ERASMUS UNIVERSITY ROTTERDAM
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Master Thesis Policy Economics

The effect of continuous earthquakes on primary school outcomes

Abstract

This study investigates the possible effect of continuous earthquakes on primary school outcomes with evidence from Groningen, the Netherlands. This is done using data from earthquakes caused by natural gas extraction and school averages of standardized tests in the last year of primary school in the period of 2011-2023. This study uses two methods: Firstly, an OLS with socioeconomic and time interaction controls comparing the earthquake municipalities to a selected group of comparable neighbouring municipalities. We find the school outcomes are lower in earthquake municipalities, but mostly due to the socioeconomic differences between the two regions. However, test scores are falling in the earthquake municipalities compared to the control group, independent from socioeconomic factors. Secondly, a fixed effects model using the timing of earthquakes in the weeks before and after the end of the test dates is used to determine whether the shock of an earthquake in a school's municipality has a direct effect on its children's test outcomes. Using the second method no evidence is found the described effect is present.

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1. Introduction

Since the Dutch government discovered the conventional natural gas fields in Groningen in 1963, they have retrieved 2,290 billion cubic metres of natural gas (Volkskrant, 2022). The Netherlands has earned over €363,000,000,000,- due to selling this reliable source of energy (*Groningers Boven Gas | Parlementaire Enquête Aardgaswinning Groningen*, 2023). However, this did not happen without a cost. After a few decades the earth beneath the inhabitants of Groningen became unstable. According to the Royal Dutch Meteorological Institute (KNMI) (n.d.) the first earthquake in the region occurred in 1986. The first earthquake above the level of 1.5 on the scale of Richter occurred in 1991. These earthquakes have risen quantitatively and force-wise since then, with magnitude peaking at 3.6 on the scale of Richter in 2012 (*KNMI*, n.d.-b) near the town of Huizinge. According to The Groningen Institute for Social Research (SCPG) (2024) this has had profound effects on, for example, stress. As well as worsening health due to persistent damage to homes due to these earthquakes.

In the past, regional calamities have had significant negative effects on children's school performances (Webbink, 2008). Stress alone as well is found to have an impairing effect on primary school aged children when performing difficult tasks (Whiting, S. B., Wass, S. V., Green, S., & Thomas, M. S. C., 2021) Do these earthquakes in Groningen and corresponding stress also effect learning outcomes? Using the location, timing and severity of the earthquakes and the results of the standardized tests we are provided by an opportunity to causally infer the effect on these earthquakes on the school results of primary school children. This compliments the existing literature as the effects of a such a long-term external stress factor on children has not yet been studied in the Netherlands.

In the Netherlands, children participate in a nationally standardized test in the last year of primary school. From 2011 onwards, the average results of each school are made publicly available by Dienst Uitvoering Onderwijs (DUO). Because of the limited data and the location of the earthquake area, we can only base our findings on scores since 2011 and the children of the province of Groningen and surrounding regions.

This research thus aims to find whether the earthquakes in Groningen have influenced children's school performances. This leads to the following main research question:

"Have the earthquakes in Groningen had an effect on primary school standardized test scores?"

This question will be answered empirically through two main sub-questions, namely the following:

1. *"How do the standardized test scores in the municipalities affected by earthquakes* compare *to the control area?"*

2. *“What is the effect of an earthquake in the week of the standardized test on test scores?”*

Other sub-questions, to be discussed in the literature review, are:

3. *“How do (natural) disasters affect human capital and children in general?”*
4. *“What are the effects of the earthquakes in Groningen on society and children specifically?”*

The practical relevance is the result of the implication that children living in these regions may be given an unequal opportunity in the education system compared to their peers living in another part of the country or another part of the province of Groningen. To be aware of injustices as these increases the ability to assure these children a fair chance.

Our research design starts off with a literature review after which an OLS controlling for socioeconomic indicators and a time interaction effect will be used to see how test scores develop in regions affected by earthquakes compared to neighbouring regions not affected by earthquakes. The first region is the treatment area and the second is the control area. To establish the treatment and control area, the choice of the Central Statistical Office (CBS) (2016) will be followed.

The second sub-question will be answered using a school-fixed effects model where using their timing, location and severity, earthquakes are linked to observations using the dates of standardized tests. Schools in municipalities where an earthquake occurs with a magnitude above a certain threshold are compared to schools whose municipality does not experience an earthquake. The same controls as described for the first sub-question are used plus a placebo test using earthquakes happening the week after the tests. This way the goal is to be left with an estimation of the potentially causal relationship between continuous earthquakes and primary school outcomes.

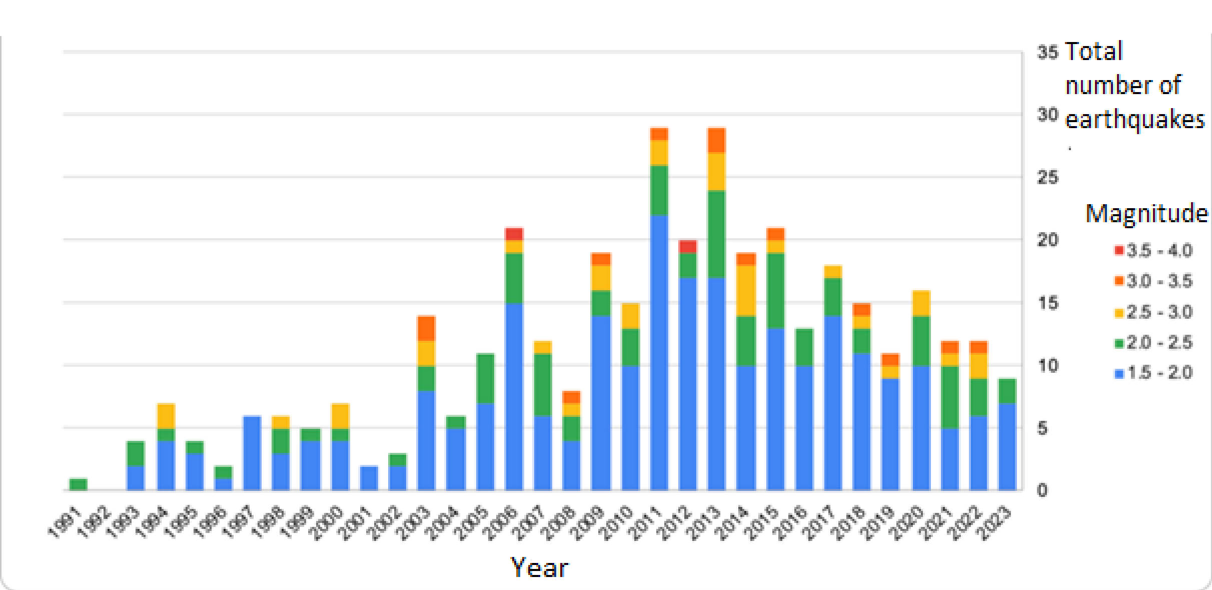
This study finds, after controlling for the several described variables, no proof that continuous earthquakes due to natural gas extraction in Groningen have had a significant direct effect on primary school outcomes in the period of 2011-2023. However, the earthquake municipalities are falling more and more behind on both socioeconomic indicators and standardized test scores compared to their neighbouring municipalities.

The rest of this study starts off with a background reading on the history of natural gas extraction in the Netherlands. Afterwards, sub-question (3) and (4) will be answered in the literature review. Then, the data is reviewed after which the empirical strategy is explained. In the results section the main estimates and its interpretations are shared. The chapter after that the main conclusions and advised policy interventions are laid out. Finally, the findings, limitations and potentials for future research are discussed.

2. Background on gas extraction and earthquakes in Groningen

As mentioned before in the introduction, the Dutch started extracting natural gas in Groningen in 1963. The Dutch Oil Company (NAM) was appointed to carry out this task as they were appointed to extract smaller natural gas fields before (Onze Historie | Nederlandse Aardolie Maatschappij, n.d.). 70% of the profits were accredited to the Dutch state ("Brief van de Minister van Economische Zaken en Klimaat", 2021) which accumulated to over €363.000.000.000,-. Thanks to this, the government was able to finance a welfare state. There seemed to be no downside to the gas extraction activities. Even when in 1991 the first earthquake was registered, no alarm bells rung. When in 2012 the strongest earthquake so far (and ever since) hit the town of Huizinge, concerns grew. Especially when in 2013 the KNMI published a report about how the country should account for earthquakes with a magnitude of 5.0 and higher on the scale of Richter in the future (Algemeen Dagblad, n.d.), the earthquakes became a real safety concern. The Dutch State Supervision of the Mines (SodM) advised in 2013 to scale back natural gas extraction as far as realistically possible (Ministerie van Economische Zaken en Klimaat, 2013). Despite this advice, the Minister of Economic affairs, Henk Kamp, and its cabinet Rutte II chose to raise the gas extraction from 40 billion to 45 billion cubic metres (Algemeen Dagblad, 2022). This angered many residents of Groningen and is in hindsight regretted by those responsible. However, the economic situation of The Netherlands and Europe was not very positive in 2013 as the European debt crisis was still active. Cutting off a major revenue stream and the source of heating for 98% of homes in The Netherlands would most likely have major societal consequences at the time. However, the gas extraction did steeply fall from 2014 onwards until the senate approved a definitive stop to gas extraction in Groningen per the 1st of October 2024 (*Senaat Steunt Einde Gaswinning Groningen*, 2024).

Figure 1: yearly number of earthquakes with a magnitude above 1,5 on the schale of Richter in Groningen. (KNMI - Aardbevingen door Gaswinning, n.d.



But the fall in gas extraction came too late to prevent extensive damage done to the region of Groningen. The number of earthquakes did peak in 2011 and 2013, as seen in figure 1, but they did not stop. To understand the process which led to letting this damage, a parliamentary inquiry was conducted by the government. This parliamentary inquiry (*Groningers Boven Gas | Parlementaire Enquête Aardgaswinning Groningen*, 2023) made ten painful conclusions such as that the damage was underestimated for too long, money was the dominant factor in decision-making, oil companies profited from 'role mixing' within the Ministry of Economic Affairs, the NAM-State combination had little eye for the public interest and the fact that the unsafe environment in Groningen has lasted unacceptably long.

The parliamentary inquiry also calculated there were 267,466 damage reports due to earthquakes at 31-12-2022. 85,000 addresses reported multiple instances of damage. 11,880 addresses are still not safe and of 7,289 it is not yet known whether they are safe. This due to a total of 1,615 earthquakes in the province of Groningen.

3. Literature review

While there has been no research on the effects of the earthquakes in Groningen on primary school students' performances, there has been research on the broader effects of these earthquakes on society and children. Moreover, there have been some relevant studies focusing on the effects of (natural) disasters and corresponding stress on children. In this literature review, sub-questions (3) and (4), as stated in the introduction, will be answered.

"How do (natural) disasters affect human capital and children in general?"

Before focusing on societal effects in Groningen: how do disasters affect human capital and children in general? Sub-question (3) lets us widen the view. Sadly, there seems to be no literature on the societal effects of continuous earthquakes. There are however studies on the effects of other types of (natural) disasters on society and children specifically.

Kousky, C. (2016) attempts to answer a multitude of questions one of which is *"how do disasters affect children and do they affect them disproportionally?".* It is important to note the author only includes research from weather-related natural disasters excluding earthquakes. So, the article cannot be directly transferred to the situation in Groningen and some sections are not relevant at all. Nonetheless, the author states children suffer during natural disasters from their reliance on caregivers who are often less able to take proper care of their offspring. Also, children are worse at communicating than adults and thus worse at communicating how they feel and suffer because of natural disasters. On the effects on schooling specifically, the author states three reasons natural disasters may affect children's schooling. *"First the disaster can destroy the schools themselves, interrupting children's education."* This is only semi-relevant to the case in Groningen. While the earthquakes have (partially) destroyed multiple schools, children are generally offered a placeholder location while school buildings are strengthened to continue education, or a completely new school building is built (Ministerie van Economische Zaken en Klimaat, 2023). *"Second, if children are hurt and malnourished, they may not attend school as frequently and/or may perform more poorly in school."* While the earthquakes are not as widespread and/or severe to stop the process of getting food into the earthquake area, children do get sick and miss school because of the earthquakes according to Ketner et. al (2024). Whether this results in performing poorly in school will be shown in the results section of this research. *"Third, in developing countries in particular, a disaster that reduces household wealth or income may lead parents to shift children out of school and into a labor market to help enhance family income. If those impacts on schooling persist—and whether they do is still an open question to researchers—they could reduce earnings later in life"*. This quote does not seem to be relevant to the situation in Groningen as there seems to be no evidence to show children are taken out of school early. This resonates with the notion of the author as this is particularly the case in developing countries, which The Netherlands is not.

Fuller, Sarah Crittenden (2013) researched the effects of hurricanes, winter storms and floods on children's school performances in North Carolina. They found hurricanes during a specific school year had a negative effect on grades while it did not affect the amount of school days missed. Winter storms during a specific school year however had a small positive effect on grades and did increase the amount of school days missed. The authors conclude damage to the home and community, such as the damage in Groningen, affects children's school performances more than missed school days.

Other studies show children living in communities hit by traumatic events such as sniper attacks (Gershenson, S., Tekin, E., & National Bureau of Economic Research, 2015) or the COVID-19 pandemic (Hammerstein et al., 2021) perform significantly worse in school. This might be the case because children disproportionally suffer from PTSD after traumatic events (Lonigan et al., 1994). In the Netherlands, children's individual standardized test grades have been known to fall due to local calamities (Webbink, 2008). The author found that there was not just a small number of underachievers but more so a downward shift in the distribution for multiple years.

While the gas drilled in Groningen is located in soft, shallow soil and thus 'conventional' and relatively easy to retrieve, it would also be possible to retrieve the so-called 'unconventional' gas from tight rock structures using modern drilling techniques (AER, 2011). This process is seen as controversial as it causes dramatic societal effects, but it especially has a negative environmental impact through air, water and ground pollution (Hirsch et al., 2017, Stangeland, 2016).

Children being negatively affected by the neighbourhood in which they grow up in is not a new concept. Chetty and Hendren (2018) made use of displacement shocks to find the neighbourhood in which a child grows up in affects intergenerational mobility. A neighbourhood tormented by earthquakes is most likely no exception to this phenomenon.

But why are early-life circumstances and school performances so important? Nobel prize winner James Heckman claims when children learn skills early on, in the home and at school, they are more capable of learning new skills later in life (Heckman et al., n.d.). Heckman calls this "skill begets skill". The theory has been supported by multiple studies such as by Lubotsky and Kaestner (2016) and Currie and Thomas (1995). Lubotsky and Kaestner (2016) used variance in kindergarten entry ages to conclude children who entered kindergarten early improved more in cognitive and non-cognitive assessments later in school, in 1st and 2nd grade. Two decades before, Currie and Thomas (1995) found an improvement in test scores among all races who were permitted to make use of the 'Head Start' program, enabling children to attend school earlier in life. This principle shows the opportunities and circumstances to learn early in life positively influences the ability to learn later in life which means a possible negative effect of these earthquakes on school performances in Groningen could be a sign for even more negative effects later in life.

To answer sub-question (4), evidence suggests (natural) disasters such as earthquakes and the corresponding damage to the community and stress, have a significant negative effect on children's wellbeing and school performances. However, these natural disasters in literature are mostly more extreme and less frequent than the earthquakes in Groningen. So, it is not certain how well transferable the evidence is. But it is clear negative impacts on learning early in life dwell on later in life.

By analysing the effect of continuous earthquakes on standardized test scores in Groningen, a gap is filled in literature by quantifying the social damage to children in Groningen and the damage done by continuous damage to communities in general, contrary to one-time disasters or purely economic factors.

"What are the effects of the earthquakes in Groningen on society and children specifically".

Kanis et. al (2024) published research which made use 'Groninger Panel' a longitudinal panel study gathering survey data on a diverse group of inhabitants of Groningen above the age of 18 years old (*Over het Groninger Panel - Sociaal Planbureau Groningen*, 2023). The survey data goes back to 2013. However, most analysis in the study starts in April 2021. They focused on the effects of the damage caused by the earthquakes to the homes the respondents live in. The broad (societal) measures used were health, emotions, social relations, perceived safety and risk perception, trust in government and institutions, and lastly societal developments. In terms of health, emotions, perceived safety and risk perception and the trust in government and institutions, the authors showed respondents with multiple cases of damage to their homes showed significantly more negative effects than respondents with either a single case of damage or none. In these four measures, the difference between the group with multiple cases and single or none, the difference has been steadily growing over time. Interestingly, respondents who suffered damage to their homes experienced a stronger connection to the people in their towns and villages than the respondents with no damage. This difference has shown to stay the same over time. This study is limited in the fact that only survey data is used. This can create bias because of the fact respondents with damage to their homes may be incentivized to answer more negatively so the government are more inclined to listen to them. In contrast, the research design proposed in the introduction negates this fact because it can be assumed there is no difference between regions whether children do their best to score as high as possible in the standardized test.

A baseline assessment about Groningen was published by Nationaal Programma Groningen (2021) in which societal measures and corresponding ambitions were put together to later monitor and reflect on. In this assessment there was a clear focus on societal and economic indicators. Moreover, there are many instances where the differences between the earthquake municipalities and reference municipalities are emphasized, as well as a described divide. Reference municipalities in this study differ from the control area in the introduction. The authors write the Groningen municipalities are linked to similar municipalities in other parts of the country. This was done based on urbanization, income, and population size. The rest of this study will keep to the definition set by the CBS. Either way, some notable differences between these earthquake municipalities and their reference municipalities are:

- Earthquake municipalities have a lower 'broad welfare'.
- Earthquake municipalities have fewer exporting companies.
- Every earthquake municipality has a lower net participation rate than every reference municipality.
- Earthquake municipalities have a 'far higher' unemployment rate.
- Earthquake municipalities have a lower socioeconomic status.
- Every earthquake municipality has a lower average spendable income than every reference municipality.

Although, education indicators seem different:

- Earthquake municipalities have a lower drop-out rate for higher education.
- Premature school drop-out rate is trending equally.

However, education indicators may have given different results due to the city of Groningen being included in the treatment group while have a university.

The authors show there is great disparity between municipalities and their reference municipalities in key societal indicators. It furthermore states ambitions to turn this around in the coming years to offset the societal damage done by the gas extraction and the resulting earthquakes.

Van Der Voort and Vanclay (2015) share a detailed overview of the gas extraction in Groningen. They show it caused an increase in damage to property and a decline of housing prices. Furthermore, they assess an increased concern of dykes breaking, feelings of insecurity, health issues, distrust, and anger. However, the authors do not show a direct link to school performances. One of the authors, Frank Vanclay, presents in a masterclass supported by the State University Groningen (RUG) more social impacts (Rudolf Agricola School for Sustainable Development, 2022). Namely, nuisance, intrusion by workers and strangers, changed feelings about home and community.

These and all forementioned societal impacts are mainly gathered from the experience of adult civilians. However, these effects can also be felt by children.

The Municipal Health Service (GGD) in Groningen wrote a folder for parents about the effects of the earthquakes on their children (GGD Groningen, 2021) and how to talk about it. The GGD tells parents the earthquake troubles wander through their children's minds, and they too can worry which may cause them to get sick or have trouble concentrating at school. In addition, children tend to accommodate for their parents' worries and try not to be a burden to them. This makes them act different at school than at home.

Ketner et al. (2024) also focused on the experiences of children in areas affected by earthquakes. The author describes common traumatic experiences for children like falling out of their bed in the middle of the night due to their house shaking, hearing objects fall, seeing their homes get more and more damaged. Many children have also been forcibly displaced from their homes so the house can get strengthened to withstand future earthquakes. Parents in the affected areas often spend a lot of time talking about and working on procedures related to the earthquakes. These parents experience a lot of stress and insecurity which negatively influences the atmosphere in the home. Timewise and emotionally parents are less able to pay attention to their children. Not only children's homes are damaged, but their schools may also need reinforcements which often results in a temporary school in another location. This damages the social rituals of the school. Routes to school, sporting clubs, family and friends become unsafe because some whole towns need to be restructured. This creates diversions and unsafe situations due to construction traffic. Friendships can be put under pressure due to the frequent displacements making meeting up with former neighbourhood children difficult. Some children also get jealous due to other families profiting from government arrangements while theirs is still waiting for an arrangement or getting a different, worse arrangement. Informants for the study working with children mention an increase in chronical stress among children causing anxiety or returning to bedwetting. Most of the mentioned effects on children are anecdotal evidence from local informants, the authors thus mention a lack of irreputable evidence based on data. This study may contribute to this area.

In response to these stories of suffering, the national government and other parties have acted to restore the region and compensate for damages done. The government financially supporting homeowners with significant damage to their homes will (partly) compensate for the damage done to those homes. Shutting down natural gas extraction in the region will help children living in Groningen in the future grow up in a safe environment. However, children currently living there will most likely forever be affected by the insecure living conditions. To help these children the GGD has a hotline for children to call to talk about the (mental) damage caused by earthquakes (*Informatie Voor Kinderen in Aardbevingsgebied | GGD Groningen*, 2023). And for a more direct approach the 'Institute of Mining damage Groningen' (IMG) has chosen to hand 6500 children a financial compensation ranging from €1500,- to €5000,- depending on the child's damages (NOS, 2023b).

To answer sub-question (4), societal effects caused by earthquakes include stress, lower socioeconomic status, a lower net participation grade, decline of housing prices and health issues. For children specifically the effects include stress, anxiety, difficulties making and keeping friends due to moving and jealousy, fear, and withholding emotions for their parents. A main pathway for these effects seems to be the damage to the homes and community. All these effects could negatively effect school achievements however it has not been quantitatively proven. Moreover, some indicators (premature and higher education drop-out rate) show students from the earthquake area do not seem to suffer from this in school achievements later in life.

4. Data

To answer the two main research questions, a quasi-experimental research design is implemented using data from various sources. These sources being:

- Average standardized test scores per school branch from 2010-2022 (DUO, 2024)
- Social economic status scores (SES-WOA) per municipality and neighbourhood from 2014-2021 (CBS, n.d.)
- Disadvantage scores per school from 2018-2022 (CBS, n.d.-a)
- Addresses of all schools in the Netherlands (*Schoolvestigingen Bo - Po - DUO Open Onderwijsdata*, n.d.)

Also, the treatment and control region distinction as used by CBS (2016) will be adhered. The CBS places the municipalities of the northern provinces, Groningen, Friesland and Drenthe, in the following groups:

Table 1: Division of treatment, control and excluded municipalities. Municipality plan as of 2024.

Treatment municipalities	**Control municipalities**	**Excluded municipalities**
Het Hogeland	Achtkarspelen	Aa en Hunze
Eemsdelta	Borger-Odoorn	Ameland
Midden-Groningen	Dantumadeel	Assen
The former municipality of Ten Boer, now part of Groningen	Noordenveld	Coevorden
	Noardeast-Fryslân	De Fryske Marren
	Oldambt	De Wolden
	Ooststellingswerf	Emmen
	Opsterland	Groningen (except Ten Boer)
	Pekela	Haren
	Smallingerland	Harlingen
	Stadskanaal	Heerenveen
	Tynaarlo	Hoogeveen
	Veendam	Leeuwarden
	Westerkwartier	Meppel
	Westerwolde	Midden-Drenthe
		Schiermonnikoog
		Súdwest-Fryslân
		Terschelling
		Tytsjerksteradiel

		Vlieland
		Waadhoeke
		Westerveld
		Weststellingwerf

Figure 2: map of the division of municipalities into treatment and control areas, following the guidelines of CBS (2016). Municipality plan as of 2016.

The treatment municipalities have a combined 33 earthquakes of at least the magnitude of 1.0 on the scale of Richter in the week before and after the CET. The control municipalities have a combined 0. The excluded municipalities have a combined 3. This was a confirmation to follow the CBS's guidelines in choice of areas together with the strong demographic differences with the municipality of Groningen.

From now on, the excluded municipalities are no longer included in the analysis.

The mentioned treatment municipalities are home to 91 primary schools while the control municipalities are home to 276 primary schools.

In the analysis, only student groups from the 8th, the last, year of primary school are included. Because of privacy reasons, average scores of schools with less than 5 students taking part in the standardized tests are removed by the data source. Standardized tests with less than 100 observations were removed from analysis. The scores of used tests in the sample are standardized using the national averages and standard deviations allowing for collective use.

Cito Eindtoets was changed into CET (Cito Eindtoets) in 2015. The official name, timing and importance of the test changed: the values and interpretation did not. Therefore, both Cito Eindtoets and CET are from now on called CET. Thrice, a school had at least 5 students take part in two different tests. These observations were combined into a weighted average in the standardized scores.

The included tests and some summarizing statistics are shown in table 2:

Table 2: Summary statistics of the different standardized tests.

Type of standardized test	Mean	Stand. mean	St. Dev.	Treatment mean	Control mean	Frequency
Cito Eindtoets	534.84	-.04	3.94	534.81	534.85	2,589
IEP	80.51	.04	4.80	79.98	80.64	989
Route 8	201.40	-.14	14.74	196.88	202.82	243
Total						3,281

Figure 3 below shows the distribution of the standardized scores of the sample for each area while table 3 shows the average standardized scores per municipality.

Figure 3: Kernel density distribution of standardized average test scores per school for each area.

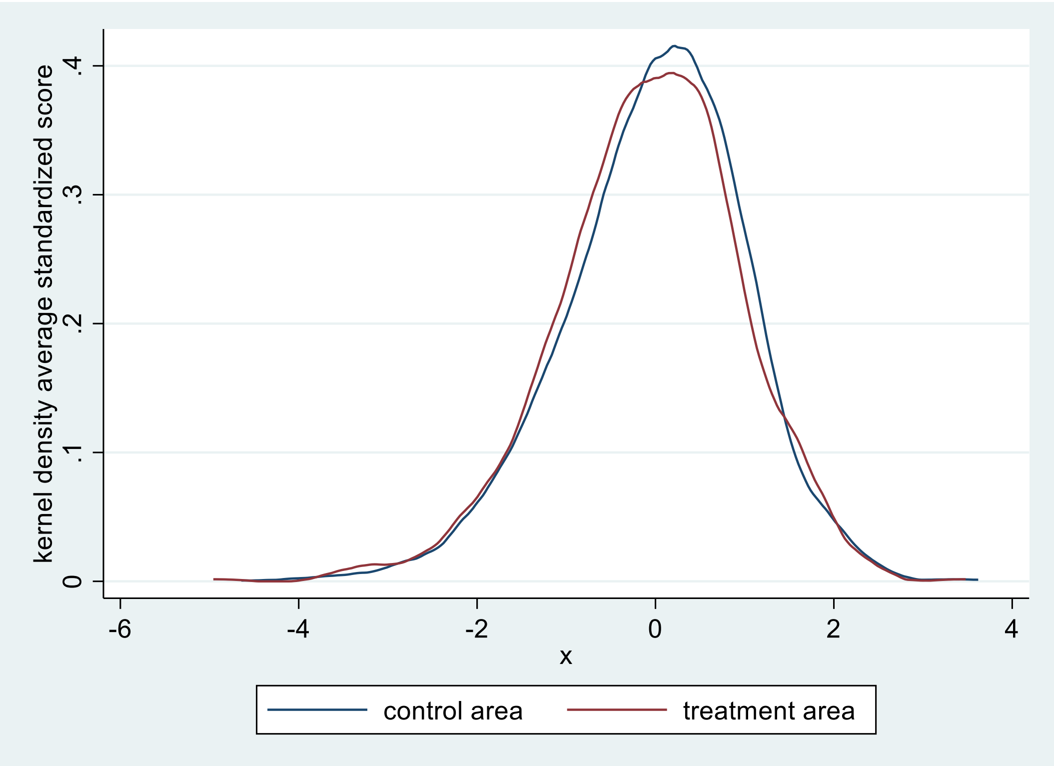


Table 3: Average standardized score of school for each municipality with each municipality sorted by treatment and control.

Treatment municipality	**Average standardized score of schools**	**Control municipality**	**Average standardized score of schools**
Het Hogeland	-.03	Achtkarspelen	-.06
Eemsdelta	-.21	Borger-Odoorn	-.17
Midden-Groningen	-.14	Dantumadeel	.13
The former municipality of Ten Boer, now part of Groningen	.42	Noordenveld	.43
		Noardeast-Fryslân	-.01
		Oldambt	-.28
		Ooststellingswerf	.09
		Opsterland	-.18
		Pekela	-.31
		Smallingerland	-.13
		Stadskanaal	-.32
		Tynaarlo	.54
		Veendam	-.41
		Westerkwartier	.20
		Westerwolde	-.11
Total	-.08	-	-.01

With a mean average standardized score of -.024 the sample school average is .024 standard deviations below the national population school average.

As controls, yearly municipality Social Economic Status – Wealth, Education and recent Labour history (SES-WOA) data is used. As well as 'disadvantage scores' per year per school. Both datasets are published by CBS (n.d)(n.d.-a).

SES-WOA culminates wealth, education and labour data into a single number per municipality for every 1st of January of each year. The national average is 0 by definition. While the test scores data stretches from 2011 to 2023, the SES-WOA stretches from 2014 to 2021. So, missing values have been replaced by the value of the nearest year for every municipality. Table 4 shows the mean social economic status is worse in the treatment area observations compared to the control area observations.

Table 4: Summary statistics of SES-WOA data for the treatment and control area.

SES-WOA	OBS.	MEAN	ST. DEV.	MIN.	MAX.
TREATMENT AREA	560	-.083	.07	-.271	.16
CONTROL AREA	1,717	-.015	.11	-.22	.24

Disadvantage scores are published per school. The score is the result of the sum of the scores of all individual children. Each individual score is affected by country of origin of parents, education level of parents, whether parents are part of a debt restructuring program, for how long the mother has been in The Netherlands and the average education level of all mothers. The disadvantage scores are used by the government as an indicator for the level of learning problems within schools. A higher score means a school is more likely to receive more money from the government to compensate for possible learning problems. The CBS replaces negative values with 0. Because the score is the sum of all students, the score is divided by the number of students taking the test to create the variable average disadvantage score. Disadvantage scores are only available from 2017/2018 onwards. Missing values are given the value of its school's disadvantage score in 2017/2018. Table 5 shows the schools in the treatment area have a higher average indicator for learning problems compared to the control area. Table 6 shows the same data but divided by the number of students taking the test in the observation.

Table 5: Summary statistics of disadvantage score data for the treatment and control area.

DISADVANTAGE SCORE	OBS.	MEAN	ST. DEV.	MIN.	MAX.
TREATMENT AREA	366	103.40	119.06	0	727.14
CONTROL AREA	1,183	98.30	102.74	0	889.73

Table 6: Summary statistics of average disadvantage score data for the treatment and control area.

AVERAGE DISADVANTAGE SCORE	OBS.	MEAN	ST. DEV.	MIN.	MAX.
TREATMENT AREA	366	6.59	6.89	0	41.54
CONTROL AREA	1,183	6.13	7.36	0	107.93

These trends however seem to change over time. Table 7 shows the effect of time in years on SES-WOA data and average disadvantage scores. SES-WOA scores are significantly shifting away from each other: the socioeconomic status of the treatment municipalities is decreasing while the socioeconomic status of the control municipalities is improving. For disadvantage score, the higher the score the lower the socioeconomic status of the school. So, while the signage is reversed, the trend is the same: improvement in the control area while the opposite happens in the treatment area. However, there is no statistically significant evidence for this conclusion as seen in column (3) and (4). This may be the case because of the limited timeframe of 2018-2023.

Table 7: Regression results for the relationship between time and both SES-WOA and the average disadvantage scores for the treatment and control area.

VARIABLES	(1) SES-WOA Control area	(2) SES-WOA Treatment area	(3) Average disadvantage score Control area	(4) Average disadvantage score Treatment area
Time in years	0.00264**	-0.00422***	-0.122	0.214
	(0.00121)	(0.00136)	(0.113)	(0.192)
Constant	-0.0232***	-0.0706***	6.449***	6.043***
	(0.00457)	(0.00520)	(0.385)	(0.585)
Observations	1,716	560	1,183	366
R-squared	0.003	0.017	0.001	0.003

*Notes: This table presents Regression results for the relationship between time and both SES-WOA and average disadvantage scores for the treatment and control area. A high SES-WOA score and a low disadvantage score indicate strong socioeconomic status at respectively the municipal and school level. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Figures 4 and 5 visualise how the scores shift away from each other. SES-WOA scores for the treatment area are trending downwards to -.1 while mean yearly SES-WOA scores for the control area are trending upwards to the national average of 0. Disadvantage scores of the two areas also seem to disperse.

Figure 4: Visualization of the relationship between time and SES-WOA scores for the treatment and control group.

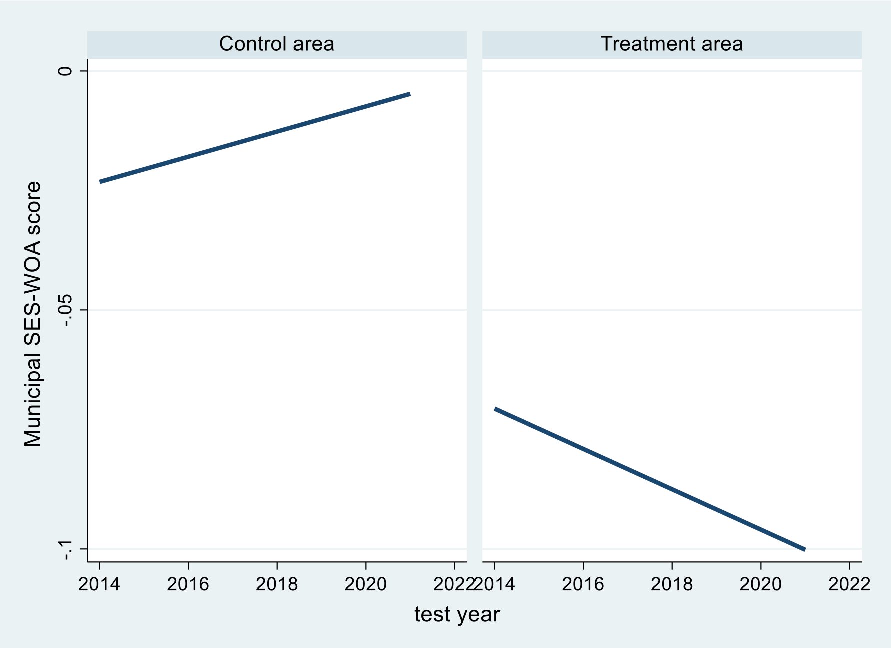
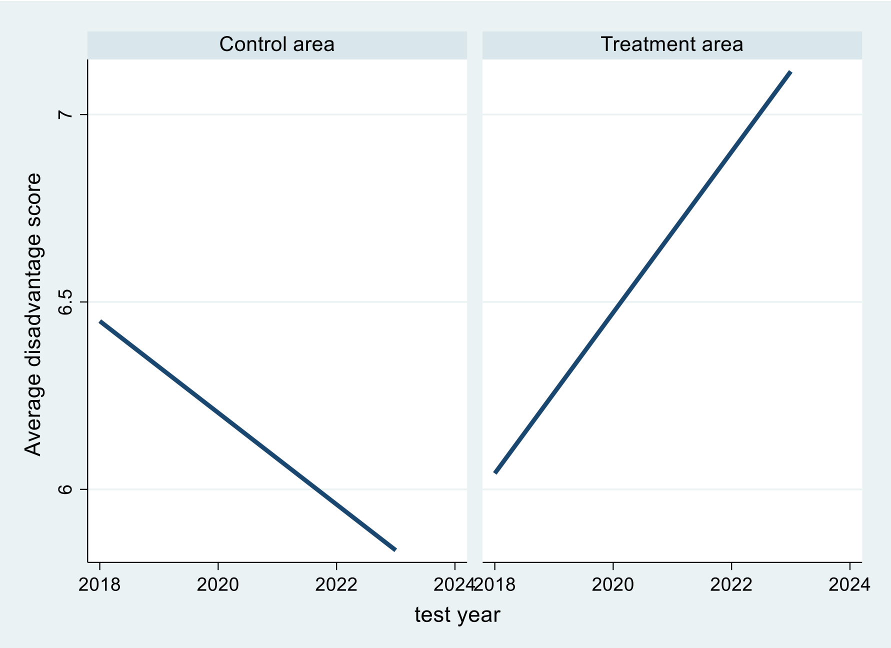


Figure 5: Visualization of the relationship of time and average disadvantage scores for the treatment and control group.



To answer sub-question (2), in addition to the data used for sub-question (1) more data is needed. Firstly, when the tests are taken. Secondly, when the earthquakes happened.

Only CET tests are available for the quasi-experimental design used for sub-question (2) since these are taken at 2 specific days while ROUTE 8 and IEP tests are taken in a window of weeks where individual schools can choose which days to use for the test. The specific dates of the CET tests are not publicly available, but it was possible to deduct these dates through the sale of second-hand 'test books' which show the test dates. These dates are shown in table 17 in the appendix. Only CET test observations are used for both the treatment group and control group.

The value of EQbefore, the explanatory variable of interest, is equal to the number of earthquakes of at least a magnitude of 1.0 on the scale of Richter in the 7 days before the end of the CET test dates in the municipality of the school. To control for bias, the variable EQbefore was added. The value of EQafter is a placebo test equal to the number of earthquakes of at least a magnitude of 1.0 on the scale of Richter in the 7 days after the end of the CET test dates in the municipality of the school. If EQafter shows a significant effect, there must be unobserved factors due to the fact that earthquakes after the test have no effect on test scores. All earthquake data is directly retrieved from the KNMI (*KNMI - Aardbevingscatalogus*, n.d.-c). Table 8 and 9 respectively describe the data of both these variables. Only observations in the treatment area have experienced an earthquake that qualifies for one of these variables. In the analysis a dummy of both variables is also used. In this case, if the value is higher than 1, it is replaced by 1. In the sensitivity analysis, different threshold values are used aside 1.0: 1.5 2.0 and 2.5. These frequencies are also shown in table 8 and 9.

Table 8: Summary statistics of the EQbefore variable, which represents the number of earthquakes with a magnitude above a given threshold occurring in the 7 days before the end of the CET test of an observation.

EQbefore	Freq. if threshold = 1.0	Threshold = 1.5	Threshold = 2.0	Threshold = 2.5
0	503	587	659	660
1	92	85	13	12
2	77	0	0	0
Total	672	672	672	672

Table 9: Summary statistics of the EQafter variable, which represents the number of earthquakes with a magnitude above a given threshold occurring in the 7 days after the end of the CET test of an observation.

EQafter	Freq. if threshold = 1.0	Threshold = 1.5	Threshold = 2.0	Threshold = 2.5
0	484	546	580	604
1	107	60	44	38
2	35	76	48	30
3	46	0	0	0
Total	672	672	672	672

Table 9 shows only 13 observations have an earthquake of at least 2.0 on the scale of Richter in its municipality in the 7 days before the end of the CET test. This is caused by 2 earthquakes in 2018 and 2023, both in the municipality of Eemsdelta. So, in the sensitivity analysis where the threshold is set at 2.0 or 2.5, a sample of both the full treatment area and only the municipality of Eemsdelta will be used. The earthquake of 2023 is of a magnitude lower than 2.5 and only has one corresponding observation.

5. Empirical strategy

Sub-question (1)

The empirical analysis starts with a comparison of the test scores in schools in the treatment area with the test scores in school in the control area. For this comparison various specifications of Equation (1) are estimated. Equation (1) is an OLS including controls and an interaction effect between the treatment dummy and the year in which the test was taken. A fixed-effects model is not possible due to the missing variance of treatment between schools. Because there are no observations of test scores possible before the earthquakes begun, the main estimate for the interaction effect should be interpreted as the trend in test scores conditional on observed differences between the treatment and control area. Missing observations before the earthquakes begun also results in no available counterfactual. This means no causal effect can be inferred using equation (1). Using analytic weights all results of various specifications of this equation account for the number of students taking the test for each observation.

$$(1)\quad Y_{it} = ß_0 + ß_1 Treatment_i + ß_2 School\ score_{it} + ß_3 Municipal\ score_{it} + ß_4 Treatment_i * Year_i + \varepsilon_{it}$$

Where:

Y_{it} equals the individual school branch average test score, standardized.

$Treatment_i$ is the treatment dummy. It equals 1 if the school branch is located in one of the treatment municipalities.

$School\ score_{it}$ equals the school's disadvantage score of that year or the imputed value divided by the number of students participating in the test.

$Municipal\ score_{it}$ equals the school branch municipal SES-WOA score of that year of the tests or the imputed value.

$Year_i$ represents the year the test was taken.

ε_{it} represents the error term.

$ß_0$ equals the constant.

$ß_1$ shows the difference in standardized test scores between schools in the treatment area and the control area, measured in standard deviations.

$ß_2$ shows the change in school branch average standardized test scores due to a 1-point increase in average school disadvantage scores, measured in standard deviations.

$ß_3$ shows the change in school branch average standardized test scores due to a 1-point increase in the municipal SES-WOA score, measured in standard deviations.

$ß_4$ shows the change in standardized test scores between treatment and control over time, measured in standard deviations.

Sub-question (2)

Contrary to sub-question (1), sub-question (2) does present an opportunity to causally infer the treatment effect. The treatment variable is the number of earthquakes stronger than 1.0 on the scale of Richter in the 7 days in a school's municipality before the end of the test. The inherently random nature of this treatment variable allows the assumption where the treatment is uncorrelated to any unobserved factors there may be. To further improve the estimation, a placebo test is introduced. This placebo test is the number of earthquakes stronger than 1.0 on the scale of Richter in the 7 days in a school's municipality after the end of the test. This variable is both inherently random and uncorrelated to the outcome variable. If the placebo coefficient is significantly different from zero, there must be unobserved factors at play. Only CET tests are used for both the control as treatment group, as these tests are taken at the same date for the entire country.

With panel data available and treatment being independent from other variables a school-fixed effect is introduced. This controls for unobserved, time-invariant factors at the school level.

Furthermore, the same socioeconomic controls as in equation (1), SES-WOA and average school disadvantage scores are used.

This amounts to the following equation (2) to estimate:

$$(2)\ Y_{it} = ß_0 + ß_1 EQbefore_{it} + ß_2 EQafter_{it} + ß_3 School\ score_{it} + ß_4 Municipal\ score_{it} + \alpha_i + \varepsilon_{it}$$

Where:

Y_{it} equals the individual school branch average CET test score, standardized.

$EQbefore_{it}$ equals the number of earthquakes above the magnitude of 1.0 on the scale of Richter in 7 days before the end of the test days.

$EQafter_{it}$ equals the number of earthquakes above the magnitude of 1.0 on the scale of Richter in 7 days after the end of the test days.

$School\ score_{it}$ equals the school's disadvantage score of that year or the imputed value divided by the number of students participating in the test.

$Municipal\ score_{it}$ equals the school branch municipal SES-WOA score of that year of the tests or the imputed value.

α_i is the unobserved individual school's fixed effect.

ε_{it} represents the error term.

$ß_0$ equals the constant.

$ß_1$ shows the change in school branch average CET test scores when a school experiences one more earthquake stronger than 1.0 on the scale of Richter in its municipality seven days before the end of the tests, measured in standard deviations.

$ß_2$ shows the change in school branch average CET test scores when a school experiences one more earthquake stronger than 1.0 on the scale of Richter in its municipality seven days after the end of the tests, measured in standard deviations.

$ß_3$ shows the change in school branch average CET test scores due to a 1-point increase in average school disadvantage scores, measured in standard deviations.

$ß_4$ shows the change in school branch average CET test scores due to a 1-point increase in the municipal SES-WOA, measured in standard deviations.

6. Results

6.1 Difference in test scores between the treatment and control area

Table 10: OLS regression results for the relationship between treatment and standardized values of standardized test scores, using different sets of control variables.

VARIABLES	(1) No controls	(2) Time interaction	(3) Time interaction, School control	(4) Time interaction, All controls
Treatment	-0.103***	0.0258	0.0353	0.106*
	(0.0385)	(0.0620)	(0.0590)	(0.0599)
Treatment*Time		-0.0234***	-0.0212**	-0.0175**
		(0.00860)	(0.00825)	(0.00831)
Disadvantage score			-0.0356***	-0.0297***
			(0.00302)	(0.00295)
SES-WOA				1.296***
				(0.163)
Constant	0.0328*	0.0328*	0.218***	0.195***
	(0.0195)	(0.0195)	(0.0251)	(0.0241)
Observations	3,818	3,818	3,818	3,818
R-squared	0.002	0.004	0.055	0.074

*Notes: The regression results of equation (1) including differing explanatory variables per column on average school test scores. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Column (4) of table 10 shows when including the interaction effect and all controls the treatment variable has a significant effect on test scores at the 10% confidence level. At this level, the average student in the treatment municipalities scored an estimated 0.106 standard deviation higher on their standardized test compared to students in surrounding control municipalities. This is quite surprising when one considers the negative estimation coefficient -0.103 in column (1) and the negative tendence in the literature review. However, as the estimated interaction coefficient is equal to -0.0175, there is a downward trend in the test scores of the treatment area as compared to the control area. Both the average school disadvantage scores and the municipal SES-WOA scores are always a significant factor at the strong 1% confidence level.

6.2 Effect of an earthquake on test scores

Table 11: Regression results for the relationship between the number of earthquakes above a magnitude of 1.0 in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables. The full sample is used.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects	(4) Fixed effects, Placebo	(5) Fixed effects All controls
EQ before	-0.0283	0.0504	-0.0358	-0.0345	-0.0335
	(0.0468)	(0.0508)	(0.0591)	(0.0600)	(0.0600)
EQ after		-0.0159		-0.00567	-0.00480
		(0.0421)		(0.0465)	(0.0466)
SES-WOA		1.032***			-0.356
		(0.178)			(1.754)
Disadvantage score		-0.0265***			0.0186***
		(0.00317)			(0.00687)
Constant	-0.0222	0.154***	-0.444***	-0.443***	-0.570***
	(0.0168)	(0.0260)	(0.0938)	(0.0941)	(0.112)
Observations	3,818	2,587	2,587	2,587	2,587
R-squared	0.000	0.053	0.020	0.020	0.024
Number of school branches			362	362	362

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore and EQafter equal the number of earthquakes with a magnitude of minimum 1.0 on the scale of Richter that occurred in the school's municipality in the 7 days before/after the end of the final test day. The full sample is included. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

The estimates in table 11 show no effect of an earthquake occurrence in the week before the tests on test scores. Socioeconomic indicators are the leading predictor for school results. However, the above results include the full sample. Table 12 below shows the results when only the treatment area is included.

Table 12: Regression results for the relationship between the number of earthquakes above a magnitude of 1.0 in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables. The sample consists of only the treatment municipalities.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects	(4) Fixed effects Placebo	(5) Fixed effects All controls
EQ before	-0.0179	-0.00260	-0.0273	-0.0331	-0.0255
	(0.0523)	(0.0542)	(0.0738)	(0.0741)	(0.0743)
EQ after		-0.0141		-0.0909	-0.0947
		(0.0443)		(0.0982)	(0.0984)
SES-WOA		-1.420***			7.076
		(0.505)			(6.412)
Disadvantage score		-0.0313***			0.0239
		(0.00466)			(0.0148)
Constant	-0.0392	0.0462	-0.344*	-0.291	0.0880
	(0.0441)	(0.0650)	(0.187)	(0.195)	(0.551)
Observations	672	672	672	672	672
R-squared	0.000	0.064	0.031	0.033	0.039
Number of school branches			91	91	91

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore and EQafter equal the number of earthquakes with a magnitude of minimum 1.0 on the scale of Richter that occurred in the school's municipality in the 7 days before/after the end of the final test day. The sample consists of the treatment municipalities. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

When only including the treatment area the individual earthquakes seem to have no significant effect on test scores. When controlling for school-fixed effects the socioeconomic indicators lose their significant effect as well.

Table 13: Regression results for the relationship between whether an earthquake above a magnitude of 1.0 occurred in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables. The sample consist of the treatment municipalities.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects	(4) Fixed effects Placebo	(5) Fixed effects All controls
EQ before 1.0 dummy	-0.111 (0.0889)	-0.0982 (0.0881)	-0.134 (0.107)	-0.177 (0.116)	-0.168 (0.117)
EQ after 1.0 dummy		-0.0471 (0.0839)		-0.121 (0.129)	-0.125 (0.129)
SES-WOA		-1.524*** (0.504)			5.905 (6.407)
Disadvantage score		-0.0307*** (0.00466)			0.0247* (0.0148)
Constant	-0.0178 (0.0448)	0.0655 (0.0658)	-0.337* (0.186)	-0.267 (0.201)	0.0156 (0.548)
Observations	672	672	672	672	672
R-squared	0.002	0.066	0.034	0.035	0.041
Number of school branches			91	91	91

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore dummy and EQafter dummy equal 1 if an earthquake with a magnitude of minimum 1.0 on the scale of Richter occurred in the school's municipality in the 7 days before/after the end of the final test day. The full sample is included. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Table 13 shows the result when the variables of the number of earthquakes before and after are replaced by dummy's equal to 1 if an earthquake occurred in the said time window or 0 if not. Again, these explanatory variables show no significant effect within the treatment group. The test results are only significantly affected by the socioeconomic data of school and municipality. When including the fixed effects model, the significance of socioeconomic indicators also dampens.

Sensitivity analysis

An alternate control group

To test the sensitivity of main research question (1) the 4 control municipalities which are geographically furthest away from the treatment municipalities will be excluded from analysis. These 4 municipalities are:

- Smallingerland
- Opsterland
- Ooststellingswerf
- Borger-Odoorn

The results are shown in table 14 below.

Table 14: OLS regression results for the relationship between treatment and standardized values of standardized test scores, using different sets of control variables. An alternate control group is used.

VARIABLES	(1) No controls	(2) Time interaction	(3) Time interaction, School control	(4) Time interaction, All controls
Treatment dummy	-0.147***	-0.0181	-0.00975	0.0673
	(0.0402)	(0.0630)	(0.0599)	(0.0608)
Treatment*Time		-0.0234***	-0.0212**	-0.0171**
		(0.00860)	(0.00825)	(0.00833)
Disadvantage score			-0.0367***	-0.0287***
			(0.00339)	(0.00325)
SES-WOA				1.452***
				(0.165)
Constant	0.0766***	0.0766***	0.270***	0.237***
	(0.0225)	(0.0225)	(0.0287)	(0.0271)
Observations	3,095	3,095	3,095	3,095
R-squared	0.005	0.007	0.060	0.088

*Notes: The regression results of equation (1) including differing explanatory variables per column on average school test scores. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. Smallingerland, Opsterland, Ooststellingswerf and Borger-Odoorn are excluded from the control group. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

When compared to the original results of table 10 the estimations of the socioeconomic school and municipal controls do change. The treatment coefficient in column (1) decreases from -.103 to -.147, while remaining significant at a 1% confidence level. The treatment coefficient in column (4) is no longer statistically significant and is thus the surprising conclusion in section 6.1 where the test scores in the treatment area are higher is no longer interpretable. The interaction coefficient changes only by 0.004 and remains significant at the same level. Using this sample, the trend is still that test scores are decreasing in the treatment area compared to the control area. The controls remain significant at the same 1% confidence level.

Increasing the threshold for including earthquakes

For sub-question and equation (2) the sensitivity is analysed by changing the scale of Richter threshold of included earthquakes. Table 15 shows the results when the threshold is increased to 1.5.

Table 15: Regression results for the relationship between whether an earthquake above a magnitude of 1.5 occurred in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects	(4) Fixed effects, Placebo	(5) Fixed effects, all controls
EQ before 1.5 dummy	-0.0301 (0.113)	-0.0177 (0.109)	-0.118 (0.149)	-0.102 (0.152)	-0.0961 (0.153)
EQ after 1.5 dummy		-0.00598 (0.0981)		0.102 (0.180)	0.0933 (0.180)
SES-WOA		-1.433*** (0.499)			6.009 (6.424)
Disadvantage score		-0.0313*** (0.00463)			0.0247* (0.0148)
Constant	-0.0419 (0.0416)	0.0413 (0.0647)	-0.334* (0.187)	-0.339* (0.187)	-0.0506 (0.544)
Observations	672	672	672	672	672
R-squared	0.000	0.064	0.032	0.033	0.039
Number of school branches			91	91	91

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore dummy and EQafter dummy equal 1 if an earthquake with a magnitude of minimum 1.5 on the scale of Richter occurred in the school's municipality in the 7 days before/after the end of the final test day. The full sample is included. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

The results suggest the earthquake dummies in no form have any significant effect on school outcomes. The estimated predicting value of the control variables disappears as well when the fixed effects are introduced. The results are however comparable to the original estimations of table 13. The results of research question and equation (2) thus seem insensitive to changing the scale of Richter threshold to 1.5.

Table 16: Regression results for the relationship between whether an earthquake above a magnitude of 2.0 occurred in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects, Placebo	(4) Fixed effects, all controls	(5) Fixed effects, all controls, Eemsdelta only
EQ before 2.0 dummy	-0.141	-0.224	-0.266	-0.187	0.223
	(0.172)	(0.183)	(0.326)	(0.337)	(1.084)
EQ after 2.0 dummy		-0.0854	-0.00407	-0.0241	-0.909
		(0.121)	(0.140)	(0.142)	(0.632)
SES-WOA		-1.451***		5.986	12.07
		(0.504)		(6.681)	(52.49)
Disadvantage score		-0.0312***		0.0242	0.0430
		(0.00460)		(0.0148)	(0.0310)
Constant	-0.0430	0.0522	-0.330*	-0.0443	1.076
	(0.0393)	(0.0648)	(0.188)	(0.559)	(7.303)
Observations	672	672	672	672	141
R-squared	0.000	0.066	0.032	0.038	0.092
Number of school branches			91	91	23

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore dummy and EQafter dummy equal 1 if an earthquake with a magnitude of minimum 2.0 on the scale of Richter occurred in the school's municipality in the 7 days before/after the end of the final test day. The full sample is included. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

When increasing the threshold to 2.0, there is still no statistically significant effect visible. Again, as in the results of table 13, 15 and 16, only socioeconomic indicators are estimated to have a significant effect on test scores. And again, this disappears when fixed effects are introduced. When focusing on the municipality of Eemsdelta, where the only two earthquakes occurred, no effect is visible as well.

Table 17: Regression results for the relationship between whether an earthquake above a magnitude of 2.5 occurred in the 7 days before the end of the test and standardized values of standardized test scores, using differing sets of control variables.

VARIABLES	(1) No controls	(2) All controls	(3) Fixed effects, Placebo	(4) Fixed effects, all controls	(5) Fixed effects, all controls, Eemsdelta only
EQ before 2.5 dummy	-0.195 (0.178)	-0.258 (0.193)	-0.355 (0.342)	-0.293 (0.350)	-0.0414 (0.529)
EQ after 2.5 dummy		-0.0312 (0.134)	-0.0209 (0.179)	-0.0663 (0.183)	-1.533 (4.950)
SES-WOA		-1.460*** (0.512)		6.044 (6.731)	30.63 (91.35)
Disadvantage score		-0.0312*** (0.00461)		0.0245* (0.0148)	0.0430 (0.0310)
Constant	-0.0423 (0.0393)	0.0433 (0.0650)	-0.338* (0.187)	-0.0461 (0.566)	3.747 (12.97)
Observations	672	672	672	672	141
R-squared	0.001	0.065	0.033	0.039	0.092
Number of school branches			91	91	23

*Notes: the regression results for equation (2) including different explanatory variables per column. Column (4), (5) and (6) include a school-fixed effect. A low Disadvantage score and a high SES-WOA score indicate strong socioeconomic status at respectively the municipal and school level. EQbefore dummy and EQafter dummy equal 1 if an earthquake with a magnitude of minimum 2.5 on the scale of Richter occurred in the school's municipality in the 7 days before/after the end of the final test day. The full sample is included. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1*

Lastly, when increasing the threshold to 2.5, the only statistically significant estimations are that of socioeconomic indicators. These (almost) disappear when introducing the fixed effects model. And again, reducing the sample to Eemsdelta does not make a notable difference except for starkly increasing the standard errors. The results of sub-question (2) are insensitive to changing the threshold for including earthquakes based on magnitude.

No earthquakes stronger than or equal to a 3.0 on the scale of Richter occurred in the 7 days before the end of a CET test within the timeframe of the data.

7. Conclusion

In the introduction two main sub-questions were introduced. Namely:

1. *"How do the standardized test scores in the earthquake area compare to the control area?"*
2. *"What is the effect of a school's municipality experiencing an earthquake in the week before the standardized test on test scores?"*

To answer sub-question 1, after controlling for socioeconomic indicators and a treatment*time interaction effect the scores of standardized tests in the treatment area are 0.106 standard deviations higher than in the control area. However, the test scores are falling in the treatment area compared to the control area. Moreover, it must be noted the first result does not replicate when using an alternate control group. Meanwhile, the result where the test scores are falling in the treatment area compared to the control area does replicate.

To answer sub-question 2, this study found no proven effect of a school's municipality experiencing at least one earthquake in the week before the standardized test on test scores.

With these answers, the next step is to answer the main research question:

Have the earthquakes in Groningen had an effect on primary school standardized test scores?

Based on the results in this research it is not possible to state the earthquakes in Groningen have had a causal effect on primary school standardized test scores. However, the difference in socioeconomic status between the earthquake area and the surrounding regions is big and growing. Moreover, the test scores are falling in the treatment municipalities compared to the control municipalities. For now, the difference in standardized test scores is mostly explained by these socioeconomic differences. If there is a relationship, it is most likely caused by the long-term stress caused by the continuous earthquakes and the incentive of inhabitants to move away or for outsiders not to move there, not by the shock of a single earthquake.

Policy recommendations

While there is no proven direct causal relationship between the continuous earthquakes and primary school outcomes in Groningen, the region is evolving into a major low-opportunity region in the Netherlands. The act of shutting down gas extraction will help the region in the future as earthquakes are already becoming less frequent and less harsh, but there is still a lot of investment and work needed to create a strong socioeconomic region attractive for (internal) immigration and for young people to stay. While the government did implement a financial compensation scheme for children living in the area suffering from the effects of earthquakes, a broad and intense plan is needed to create a strong region ready for the future.

8. Discussion and limitations

Despite the fact there is no conclusive answer to the main research question, the study is still complimentary to existing literature. For example, the claims in literature from for example Nationaal Programma Groningen (2021) about how the earthquake region is falling behind on numerous socioeconomic indicators seem to have been confirmed. In the literature review, it was concluded earthquakes and other (natural) disasters have had a significant effect on school outcomes. This was not the case in the results section. This may be the cause due to the earthquakes not being powerful enough or the 'lack' of direct deaths compared to the disasters in studies such as by Webbink (2008) or Fuller, Sarah Crittenden (2013).

Or simply because of this study's limitations. For example, the dataset of school outcomes only starts in 2011 while the first earthquakes occurred in the 20th century. Because of this, the difference-in-difference method could not be used to set up a more realistic counterfactual for sub-question (1). The socioeconomic controls also have an even shorter timeframe than the school outcomes which means missing values had to be imputed. The school outcomes data itself is limited due to the fact it consists of school averages rather than individual outcomes. If so, a more accurate estimation would have been possible controlling for individual characteristics and children moving in and out of the treatment area.

In sub-question (2), an earthquake is linked to an observation when it occurs in the same municipality. In future, improved, research it is an option to grant each earthquake for each observation a 'treatment score' depending on power, distance from the school and time left before the tests. If individual student data is available, it would even be possible to grant each earthquake a comparable treatment score but for individual students using home addresses. If all test dates for all individual schools are gathered for the IEP and ROUTE 8 tests, a bigger sample would be possible as well.

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10. Appendix

Table 18: List of CET test dates in the period of 2010/2011-2022/2023. Source: various covers of test books for sale online

CET test dates
1-2 February, 2011
7-8 February, 2012
5-6 February, 2013
11-12 February, 2014
21-22 April, 2015
19-20 April, 2016
18-19 April, 2017
17-18 april, 2018
16-17 April, 2019
No CET test due to the COVID-19 pandemic
20-21 April, 2021
19-20 April, 2022
18-19 April, 2023