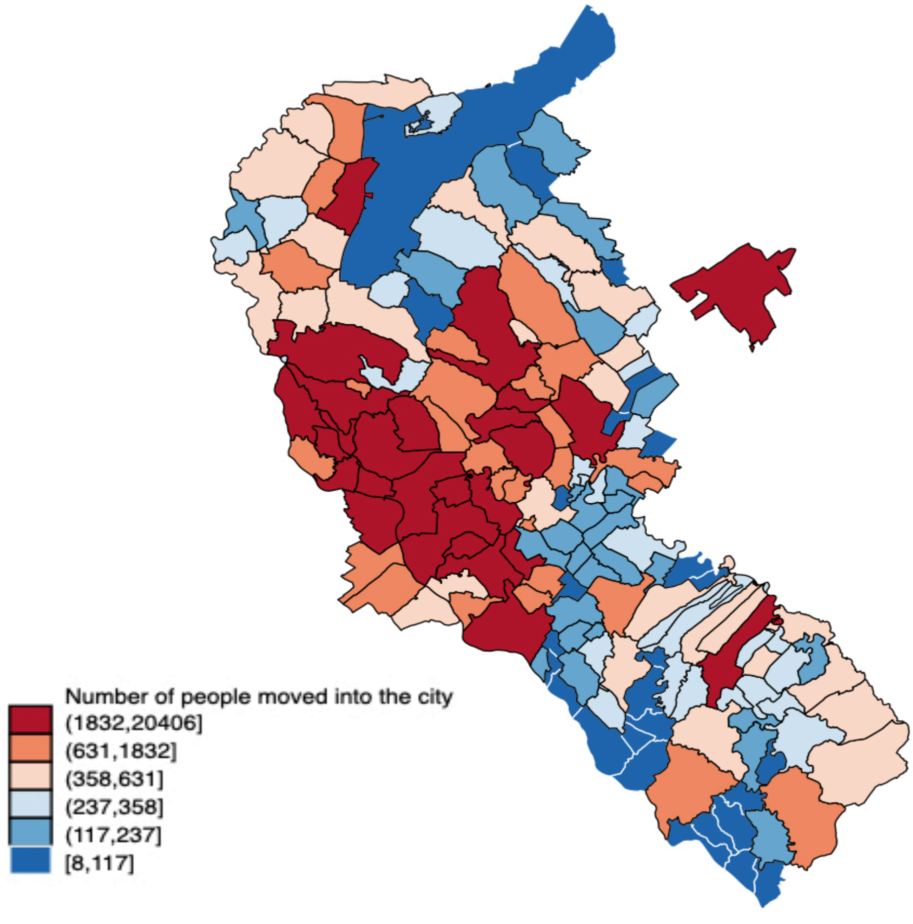

Figure 1. Migration patterns of people to cities and villages in the Bratislava region, Dunajská Streda district and city of Trnava between 2012 and 2019.
Source: Statistical Office of the Slovak republic, 2020.

Between 2001 - 2011 the number of commuters to Bratislava increased by almost 20,000 (Michniak, 2016). In 2011, more than 50 percent of all commuters to Bratislava commuted from three neighbouring districts (Senec, Pezinok, Malacky). The increasing number of commuters to Bratislava from its neighbouring areas during the period 2001–2011 points to the progressing suburbanisation in the areas around the capital city (Šveda and Podolák, 2014; Šveda and Šuška, 2014). Significant commuting flows of an economically active population to Bratislava also steam from districts a bit further away, e.g. Dunajská Streda (35 percent of all commuters), Galanta, Šaľa, Trnava and Senica (20-30 percent of all commuters). The commuting travel to Bratislava is also supported by intensive bus and train transport connections.

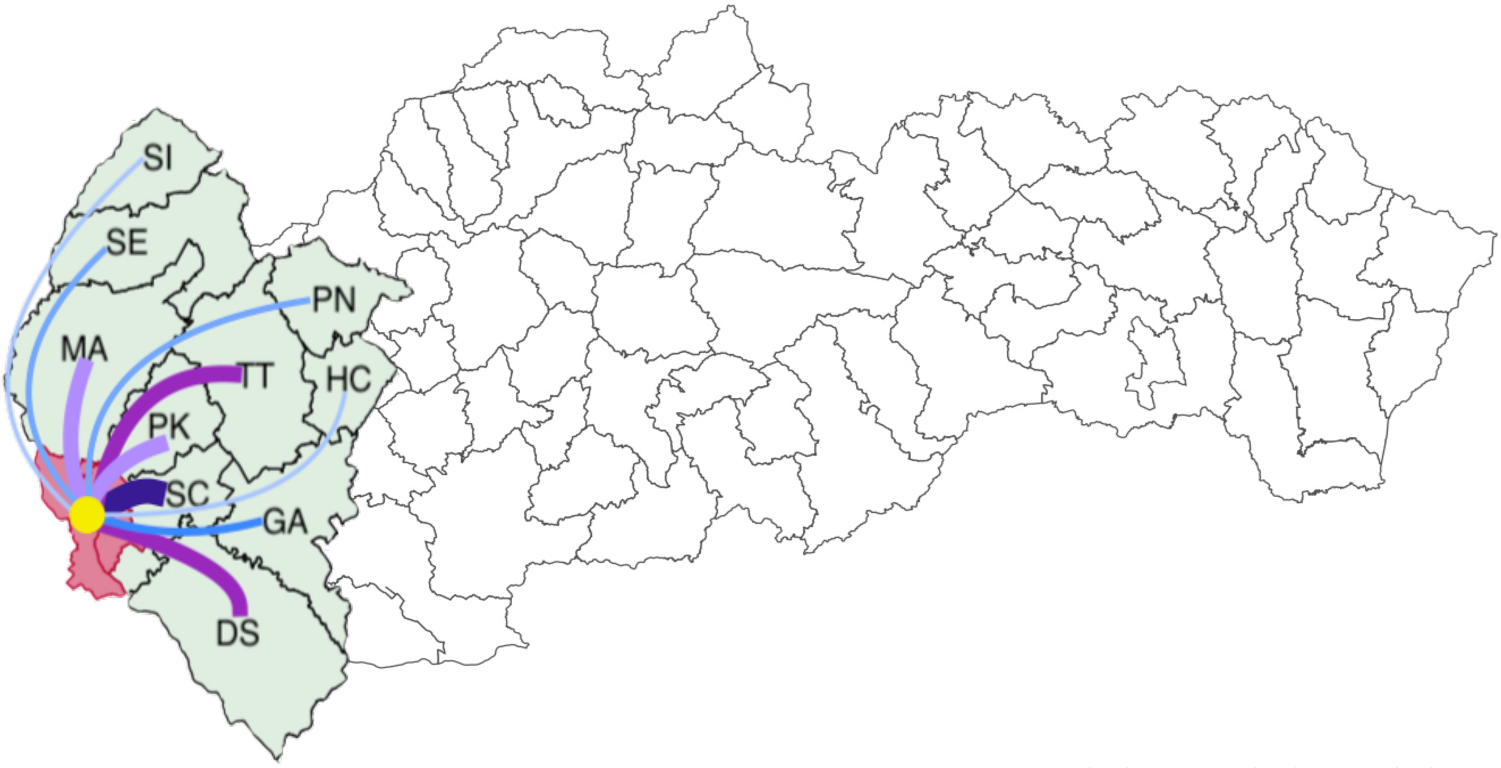

Figure 2. Daily commuting flows to Bratislava from neighbouring districts – Dunajská Streda (DS), Galanta (GA), Senec (SC), Pezinok (PK), Malacky (MA), Senica (SE), Skalica (SI), Trnava (TT), Piešťany (PN) and Hlohovec (HC).
Source: Šveda, Bago and Barlík (2019) – Analýza dennej priestorovej mobility s využitím pasívnych lokalizačných údajov mobilnej siete v Bratislavskom a Trnavskom kraji.

Šveda, Bago and Bralík (2019) study the commuting patterns to Bratislava by analysing the movement of more than 1.3 million SIM cards. The authors find that almost 133,000 SIM card holders commute to Bratislava on daily basis from the surrounding districts. They find that the strongest commuting pattern to Bratislava are from the Senec, Trnava and Dunajská Streda districts. *Figure 2* illustrates the daily commuting flows to Bratislava from neighbouring districts.

According to the data by the Statistical Office of the Slovak Republic (2020) out of over 26,000 people, which moved to Bratislava suburban areas between 2015 - 2019[8], more than 50 percent moved to the Senec district. Thus, with regard to this particular trend, which can be observed also in the areas around other larger cities in Slovakia, the discounts on the rail commuter travel were also introduced to provide incentives for commuters to switch from cars to trains and to decrease the road congestion and air pollution.

The Statistical Office of the Slovak Republic defines for statistical purposes a commuter as a person, who works outside the place of their permanent residence. The Statistical Office processes the data on commuting based on the data related to the location (i.e. municipality, district) of permanent residence of a commuter and their place of work.

The popularity of Bratislava with regard to commuting is based on the fact that it is the largest city and the capital city of the country and an administrative, social, cultural and economic hub of the country. The majority of foreign companies are also registered there. Thus, the city provides ample opportunities for employment and studying. Then, it should not be surprising that Bratislava is the largest commuting centre in Slovakia.

Strong commuting trend also exists between Košice, which is the largest city in Eastern part of Slovakia, and the capital city - Bratislava. Eastern Slovakia is the least developed region of Slovakia with traditionally higher levels of unemployment. Thus, it is also the geographical and administrative area from where people commute to more developed parts of the country, but they also move abroad to find better employment opportunities. Obviously, in such cases, they do not commute on a daily basis, but travel to their work destinations and many of them move on a more permanent basis (then, this mobility can be studied as migration flows). In case of less economically developed regions, migration and commuting from these regions and cross-border commuting become a necessity for ensuring their subsistence income for many of their inhabitants, due to the lack of job opportunities in the location of their residence.

[8] The estimated number represents the net number of people that moved into the district, i.e. the number of people moved in minus the number of people that moved out from the district.

IV. The Data

Main sample of the data used in our analysis is for the period between November 2012 and November 2016. The data include the capital city Bratislava and its surrounding regions. We use three different data sources to study the impact of rail subsidies on air quality and migration/moving decision of inhabitants.

The data on the travel patterns and usage of "free of charge rail travel" subsidies presented above was obtained from the statistical data of the Slovak Rail Company. In addition, the data on the subsidies and the details of the policy itself were obtained from official government press releases, government legal acts and regulations and from newspaper archives.

A. Pollution Data

The daily data for the period November 2013 - November 2015 on concentration of main pollutants were obtained from the Slovak Hydrometeorological Institute (Slovenský Hydrometeorologický Ústav, SHMU), which measures the concentration of air pollutants across Slovakia. In our sample, we include two measuring/monitoring stations from the Bratislava region.[9] We focus our attention on the concentration of three main tailpipe chemicals that are produced by an automobile, while in use, i.e. nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and inhalable coarse particles with a diameter of 2.5 - 10 micrometres (PM_{10}). *Figures A1, A2* and *A3* in the Appendix illustrate, how the concentration of these pollutants varies over the course of two months around the policy introduction day.

B. Weather and Holiday Data

The location-specific daily weather data were obtained from the Slovak Hydrometeorological Institute (SHMU) for the period November 2013 - November 2015.[10]

[9] One of the measuring stations chosen is located in an area, where rail transportation is used for commuting (i.e. the treatment group), and two measuring stations are located in an area, where rail transportation is not accessible (i.e. the control group).
[10] The locations coincide with the location of the measuring stations that report the concentration of emissions in our pollution sample.

These include daily measures of temperature (maximum and minimum daily temperature), amount of precipitation in millimetres and average wind speed. We use the weather data to control for the effects of the weather conditions on the level of air pollution. In addition, we control for the effects of holidays on the quality of air in the Bratislava region. We constructed a dummy variable that carries the value of one for days of school/public holidays, and zero otherwise. The information about school/public holidays comes from the Ministry of Education, Science, Research and Sport of the Slovak Republic (Ministerstvo školstva, vedy, výskumu a športu Slovenskej republiky).

C. Migration Data

The data on migration of inhabitants to villages and towns in the suburban areas of Bratislava from the period November 2013 - November 2016 were obtained from the Statistical Office of the Slovak Republic (2020). In particular, these include the statistical data on the numbers of people moving into a village or a town. In our sample, we include ten municipalities. Five of them have access to both rail and bus transportation, while five have access to bus transportation only. This allows us to separate the observations into a treatment and a control group. *Figure A5* in the Appendix illustrates how the migrating flows changed over the course of 2 years around the introduction of the rail transport subsidy. Moreover, municipalities from both treatment and control groups belong to the same commuting zone, thus, the bus and train tickets would be of the same price in both of them.

In addition, we control for the village fixed effects such as the distance to the capital and the population density of the municipality. We also control for the seasonality in the moving patterns, as people are most likely to move during the period between April-September.

V. Methodology and Empirical Strategy

In this section, we will outline the methodology and the empirical approaches used in the analysis and evaluation of the impact of the introduction of rail subsidies on air quality and migration flows in the Bratislava region (Slovakia).

The main analytical tool that we use in the identification strategy is a difference-in-differences method (DID). The difference-in-differences method allows us to analyse the treatment effect of the introduction of the transportation subsidy. The DID method enables to compare the outcomes before and after the treatment, i.e. we can compare the outcomes before and after the "free of charge travel" policy came into action on 17th November 2014.

The difference-in-differences design is a method of estimating the average treatment effect on the treated (ATT). Compared to other empirical methods, difference-in-differences approach (DID) compares the changes in outcomes across time periods. For DID to be valid, the treatment does not need to be randomised, but the treatment has to be exogenous. As long as the treatment and control groups differ in some initial characteristics that remain fixed over time, DID estimates will be unbiased.

The date, when the rail transportation subsidy came into action, i.e. 17th November 2014, tells us that those eligible, can travel free of charge since that day and others can take advantage of reduced prices of weekly/monthly travel cards. Thus, we can exploit this threshold to study the effects of this policy.

The date, when the policy came to action, was announced in advance and the introduction of the policy was not postponed. To fully benefit from the subsidy (i.e. to travel for free) one has to meet the age requirements. Given the stringed eligibility requirements, those who did not meet the criteria, were not allowed to take advantage of the free rail travel subsidy. In order to obtain unbiased difference-in-differences estimates, the common trend assumption needs to be satisfied. This implies that in the absence of the treatment, the difference between the treatment and the control groups should be constant over time. In addition, the composition of the treatment and the control group should not change over the period studied.

As the policy came into action nationwide, it is not possible to use a natural control group. Therefore, we designed control groups so that we were able to obtain to average treatment effect of the rail travel transportation subsidy. In the following sections, we describe the details of the ways how the control groups were constructed.

A. Pollution

First, we outline the method that we will use to estimate the causal effect of the introduction of rail subsidies on air quality. As mentioned previously, the policy was introduced nationwide. Thus, we constructed a synthetic control group. We chose a measuring station in the Bratislava outskirts, where people do not use rail transportation as a mean for commuting. Thus, even after the introduction of the rail transportation subsidy, those living in these areas cannot take advantage of the free rail travel subsidy. Nevertheless, the connection from these locations to Bratislava is facilitated by public bus transportation (this was the case also before the introduction of the rail transportation subsidy).

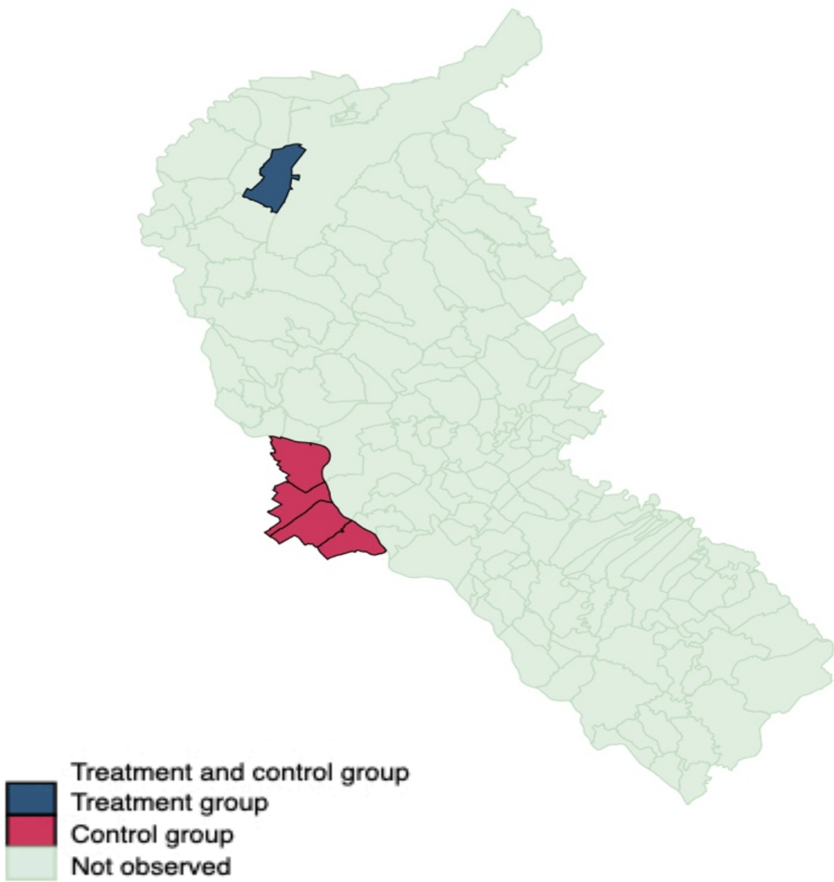

Figure 3. Geographical location of treatment and control groups for the pollution analysis.

The observations in the treatment group come from the measuring station located in Malacky. The town Malacky has access to a rail line to Bratislava, which is widely used by commuters. *Figure 3* shows the location of the measuring stations for the treatment and control groups.

Now, we progress to the outline of the difference-in-differences specification that we use to estimate the causal effect of the introduction of rail transport subsidies on the air quality:

$$y_t = \alpha + \beta_1 After_t + \beta_2 Rail_t + \beta_3 (After_t \times Rail_t) + \beta_4 \boldsymbol{X}_t + \varepsilon_t \quad (1)$$

where y_t is the natural logarithm of air pollutant concentration at time t, $After_t$ is a dummy variable indicating whether the rail transport subsidy was in place at time t, $Rail_t$ is a dummy variable indicating whether the measuring station is in the location, where there is rail transportation available at time t, $After_t \times Rail_t$ is an interaction term which gives us the estimated treatment effect, $\boldsymbol{X_t}$ is a vector of other explanatory variables such as the average wind speed, maximum and minimum temperature, precipitation and controls for holidays and working days, and ε_t is the residual. We are interested in the coefficient β_3 which is the difference-in-differences estimate. As suggested by the previous research (e.g. Chen and Whalley, 2012), we would expect the introduction of rail fare subsidies to be negatively related to the concentration of the studied tailpipe pollutants. However, Chen and Whalley (2012) suggest that the demand for rail transportation is positively correlated to the demand for automobile travel. In addition, train ridership tends to be high, when automobile usage is high, because of the fact that the demand for rail and automobile travel tends to be high during the same time period, e.g. people tend to travel/commute most during peak times and during the working days of the week. This could mean that the sign of the expected relationship between air pollution and train ridership would be ambiguous. Also, the standard errors can be biased because of serial correlation. Thus, we will use robust standard errors.

The identifying assumption is that in the absence of the introduction of the rail transport subsidy, the concentration of the studied air pollutants would follow the same trend in both the treatment and control groups. Another assumption that has to be satisfied in order to obtain unbiased estimates is that the composition of the treatment and control groups does not change during the period studied. We believe that this assumption is satisfied as the measuring stations were located in the same area during the entire time period considered by our study.

B. Migration

Our preferred identification strategy to determine the effect of the rail subsidies on migration of inhabitants is the difference-in-differences method (DID). In this instance, we also created a control group synthetically. We chose municipalities that do not have access to rail transportation as our control group. Observations from municipalities that have access to rail transportation with a direct connection to Bratislava represent our treatment group.

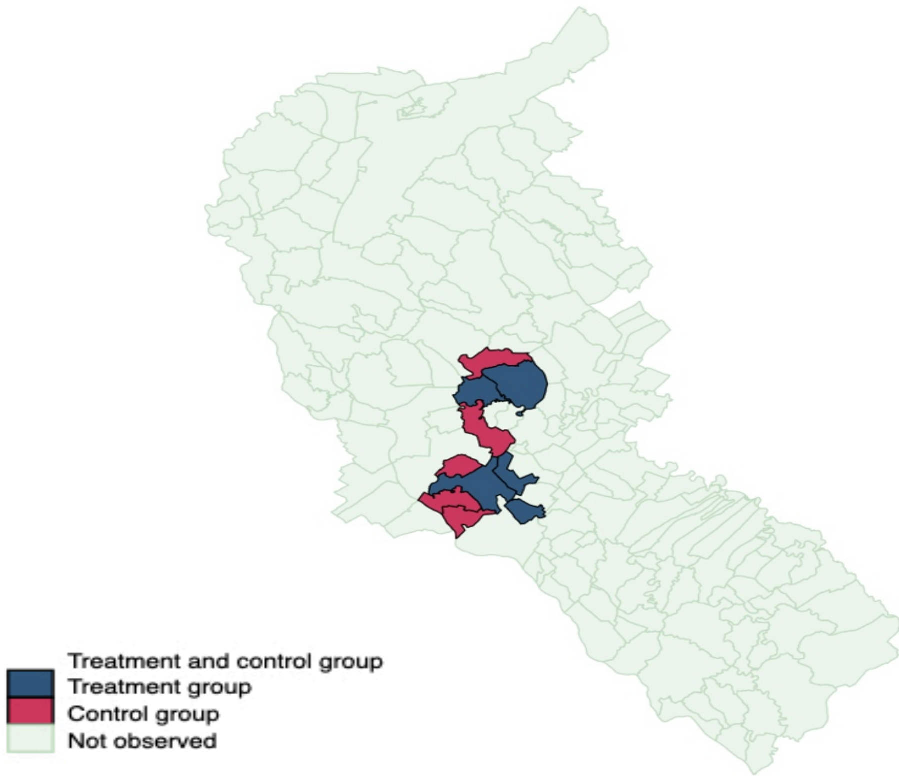

Figure 4. Geographical location of treatment and control groups for the migration analysis.

Both treatment and control groups have access to direct bus connections to Bratislava. We chose municipalities from treatment and control groups in a close proximity, so that the commuting costs and property prices were similar (see *Figure 4* for the location of the treatment and control groups). However, it is highly unlikely that those living in municipalities without access to rail transportation would travel to a nearby municipality with access to rail transport to connect for the rail service, this can be due to the time lost by travelling to a railway station in another municipality, related cost, or the lack of parking possibilities at the rail stations.

Difference-in-differences specification for this analysis is formulated as follows:

$$(2) \qquad Move_t = \alpha + \gamma_1 After_t + \gamma_2 Rail_t + \gamma_3 (After_t \times Rail_t) + \gamma_4 \boldsymbol{X}_t + \varepsilon_t$$

where $Move_t$ is the natural logarithm of the number of people that moved to a selected location at time t, $After_t$ is a dummy variable indicating whether the rail transport subsidy was in place or not, $Rail_t$ is a dummy variable indicating whether the area had access to rail transportation at time t, $\boldsymbol{X}_t$ is a vector of covariates such as population density at time t, seasonal dummies, number of days in a month, location specific fixed effects such as the distance from the capital Bratislava and size of the municipality and ε_{it} is the residual. We are interested in the difference-in-differences coefficient γ_3, which we expect to capture the increase in migration after the introduction of the studied policy.

The standard errors may be serially correlated as certain characteristics may be common among municipalities that are located in near proximity. Thus, we will cluster the standard errors at the area level as suggested by Bertrand, Duflo and Mullainathan (2014) – in particular, we will cluster municipalities based on the transportation zone they belong to.

The main identifying assumption is that in the absence of the treatment (i.e. in the absence of the rail transport subsidy introduced on the 17^{th} of November 2014) the trend in migration to municipalities studied should be the same for both the treatment and the control group. Another assumption that has to be satisfied in order to obtain unbiased estimates is that the composition of the treatment and the control group does not change over the period analysed. We expect these assumptions to be satisfied. Moreover, we expect that the moving decisions were most likely unaffected by other factors at that specific point of time, however, there might have been some unobserved factors that could have affected people's decisions to move to certain locations, e.g. changes in preferences, which we have not considered. The main problem we face with regard to this specification is that the data on migration is available on monthly basis only and not on a daily basis. Thus, we are not able to use the precise date of the policy introduction as a threshold for the "after" policy intervention observations, thus, we use the month of November 2014 as a threshold instead.

VI. Results

In this section, we present the estimation results of the analysis outlined in the previous section. In addition, we also present the results of the sensitivity analysis.

A. Pollution

In this section, we present the estimation results of the difference-in-differences analysis of the impact of rail transportation subsidy on air pollution.

Table 5. Summary of pollution and weather descriptive statistics with the summary of the means of variables with standard deviation in parentheses.

	Col.1 General	*Col.2 Before policy introduction*	*Col.3 After policy introduction*	*Col.4 Treatment group*	*Col.5 Control group*
Concentration of NO_2 [µg/m^3]	22.9884 (9.9447)	22.9346 (9.8517)	23.0588 (10.0745)	20.5065 (8.7756)	25.1680 (10.3970)
Number of observations	1,157	656	501	541	616
Concentration of PM_{10} [µg/m^3]	27.1878 (13.0282)	28.1388 (14.2171)	26.2123 (11.6162)	26.1763 (12.7048)	28.5020 (13.3357)
Number of observations	1,106	560	546	625	481
Concentration of SO_2 [µg/m^3]	6.6799 (2.8763)	5.91031 (2.8294)	7.5426 (2.6788)	8.3395 (2.0155)	5.0307 (2.6466)
Number of observations	1,262	667	595	629	633
Average wind speed [km/h]	3.6664 (2.0208)	3.5763 (2.0825)	3.7564 (1.9546)	3.0784 (1.8165)	4.2544 (2.0446)
Max daily temperature	16.3969 (9.2825)	16.3625 (8.5571)	16.4313 (9.9593)	16.6018 (9.1623)	16.1921 (9.4030)
Min daily temperature	6.9927 (7.1914)	7.2297 (6.6775)	6.7563 (7.6670)	6.2569 (7.2482)	7.7285 (7.0628)
Precipitation [mm]	1.9274 (5.8436)	2.1033 (6.8096)	1.7519 (4.7868)	1.8590 (6.1595)	1.9958 (5.6004)
Number of observations	1,462	730	732	731	731

Table 5 presents a summary of pollution and weather descriptive statistics. The table shows the means for the entire observation period (i.e. November 2013 - November 2015) in column 1, means of observations before and after the introduction of the policy in columns 2 and 3 respectively. Finally, columns 4 and 5 present the means of observations of the treatment and control groups.

The results in *Table 5* suggest that the concentration of nitrogen dioxide and inhalable coarse particles (PM_{10}) is on average lower in the treatment group than in the control group. However, the concentration of sulphur dioxide is on average lower in the control group. If we look at the descriptive statistics before and after the introduction of the rail transport subsidy, we see that on average the concentration of nitrogen dioxide and sulphur dioxide is higher after the policy came into action.

The estimated results of the concentration of major air pollutants (i.e. nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and inhalable coarse particles with a diameter of 2.5 – 10 micrometres (PM_{10})) are summarised in *Tables 6, 7 and 8*. We present the results of the analysis considering various time specifications – we estimate difference-in-differences estimates using 365 day to 30 day bandwidth around the policy introduction date. Moreover, in the panel A, we present the results without controls, whereas in the panel B, we present the estimation results taking into account controls for weather, holidays and a day of the week controls.

We find that in Slovakia, the introduction of rail transportation subsidies has a negative effect on the concentration of nitrogen dioxide and sulphur dioxide in the area with access to rail transportation, i.e. it helps to improve the air quality.

In particular, the estimated results in *Table 6* suggest that the introduction of the "free rail travel policy" helps to decrease the concentration of nitrogen dioxide in the air by 28 to almost 46 percent. Moreover, these estimates are statistically significant at 1 percent level.

Table 6. The effect of rail transport subsidy on the concentration of nitrogen dioxide NO_2 with the dependent variable being the logarithm of nitrogen dioxide concentration.

Dependent variable logNO_2	Col.1 DID $\pm$365 days	Col.2 DID $\pm$180 days	Col.3 DID $\pm$60 days	Col.4 DID $\pm$30 days
Panel A: No controls				
$After \times Rail$	-0.2983*** (0.0407)	-0.2555*** (0.0589)	-0.1412 (0.1124)	0.0096 (0.1028)
Number of observations	1,157	655	194	121
Panel B: weather and holiday controls				
$After \times Rail$	-0.4577 *** (0.0407)	-0.3067*** (0.0458)	-0.2895*** (0.0937)	0.0737 (0.0862)
Number of observations	1,157	655	194	121

Robust standard errors are reported in the parentheses.
**** significant at 1 percent level*
*** significant at 5 percent level*
** significant at 10 percent level*

Table 7. The effect of rail transport subsidy on the concentration of particles PM_{10} with the dependent variable being the logarithm of PM_{10} particles concentration.

Dependent variable logPM_{10}	Col.1 DID $\pm$365 days	Col.2 DID $\pm$180 days	Col.3 DID $\pm$60 days	Col.4 DID $\pm$30 days
Panel A: No controls				
$After \times Rail$	0.1981*** (0.0593)	0.4615*** (0.0903)	0.2777** (0.1352)	0.1135 (0.1561)
Number of observations	1,106	537	199	122
Panel B: weather and holiday controls				
$After \times Rail$	0.1341** (0.0577)	0.3258*** (0.0923)	0.1755 (0.1223)	0.0896 (0.1507)
Number of observations	1,106	537	194	121

Robust standard errors are reported in parentheses
**** significant at 1 percent level*
*** significant at 5 percent level*
** significant at 10 percent level*

After including weather, holidays and a day of the week controls, we find that the introduction of rail travel subsidies affects positively the concentration of the inhalable coarse particles with a diameter of 2.5 – 10 micrometres (PM_{10}) in the treated area, which is contrary to what we expected. Specifically, we find that after the rail subsidies were introduced, the concentration of inhalable coarse particles (PM_{10}) increased by approximately 13 percent if we consider the 365 day bandwidth, and by almost 32 percent if we take into account the 180 day bandwidth around the policy introduction threshold in the area with the access to rail transportation (see *Table 7*). These results are statistically significant at 5 and 1 percent significance level respectively. However, we find that the difference-in-differences estimates are not statistically significant if we consider a narrower bandwidth around the date of the introduction of the rail transport subsidy (i.e. a 60 and a 30 day bandwidth).

Table 8. The effect of rail transport subsidy on the concentration of sulphur dioxide SO_2. Dependent variable is the logarithm of sulphur dioxide concentration.

Dependent variable logSO_2	*Col.1 DID ±365 days*	*Col.2 DID ±180 days*	*Col.3 DID ±60 days*	*Col.4 DID ±30 days*
Panel A: No controls				
$After \times Rail$	-0.3563*** (0.0432)	-0.1880*** (0.0526)	0.3096*** (0.0894)	0.2125* (0.1223)
Number of observations	1,262	676	229	117
Panel B: weather and holiday controls				
$After \times Rail$	-0.3490*** (0.0418)	-0.1856*** (0.0523)	0.3460*** (0.0851)	0.2468** (0.1200)
Number of observations	1,262	676	229	117

Robust standard errors are reported in parentheses.
**** significant at 1 percent level.*
*** significant at 5 percent level.*
** significant at 10 percent level.*

Table 8 presents the estimation results of the impact on the concentration of the sulphur dioxide in the air. The estimates suggest that there is a negative relationship between the introduction of rail subsidies on the concentration of sulphur dioxide for the larger bandwidths (i.e. 365 and 180 days). However, we find a positive relationship when we consider a shorter time specification (i.e. 60 and 30 days). Considering the one-year bandwidth around the policy introduction date, we find that the concentration of SO_2 in the air falls by almost 35 percent after the "free rail policy" came into action in the treatment area. This result is statistically significant at 1 percent level. On the other hand, if we consider observations closer to the date when the policy was introduced, we find that the concentration of SO_2 in the air increases by about 25 up to 35 percent. But if we consider the observations 30 days around the policy introduction date, we find that the statistical significance of the estimate is weaker, i.e. it is significant at 5 percent level.

Overall, we find that the introduction of the rail transport subsidies helps to reduce concentration of tailpipe pollutants, and thus helps to improve the air quality in the area that has access to rail transportation. Rather surprisingly we find that the introduction of the rail transport subsidies has a positive and statistically significant effect on the concentration of particles PM_{10}. Why this is the case should be studied by further research.

A possible threat to the credibility and unbiasedness of our estimates can be based on the number of observations. In particular, some of the observations are missing due to technical problems and maintenance of the measuring stations. In addition, there might be factors playing the role, which we were not able to account for, for example atmospheric or weather anomalies that could affect the concentration of the tailpipe pollutants in the air and therefore, also affect air quality. Due to the fact that we consider only one measuring station in the treatment group and one in the control group, the results may be specific only with regard to these two locations. Therefore, the external validity of our estimates can be limited and questioned.

In order for the difference-in-differences estimates to be unbiased, the common trend assumption has to be satisfied. We believe that in our analysis, the common trend assumption holds. In the absence of the treatment (i.e. the introduction of the "free rail travel policy"), the air pollution would follow the same pattern, or trend in the treatment and in the control groups. If the subsidy has not been introduced, there would have not been any new incentives at that specific point of time to switch from using cars to using rail transportation for commuting.

B. Migration

Next, we present the estimation results of the impact of "free travel rail" subsidy introduction on the migration into satellite villages in the Bratislava region of Slovakia.

Table 9 shows the summary of the characteristics from the related migration data. The first column presents the summary of the descriptive statistics for both treatment and control groups during the observation period, i.e. between November 2014 and November 2016. Columns 2 and 3 show the summary characteristics before and after the "free rail travel policy" introduction, while columns 4 and 5 show the summary of the characteristics of the treatment and control groups. We see that the municipalities located in the treatment group are on average larger and have higher population density than villages in the control group.

Table 9 also indicates that more people moved to municipalities with access to rail compared to municipalities without access to rail transportation.

Table 9. Summary of the migration descriptive statistics with the summary of the means of variables with standard deviation in parentheses.[11]

	Col.1 General	*Col.2 Before policy introduction*	*Col.3 After policy introduction*	*Col.4 Treatment group*	*Col.5 Control group*
Number of people moved in	18.104 (17.78409)	15.3 (18.35357)	20.908 (16.76831)	19.464 (14.84947)	16.744 (20.2385)
Access to rail transportation	0.497992 (0.5004987)	0.5 (0.501003)	0.5 (0.501003)	1.0000 (0.0000)	0.0000 (0.0000)
Distance to the capital in kilometres	18.25 (4.003819)	18.25 (4.007836)	18.25 (4.007836)	18.7600 (4.5887)	17.7400 (3.2480)
Size of village in square kilometres	15.47779 (6.839821)	15.47779 (6.846685)	15.47779 (6.846685)	17.5871 (8.5150)	13.3684 (3.51008)
Population density per square kilometre	224.8392 (103.6183)	212.5553 (98.71144)	237.123 (107.0966)	240.9359 (103.6228)	208.7424 (101.285)
Number of observations	500	250	250	250	250

[11] The observations also include October 2012 and October 2016.

Table 10 reports the estimation results of *equation (2)* using various time specifications. The variable of our interest is the difference-in-differences estimate ($After \times Rail$), which provides the estimation of the treatment effect. In columns 1 and 2 we consider longer period around the policy introduction, whereas in columns 3 and 4 we consider the estimated effect during a shorter period around the policy introduction – 6 and 3 months, respectively. In all columns we include the same controls, i.e. we control for the distance of the village from the capital city Bratislava, size of village in square kilometres, population density. We also control for the possible seasonality in moving decisions and number of days in a month.

Contrary to what we expected, the estimated results suggest that the impact of the introduction of the rail travel subsidies has a negative effect on migration to villages with access to rail transportation. However, these results are not statistically significant for all four time period specifications. Thus, we find that the introduction of rail transportation subsidies had no effect on people's decision to move to municipalities with direct access to rail transportation.

Table 10. Effect of the introduction of rail transport subsidies on migration.

	Col.1 *DID* $\pm$*2 years*	*Col.2* *DID* $\pm$*1 year*	*Col.3* *DID* $\pm$*6 months*	*Col.4* *DID* $\pm$*3 months*
$\boldsymbol{After \times Rail}$	-0.1170 (0.1479)	-0.3829 (0.2754)	-0.0908 (0.3971)	-0.0432 (0.6778)
Years included	2012-2016	2013-2015	2014-2015	2014-2015
Number of months	48	24	12	6
Number of observations	432	218	114	62

Clustered standard errors at the commuting zone level are reported in the parentheses.
**** significant at 1 percent level*
*** significant at 5 percent level*
** significant at 10 percent level*

Nevertheless, we find a significant relationship between the migration to specific municipalities and their size and population density. The estimated results indicate a positive relationship between the size of the municipality, the population density and the decision to move there. The estimates of the size of the municipality are statistically significant for all time specifications, except for the shortest time specification around the policy introduction date. We find that the estimated results of the impact of population density on migration decisions to certain municipalities are only not significant for the 1 year time specification around the policy introduction date (see *Table A2* in the Appendix for results). This suggests that people are more likely to move to places that are larger and also have larger population. This may be due to the fact that usually larger municipalities offer their residents more services and provide access to various amenities like shops, schools, restaurants, etc. Also, the choice of available housing can be larger in larger villages.

The estimated results suggest that the introduction of the rail transport subsidies had no impact on the migration of population into satellite villages around Bratislava that have access to rail transportation.

If we assume that people in their productive age are most likely to move, considering that the "free rail travel" subsidies are targeted at the population outside of the productive age, i.e. children, students and pensioners, it is not that surprising that the introduction of such a policy did not affect significantly the moving decisions of people in the studied region in spite of the fact that the subsidies for the discounted weekly and monthly travel were introduced at the same time. Another possible explanation, why the introduction of subsidies had not a significant impact on the migration of commuters to Bratislava to municipalities with access to rail transportation could be that Bratislava central railway station is located in the centre of Bratislava, thus, those working outside of the city centre would have to use additional type of public transport to reach their destination, which would diminish the advantage of the rail travel. This would reduce its convenience and prolong the commuting time. Thus, these results suggest that the policy did not motivate people to move to the locations that have access to rail transportation.

We believe that the common trend assumption is satisfied in our analysis as it is most likely that even without the introduction of the "free rail travel policy" the decision to migrate to satellite municipalities around Bratislava would follow a similar pattern, regardless if the municipality had access to rail transportation or not. However, there can still exist other factors that affect the moving decision, which we did not account for. For example, the decision to move to a certain location is normally affected by relative property prices. However, we were not able to obtain such data for the period studied and specifically for municipalities of our interest. Moreover, the estimated results may only apply to the location studied, i.e. to the Bratislava region. Thus, this may pose a threat to the external validity of our estimates.

C. The impact of the suspension of free rail travel subsidies for students and pupils on the reduction of mobility during the COVID-19 lockdown

The COVID-19 pandemic affected Slovakia in Spring 2020. The country introduced strict lockdown measures as soon as first infections were identified in Slovakia. These included the closure of universities, secondary and elementary schools. As a part of the measures implemented by the government in the fight against the coronavirus, the free rail travel was suspended for pupils and students. The government decided to introduce this temporary measure because students did not limit their travel more substantially even though schools and universities were closed, and the teaching was carried out in the online format.

The rail subsidies for pupils and students were suspended for the period between 1st April and 31st May 2020[12]. During this period, pupils and students could purchase tickets with a 50 percent discount from the basic fare for the second-class carriages.[13]

As an extension of our analysis we carried out an ordinary least squares analysis by regressing the log number of daily cases on the number of tests carried out and a series of dummy variables taking value 1, when a given measure to fight COVID-19 was in place, and 0 otherwise. After we conducted and ran a simple OLS regression analysis, we found that the suspension of the "free rail travel subsidies" for pupils and students did not have a significant impact on the reduction of confirmed COVID-19 cases. However, our analysis also suggests that other introduced measures such as the closure of schools and borders, or imposing

[12] The Slovak government partially allowed schools to open since 1st June 2020, and at the same time, it reintroduced free rail travel for pupils and students.

[13] However, it should be noted that free travel subsidies for pensioners, who are one of the most vulnerable groups with regard to the impact of the infection by the novel coronavirus COVID-19, were not discontinued during the lockdown. As reported by the government (Úrad Vlády SR, 2020) during the last two weeks of March 2020 (16th – 29th), pensioners took on average more than 4200 trips per week. During the first week of April the number of trips by pensioners increased to almost 5000 trips per week. However, the largest increase in the travel of pensioners was observed in the second half of April, when pensioners took on average 5500 trips a day. Because of such a sharp increase in the usage of the rail transport by members of the most vulnerable group, the government considered suspending the rail subsidies also for the pensioners over the age 62. However, so far this measure was not introduced.

mandatory state quarantine, had a significant effect on the reduction of confirmed COVID-19 cases (see *Table 11*).

Table 11. The impact of measures taken by the Slovak government against the fight of the coronavirus COVID-19. The period studied is from the 13th of March until the 30th of June.

	OLS estimates
Number of tests	0.0002** (0.0001)
State quarantine	-1.0352*** (0.3072)
Borders closed	0.8764*** (0.3238)
Schools closed	-0.8847** (0.4388)
Rail subsidies for students cancelled	0.0323 (0.3847)
Number of observations	107

Robust standard errors are in parentheses.
**** significant at 1 percent level.*
*** significant at 5 percent level.*
** significant at 10 percent level.*

Nevertheless, there are strong limitations of this analysis. Given that there is only a treatment group and no control group, the estimated results have no causal interpretation. Moreover, since the majority of the explanatory variables are dummy variables, the estimated results do not have to be indicative of, or explain, the impact of the measures taken by the government in the fight against coronavirus on the number of daily cases.

In addition, the considered measure does not seem to have a more substantial impact on the mobility of individuals using rail transport. When looking at the mobility data reported by Google (2020) compared to the baseline there has not been a significant drop in the mobility of people in the transit stations (i.e. places such as public transportation stops, bus and train stations) after the government suspended the rail travel subsidies for children and students. The trend in mobility was rather stable and it slowly started increasing at the beginning of May, when the lockdown measures started to be lifted.

Perhaps, the effect on reducing the mobility of the people would have been more significant, if the government suspended the subsidies/discounts for all eligible groups.

VII. Discussion and conclusions

Based on the analysis carried out we can conclude that the introduction of rail transportation subsidies in Slovakia on 17th November 2014 helped to reduce the concentration of some air pollutants in the air. We find that the introduction of such policy led to the reduction of the concentration of nitrogen dioxide and sulphur dioxide in the air. However, our analysis also indicates that the introduction of the "free rail travel subsidy" led to the increase in the concentration of the inhalable coarse particles (PM_{10}) in the location studied. The results of the empirical analysis also suggest that after the introduction of the rail transport subsides, the demand for rail travel has been increasing on annual basis and this also applies to the demand by those, who are not eligible for free rail travel subsidy. This suggests that introducing rail subsidies also attracted more users, who might have used an alternative transportation mode such as a car before. The results of our research suggest that subsidising public rail transportation contributes to reducing the concentration of air pollutants in the air, countries trying to reduce air pollution could use similar policies using rail services.

Our analysis contributed to the research of public rail travel subsidies and their impact on air pollution and migration patterns to sub-urban areas, especially with regard to the study of related policies in Slovakia. However, further research is needed to deepen the robustness of the results. As we only used one pollution measuring station in the treatment and one in the control group, more robust estimates would be achieved, if the data from other measuring locations were also used. Thus, this would increase precision and validity of the estimated effects. Moreover, since the observations for some days were missing in our dataset, the preciseness of our estimates can be slightly negatively affected. Further research could also focus on including other factors that could have affected the air pollution but were not accounted for in our analysis.

The results of our research also indicate that the introduction of rail transport subsidies did not affect people's decisions to move to municipalities with direct access to rail transportation services in the Bratislava region. As already mentioned above, there may be several reasons, why after the introduction of rail subsidies the access to rail network is not a significant factor in the decision to move to a municipality with such an access. Moreover, additional analysis is needed to verify this result. In our study, we considered only the migration flows to 10 municipalities in the Bratislava region. Further research should be conducted using data for more municipalities in the Bratislava region and in other regions of Bratislava. In addition, other relevant factors, such as the property prices in the studied locations should be considered. However, we assume that the property prices are also correlated with the distance from the capital Bratislava. Thus, since we controlled for the distance of a municipality from Bratislava, we have been able partially to take into account the missing data on the average property prices.

The analysis of the effects of public transport subsidies is an important topic with high policy relevance. In the current economic recession caused by the COVID-19 pandemic associated with increasing unemployment levels and its larger negative effects on lower income strata of the population, the issue of public rail travel subsidies becomes even more relevant. Next to the current economic downturn, the world faces the climate change crisis and this study also contributes to the discussion of transportation subsidy policies as a way to limit negative impact of car traffic on the environment. However, this research could be further extended and focus also on the study of the effects of rail transport subsidies on other variables such as life satisfaction, gender equality and others. In addition, it would be also important to study the effects of the policy on those groups of population that the policy is targeted at. But to study these effects, we would need a different dataset and also other analytical methods should be used.

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IX. Appendix

A. Tables:

Table A1. Number of people who purchased monthly (mth) and weekly (wk) discounted rail travel cards per year in selected regions – Bratislava region (BA), Trnava region (TT) and Žilina region (ZA).

Region of origin	Destina-tion region	2015		2016		2017		2018		2019	
		Mth	Wk	Mth	Wk	Mth	Wk	Mth	Wk	Mth	Wk
BA	BA	22,728	63,662	20,478	75,191	20,034	89,555	21,582	98,096	23,328	103,852
	TT	17,723	59,887	17,268	79,646	16,542	91,496	15,917	98,830	15,469	103,278
TT	BA	17,641	59,528	17,182	79,245	16,391	91,015	15,870	98,073	15,575	104,053
ZA	ZA	22,052	132,036	19,780	161,435	19,049	169,121	18,116	169,782	17,412	163,282

Source: Data provided by the Slovak Rail Company (ZSSK).

Table A2. Effect of introduction of rail subsidies on migration.

Dependent variable: log(number of people moved)	*Col.1 DID ±2 years*	*Col.2 DID ±1 year*	*Col.3 DID ±6 months*	*Col.4 DID ±3 months*
Size of municipality [km²]	0.0689*** (0.0165)	0.0522*** (0.0127)	0.0616* (0.0253)	0.0572 (0.0314)
Population density	0.0047* (0.0020)	0.0037 (0.0021)	0.0045* (0.0020)	0.0049** (0.0018)
Number of months	48	24	12	6
Number of observations	432	218	114	62

Clustered standard errors at the commuting zone level are reported in the parentheses.
**** significant at 1 percent level*
*** significant at 5 percent level*
** significant at 10 percent level*

B. Figures:

Figure A1. The map of Slovakia – the studied districts are highlighted in brown clour – Bratislava (BA, Senec (SC), Pezinok (PK), Malacky (MA), Dunajská Streda (DS) and Trnava (TT) districts.

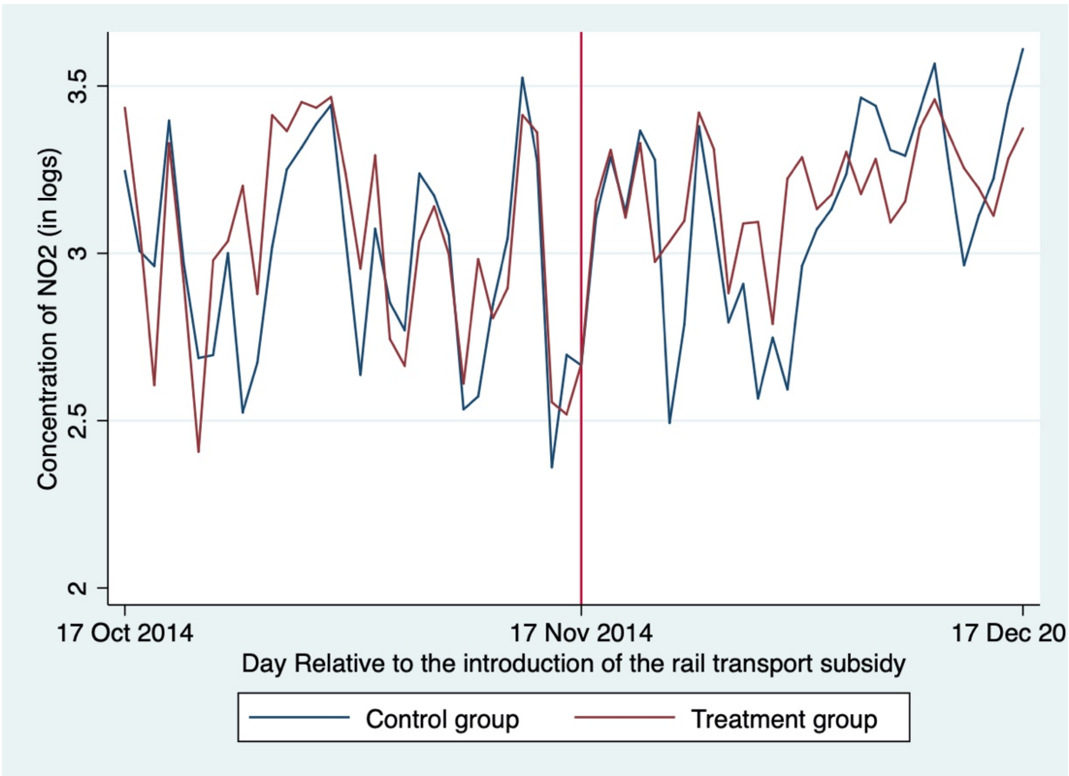

Figure A2. The development of the concentration of NO_2 in the treatment and control group during the period
of 2 moths around the introduction date of the rail transport subsidy.
Source: Slovak Hydrometeorological Institute, 2020

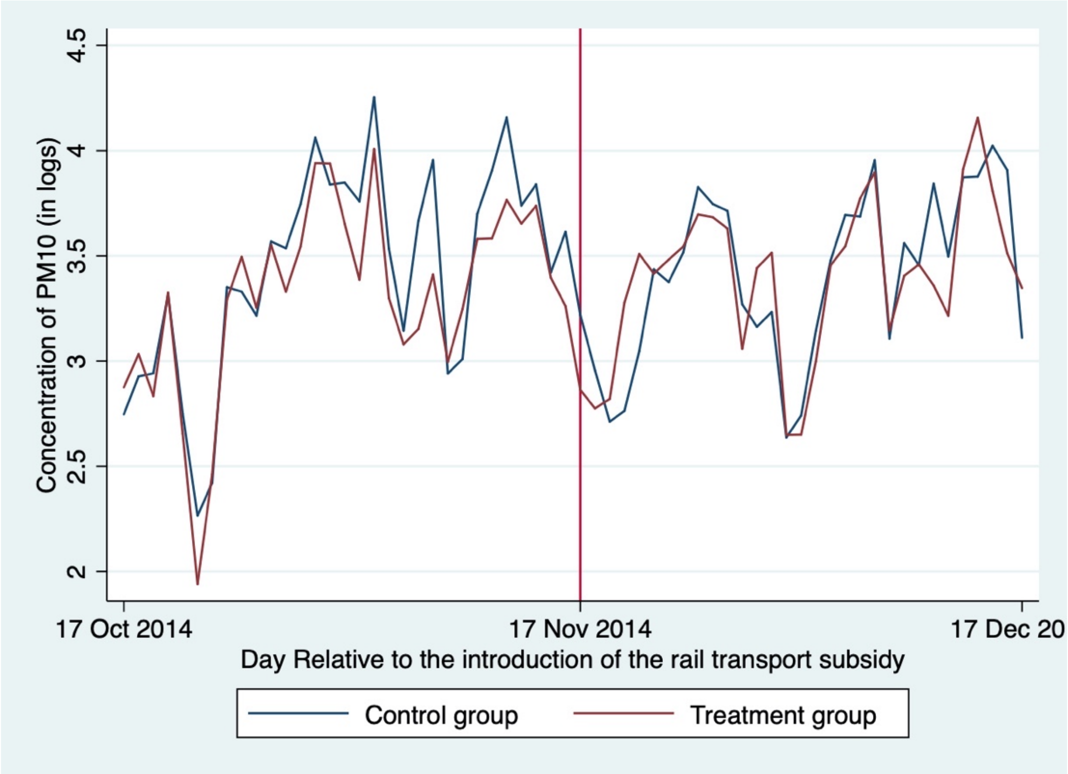

Figure A3. The development of the concentration of PM_{10} in the treatment and control group during the period
of 2 moths around the introduction date of the rail transport subsidy.
Source: Slovak Hydrometeorological Institute, 2020

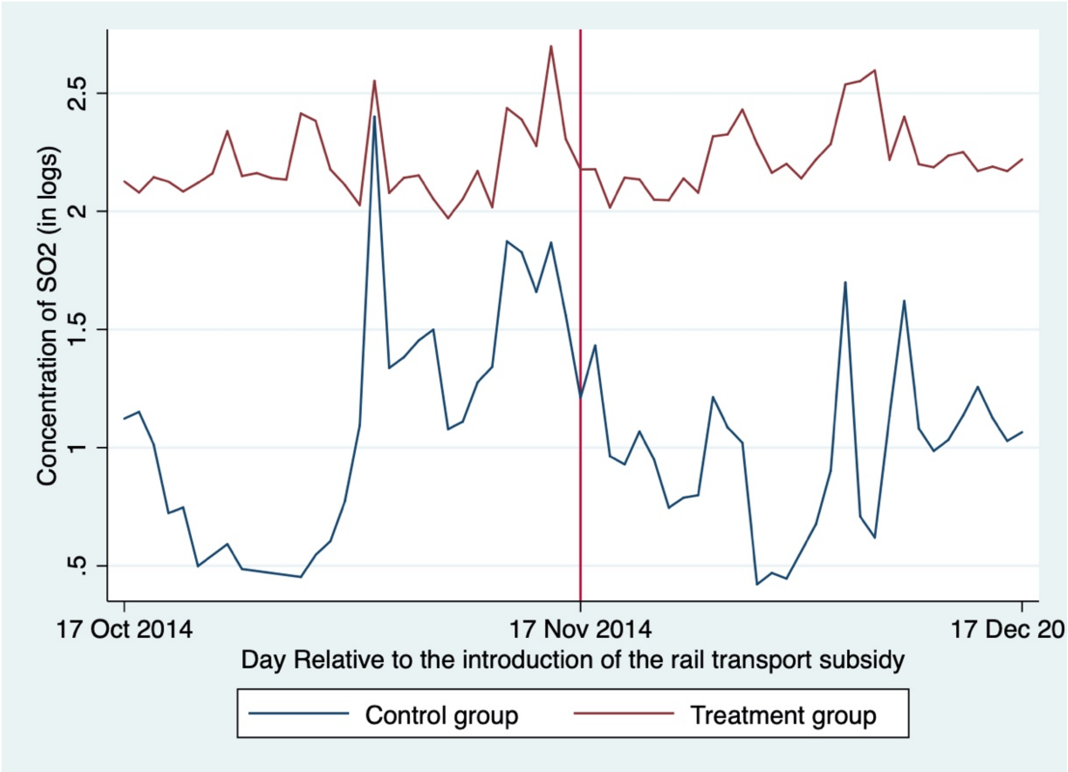

Figure A4. The development of the concentration of SO_2 in the treatment and control group during the period of 2 moths around the introduction date of the rail transport subsidy.
Source: Slovak Hydrometeorological Institute, 2020

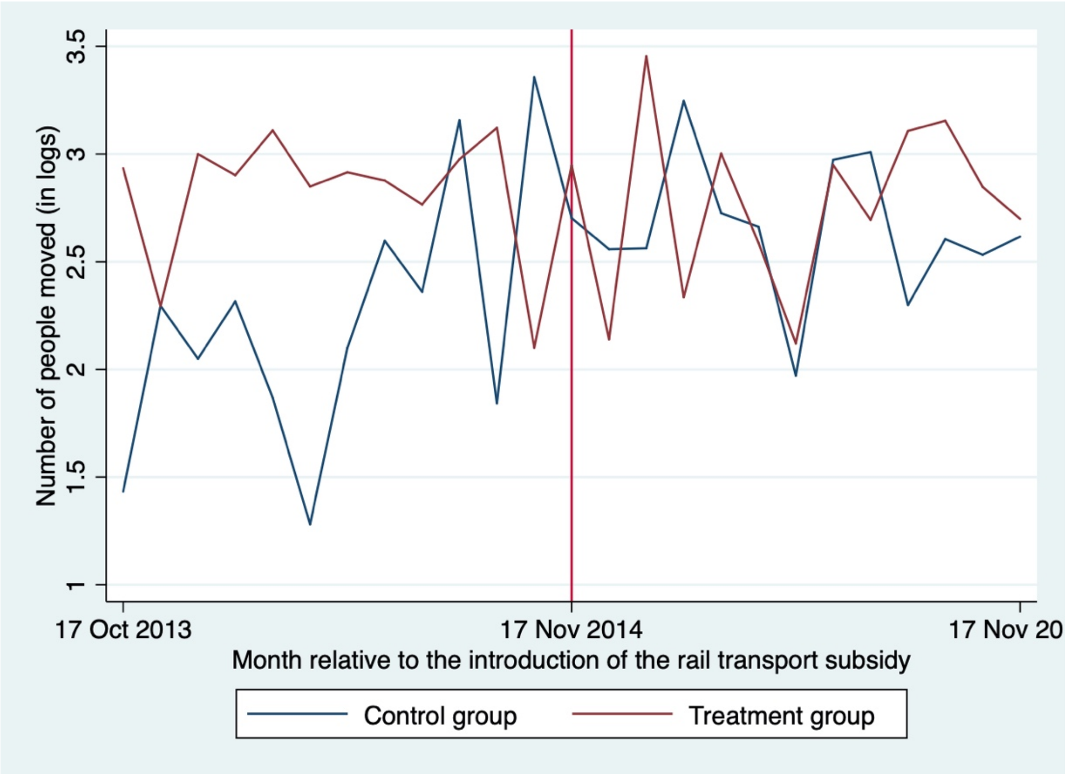

Figure A5. Migration flows in the treatment and control group during the period of 2 years around the introduction date of the rail transport subsidy.
Source: Statistical Office of the Slovak Republic, 2020.