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# The Impact of The Neonicotinoid Pesticide Ban on Crime and Early Education in Agricultural Areas of Sweden

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Abstract. In 2013, the European Union banned the use of neonicotinoid pesticides on bee-attractive plants sown between January and June. Neonicotinoids were a popularly used pesticide because pests were not resistant against it. This pesticide acts as a neurotoxin and is known to impact cognitive functioning and behavior as well as lead to short- and long-term health complications in humans and mammals. For Swedish communities living near agricultural areas, it is possible that residents are impacted by constant exposure to micro-amounts of this chemical. With a difference in differences event study design, the likely reduction in ambient neonicotinoid exposure as a result from the ban appears to decrease crime rates over time, but the proportion of 3rd graders who reach a proficient comprehension in math and reading appear unaffected.

Keywords: Neonicotinoids, Agricultural Policy, Human Capital, Crime, Education, Sweden

JEL: K42, Q18, Q53

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# 1 Introduction

In today's modern and industrialized world, pesticides are frequently used for food and crop production. With advancements in technology and the adoption of monocropping, or when only a single type of crop is grown on a plot at a time, farmers have become dependent on pesticides to protect their harvests. Monocropping may represent a great way for farmers to make efficient use of their land, time, and expensive machinery, but this practice can allow for pests such as insects, fungi, and diseases to easily spread from plant to plant. Thus, farmers often rely on pesticides to protect their harvest from devastation, which also benefits society by providing a steady and reliable supply of food. Although farmers and consumers do benefit from using pesticides, there are also costs.

For a pesticide to be effective, it needs to be toxic. For the environmental areas surrounding a farm, this has obvious consequences as agricultural runoff that contains pesticides unintentionally harms the wildlife surrounding a farm (Mao et al 2022). In addition, farmers frequently suffer both acute and long term health complications because of their exposure to pesticides (Chatzimichael et al 2021; Khan 2009; Pingali et al 1994; Soares and Marcelo 2012). Based on these facts, it is reasonable to wonder what effects, if any, do pesticides have on the health and well-being of those in nearby communities. I hope to answer this with my research by exploiting a pesticide ban in the European Union (EU) to see if rural communities benefit because of it.

This paper aims to explore short-term impacts on societal well-being among agricultural communities in Sweden after the EU banned the outdoor use of neonicotinoid pesticides in 2013 on bee-attractive plants sown between January and June (European Commission 2013). Though this ban was intended to protect pollinators, medical and economic literature suggests additional improvements in cognitive performance, namely in young children and especially in boys, as well as a decrease in crime rates (Grönqvist et al 2020; Ding and Bao 2013; Rice et al 2000). In this thesis, I chose to investigate the impacts that the ban has on the proportion of Swedish 3rd grade students who reach a proficient level of understanding in math and reading as well as reported crime rates for Swedish rural municipalities. Sweden is a great setting for this study due the popularity of growing crops that were impacted by the ban. Sweden has an interesting quality that other countries do not possess in that Swedish farmers who grow impacted crops may realistically use alternative pesticides without suffering much crop loss unlike other European farmers [1] (Lundin 2021).

To evaluate the impact of the ban, I used a difference in difference design to compare crime rates and 3rd grade schooling proficiency rates within Swedish agricultural municipalities - comparing rates between municipalities that have grown a lot of bee-attractive crops with those that have not in the years leading up to the ban. The results of my analysis suggest that the proportion of 3rd grade children who reach a proficient understanding of math and reading are unaffected by the ban whereas crime rates appear to drop after the ban was put in place.

My research provides additional supporting evidence of previous studies and also sheds light on new areas that should be studied more. My results

[1] Swedish farmers have the option to use pyrethroids instead of neonicotinoids because pests in Sweden are not resistant to this pesticide while elsewhere in Europe, pests have developed a resistance

have similar findings to other studies on neurotoxin exposure in that there is a connection between exposure and criminal activity (Grönqvist et al 2020; Rice et al 2000). That being said, my results differ from the findings of other studies on the impacts of children's academic performance in that I found no impact, but there are some possible explanations for this which are to be discussed later (Grönqvist et al 2020; Cimino et al 2017; Ding and Bao 2013). With specific reference to the effects of neonicotinoids, my results are in line with previous literature in that neonicotinoid exposure impacts mammals' behaviors (Costas-Ferreira et al 2021). My research however further expands this area of study because the effects of neonicotinoids on humans are not well documented.

Regarding previous research on policy changes resulting in impacts on well-being, I have relatively similar results to Grönqvist et al's (2020) study which focused on the effects of phasing out lead from gasoline. Grönqvist and I, in our own separate studies, found evidence of decreased criminal activity resulting from banning the use of a neurotoxin. I contribute to the agricultural economics literature by providing evidence for the adverse impacts of pesticides on human capital. The current agricultural economics literature on pesticides and health impacts mainly regard the health of the farmer, but one study based in China found that agricultural pesticides are negatively impacting the elderly population in the surrounding community (Lai 2017). I join Lai in highlighting the impact that pesticides have on their surrounding community.

# 2 Background

## 2.1 Policy Background

In 2013, the EU prohibited the use of 3 commonly used neonicotinoid pesticides on bee-attractive plants sown between January and June (European Commission 2013). The 3 neonicotinoid substances in question are clothianidin, imidacloprid and thiamethoxam. Neonicotinoids are neurotoxins that attack the central nervous system of the pests who attempt to eat either the seed or any other part of the plant (Gunnarson 2013). Typically, neonicotinoids are applied as a coating around the seed before it is sown into the ground. This protects the seed from subterranean pests. As the plant grows, it will have trace amounts of the pesticide in the plant body to protect it against pests who wish to eat the plant (European Food Safety Administration n.d.).

Neonicotinoids were first approved for agricultural use in the EU in 2005. At the time, it was believed that it had no impact on pollinators. However, several years later, it was suspected that neonicotinoids negatively impacted pollinators[2], which led to the 2013 ban on the use of neonicotinoids on bee-attractive crops sown in the spring[3]. The ban had a grace period that allowed farmers to sow seeds coated with this pesticide before February 2014. In the subsequent years, the effects neonicotinoids had on pollinators were further

[2]In extremely low doses, bees were seen to be confused and unable to return home. In most cases however, the bees died (Gunnarson 2013; Rundlöf 2015

[3]bee-attractive crops sown in the spring are impacted by the ban because they will flower and attract bees at a crucial time for bees as they emerge from winter and need to feed. Winter crops are not impacted in this ban with the rationale that these crops will flower before the bees emerge in full force

studied, and the EU expanded the ban to impact all outdoor crops in 2018 with a grace period that expired in December 2018 (European Commission 2013). That being said, some countries within the EU, including Sweden, have granted exceptions for emergency use of this pesticide (Epstein et al 2022).

In Sweden and in the EU, there were mixed reactions. Bee keepers rejoiced, but farmers became worried. Farmers who grew rapeseed and other bee-attractive crops were forced to either use an inferior pesticide, such as pyrethroids[4], or grow a different crop. Swedish farmers, however, may not have been as concerned as farmers in other EU countries. One reason is that pyrethroids, despite being less effective compared to neonicotinoids, is still a viable option for Swedish farmers because pests in Sweden are not resistant to the pyrethroids like they are in other EU countries (Lundin 2021). Additionally, around this time, an improved variant of winter rapeseed was cultivated, producing higher yields in comparison to spring rapeseed and reducing the need for heavy pesticide use due to the decreased presence of pests during Sweden's autumn and winter. Even without the neonicotinoid ban, winter rapeseed seemed like a more appealing crop to grow. As Lundin noted, the amount of spring rapeseed grown plummeted while winter rapeseed increased[5] (Lundin 2021). Impacted farmers likely experienced financial stress, stress when figuring out how to adapt to the ban, or both. That said,

[4]Before the use of neonicotinoids, pyrethroids were commonly used. When pests started to become resistant to pyrethroids, neonicotinoids became the preferred pesticide

[5]It should be noted that winter rapeseed and spring rapeseed are not as close substitutes as they might initially appear because of the schedule that a farmer has for his or her field. The timing of spring rapeseed might have fit perfectly for the farmer's schedule as the farmer planed to sow a different crop in the autumn, not winter rapeseed

as seen in **Figure 1**, the agricultural municipalities wealth, measured as median and mean income, in both the control and treatment group in my study evolved similarly over time and did not sharply decrease after the ban took effect in 2014, despite one report pointing out that the this ban would result in an economic loss of over 500 million EUR for the European union as a whole (Noleppa 2017) [6]


Figure 1: Median and mean incomes for treatment and control group municipalities (Data sourced from SCB)

## 2.2 Literature

Of the health economics literature that focused on the farmer's pesticide use, a vast majority focused on the cost benefit analysis of using pesticides from the farmer's perspective (Chatzimichael et al 2021; Khan 2009; Pingali et al

[6]This study was financed by Bayer, a chemical producer

1994; Soares and Marcelo 2012). Farmers typically use pesticides to improve yields and, consequently, the farm's revenue. That said, it appears that farmers often fail to properly consider the corresponding medical costs and decreased quality of life that they face after applying pesticides. In these studies, the researchers concluded that farmers act irrationally. The cost benefit analysis conducted indicated that the cost of the medical bills, the lessened quality of life, and the decreased productivity while suffering from acute negative consequences outweighed the benefits from the improved yield. Despite it being in the farmer's best interest to refrain from using pesticides, it is still common practice.

Pingali et al.'s (1994) study based in the Philippines found that members of the farmer's household also suffered consequences of pesticide applications. Members of the household suffered both short-term and long-term consequences as well as limited productivity. This study showed that individuals who live in an area surrounding a farm, albeit immediate surrounding area, face negative health consequences of pesticide applications.

Chatzimichael et al's (2021) study in Greece not only found negative health consequences among farmers who use pesticides, but also examined the factors that contribute to a farmer's choice to use organic practices. Age was important as older farmers are more accustomed to using pesticides and less likely to take the financial risk of switching up their operation. Additionally, it takes time to fully receive the benefits of organic farming, time that they do not necessarily have. Education was also important as educated folks are more likely to understand and appreciate the benefits of organic farming. Subsidies were associated with a higher likelihood of using organic farming practices because subsidies alleviate the financial burden associated with switching methods as well as the increased risk of crop loss due to pests. Finally, larger plot size directly correlated with increased switching costs and increased risk. Chatzimichael et al (2021) concluded that organic farming is preferable because the avoided health risks outweigh the improved yield from pesticide applications but also because organic produce is sold at a higher price. When designing policy, governments may wish to take these factors into consideration

Most agricultural economics studies on pesticide use investigate the impacts and decisions that a farmer faces, but one study by Lai (2017) focused on the impacts pesticides have on the surrounding community in China. More specifically, Lai studied the impact of drinking water contaminated by agricultural runoff. In this study, Lai looked at the neurotoxic insecticides of imidacloriprid and fipronil as the active substances impacting residents[7]. Lai used a triple difference design that contrasted populations who consume surface water from those who consume ground water; areas with high amounts of pesticide use and those with low amounts; and finally, before and after 2004 which was the year China began subsidizing agriculture. In the model, Lai included regional GDP and the number of hospitals in each region as control variables among many other individual specific factors. Lai found a causal relationship between the use of pesticides and increased instances of degenerative diseases amongst elderly populations. Lai further concluded that the policy to subsidize farmers and encourage pesticide use is actually causing more harm than good because of the health consequences suffered

[7]Recall, imidacloriprid is one of the neonicotinoid substances affected by the EU's 2013 ban on bee-attractive crops sown between January and June

by older people.

In the medical and scientific literature, the results are limited, weak, and mixed when it comes to evaluating the health implications of pesticide use on nearby communities (Sabarwal et al 2018; Cimino et al 2017; Khanjani et al 2005). Measuring the long term impacts of experiencing low doses of pesticides is very difficult to accurately measure and evaluate in a natural environment because there are too many variables that just cannot be controlled for. Further, the manner of exposure is also not standardized in natural experiments. Additionally, purposefully exposing people to pesticides for a more controlled study is full of ethical complications (Sabarwal et al 2018; Cimino et al 2017). That said, there are studies that provide suggestive evidence that pesticides pose problems for human health (Khanjani N et al 2005).

As seen with Lai (2017), the older population suffers from pesticide exposure, but children are also a vulnerable demographic. In a comprehensive review, Ding et al (2016) focused on the impacts that children face when exposed to pesticides. Ding notes that children and fetuses are an incredibly vulnerable demographic because, proportional to body mass, they consume more food, water, and air that could be contaminated with pesticides than the average individual. Additionally, because children and fetuses have developing bodies and organs that are not quite fully functional, they do not have the capacity to produce sufficient quantities of enzymes to break down toxins like adults do. And thirdly, children engage in activities that increase their likelihood of exposure - they stick things in their mouths and crawl around on the ground where pesticides may have settled. In these ways, children are an incredibly susceptible demographic when it comes to pesticide exposure.

The danger that young children and fetuses face with pesticide exposure is further supported by other medical research. In one medical study, Bradman et al (2003) discovered that fetuses can have exposure to commonly used agricultural pesticides. They discovered this by examining the amniotic fluid that encapsulates the developing fetus during pregancy. Although Bradman et al's study was primarily focused on showing fetal exposure to pesticides, they did state that this exposure can have serious consequences for the child's development. Rice et al (2000) expanded on these consequences in their review. Children have developing nervous systems, and exposure to pesticides, especially neurotoxic pesticides such as neonicotinoids, can impede the child's development, leading to decreased cognitive functioning, and even increased aggression and likelihood to commit criminal activity.

The effect of neurotoxins on humans is fairly well-documented, but the effect that neonicotinoids have in particular is limited. In a systematic review by Costas-Fierreira et al (2021), they found many studies documenting the effects neonicotinoids have on mammals, namely rodents like rats but also bats and even a study on deer. With mixed results due to differences in testing conditions, rodents in some studies did show noticeable changes in their behavior, motor activity, memory, and learning ability when compared to the control group. In the studies involving bats, the bats that were exposed to neonicotinoid pesticides, namely imidacloprid, had difficulty echolocating and maintaining consistent flight paths.

When reviewing studies focusing on human exposure, Cimino et al (2017) found mixed results on acute consequences but suggestive evidence for long term consequences of neonicotinoid exposure. Among the studies that focused on acute reactions to neonicotinonid exposure, most reported treatment groups suffering negative reactions such as nausea and dizziness among other symptoms. Although these studies all focused on measuring the acute effects, because they were observational studies relying on hospital or poison control agency data, neither the dose nor the avenue of exposure was standardized for the participants in the studies. That being said, for all studies in the review focusing on the chronic effects of exposure, exposure to neonicotinoids led to negative effects such as increased birth defects, increased instances of autism, memory loss, and finger tremors.

Another important study to note is Grönqvist et al's (2020) study focusing on the effects that Sweden's decision to phase lead out of gasoline had on children's development into adulthood. Although lead is not a pesticide, it is a neurotoxin, and this study showed the beneficial impacts on people when a neurotoxin is removed from the surrounding environment. In the 1970s and early 80s, Sweden phased out and banned lead from being used in gasoline. By using samples of moss to determine which geographic areas would be affected most by the ban, Grönqvist et al studied the effect this policy had on individuals born before and after the policy measure. To measure the impact, Grönqvist et al used micro data that included student GPAs, crime convictions, cognitive and non-cognitive behavioral scores from men fulfilling their mandatory military draft requirement, and earnings. The results of this study were that academic performance, cognitive skills, and non-cognitive skills all increased while the instances of criminal convictions decreased as a result from lower exposure. Additionally, this reduction appears to impact boys more strongly.

## 3 Data

For my analysis, I used data at Sweden's municipality level that ranges from 2006 to 2022[8]. Most of my data came from SCB, but I used Brå for crime-related data, Skolverket for school-related data, and Jordbruksverket for data on agriculturally related matters.

To determine which Swedish municipalities to include in my analysis, I needed to figure out which municipalities were agricultural. Therefore, I used data on municipal land area from SCB and data on total arable land for each municipality from Jordbruksverket to proportionally determine which municipalities had a lot of farming activity[9] [10]. To be considered an agricultural municipality in my study, a municipality needed to have 30% or more of its municipal land be used for farming each year for 16 out of the sampled 17 years between 2006 and 2022. Out of the 290 Swedish municipalities, 43 met this requirement.

It should be noted that the area of municipal land did change slightly year to year, likely due to errors in measurement and/or changes in natural

[8] Although household data would be preferable as it would allow for comparison of nuance between households inside a single municipality, much of this data is not publicly available

[9] Accessed: 3 March 2023, https://www.scb.se/hitta-statistik/statistik-efter-amne/miljo/markanvandning/land-och-vattenarealer/

[10] Accessed: 23 March 2023, ,https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets\%20statistikdatabas/Jordbruksverkets\%20statistikdatabas__Arealer__1\%20Riket\%20l\%C3\%A4n\%20kommun/JO0104B2.px/?rxid=5adf4929-f548-4f27-9bc9-78e127837625

features such as erosion, height of water level/tide at time of measurement, etc. Further, farmed land is defined as total land that has been used for growing some type of crop, which is distinguished from forestry land, land used to raise livestock, as well as land that is left uncultivated. This measurement also varies year to year as land use changes (e.g. a farmer decides to stop growing corn and starts to rear pigs instead).

Of the 43 municipalities that consistently met the threshold, 5 municipalities had noticeably higher populations than all of the others in the study. In order to prevent bias that may result from including large populous municipalities, both in the weighting of my analysis and also in unobserved qualities, I excluded them from the sample resulting in 38 municipalities for the analysis.

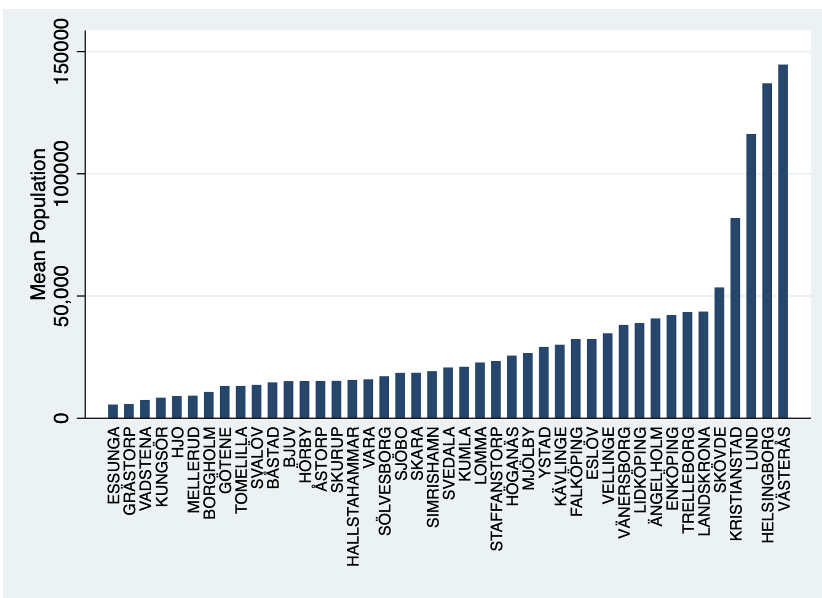


Figure 2: Mean Population of Swedish Agricultural Municipalities (Data sourced from SCB)

In order to separate municipalities into treatment and control groups, I needed to determine which municipalities grew a significant amount of bee-attractive crops in proportion to their municipal land size. Therefore, I used crop data from Jordbruksverket that specified how much land area was dedicated to which crop for each municipality in each year[11]. By dividing the sum of the areas that grow bee-attractive crops by total municipal land area, I determined how much land was used for growing impacted crops for each municipality and year. For the 6 of the 8 years between 2006 and 2013, if an agricultural municipality had 10% or more of its total land used to grow bee-attractive crops, it was placed into the treatment group. A list of municipalities and their treatment/control assignment can be found in the appendix.

Because of the fair trade agreement between EU countries, the specific sale and use of certain pesticides is unclear (O Lundin, Personal Communication, February 24 2023). That being said, it is understood that Swedish farmers used neonicotinoid pesticides on the crops affected by the ban (Lundin 2021; Gunnarson 2013; Rundlöf 2015). Additionally, a vast majority of bee-attractive crops were grown using conventional farming techniques. **Figure 3** and **Figure 4** show the proportion of conventionally grown crops, as opposed to organically grown crops, in this study's two most prominent counties[12].

[11] Accessed: 23 March 2023, https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets\%20statistikdatabas/Jordbruksverkets\%20statistikdatabas__Arealer__1\%20Riket\%20l\%C3\%A4n\%20kommun/JO0104B2.px/?rxid=5adf4929-f548-4f27-9bc9-78e127837625

[12] Accessed: 18 April 2023, https://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets\%20statistikdatabas/Jordbruksverkets\%20statistikdatabas__Ekologisk\%20produktion__1\%20Ekologiskt\%20odlad\%20jordbruksmark/JO0104C06.px/?rxid=5adf4929-f548-4f27-9bc9-78e127837625

Unfortunately, some data is missing, but over all, most crops affected by the ban, namely cereals, corn, peas, beans, and rapeseed were grown using conventional farming methods that likely included neonicotinoid pesticides before the ban. Additionally, **Figure 5** shows the total land area used to grow bee-attractive crops among the municipalities in the treatment group.

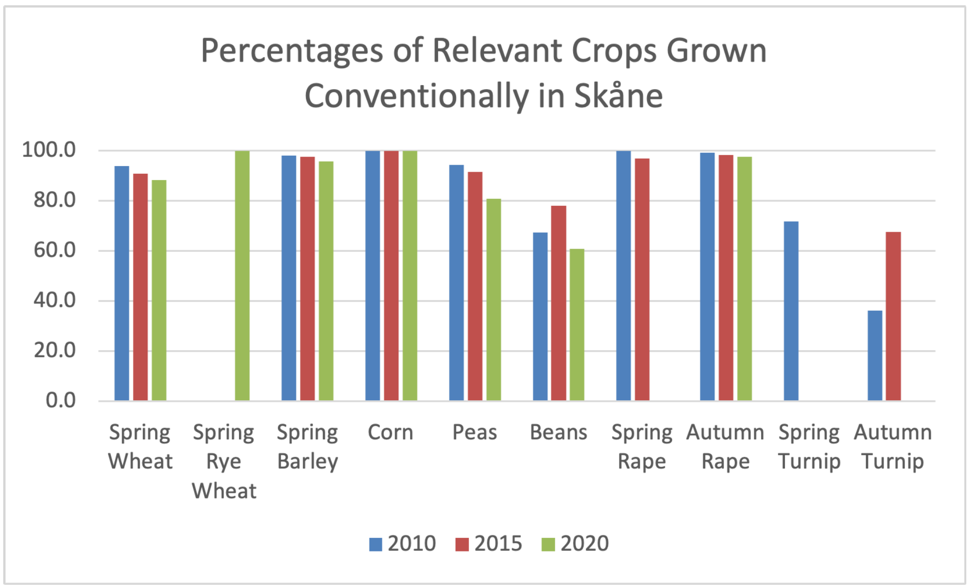


Figure 3: Percentages of Relevant Crops Grown Conventionally in Skåne (Data sourced from Jordbruksverket)

In order to measure cognitive and learning ability, I used data on 3rd grade math and reading proficiencies from Skolverket's national tests[13]. Starting in 2009, Skolverket annually recorded the total number of 3rd grade students who took the national math and reading test as well as the percentage of boys, girls, and boys and girls combined who reached a sufficient level of

[13]Accessed: 22 March 2023, https://www.skolverket.se/skolutveckling/statistik/sok-statistik-om-forskola-skola-och-vuxenutbildning?sok=SokD&niva=K&omr=natprov&exp=52&lasar=2022&uttag=null

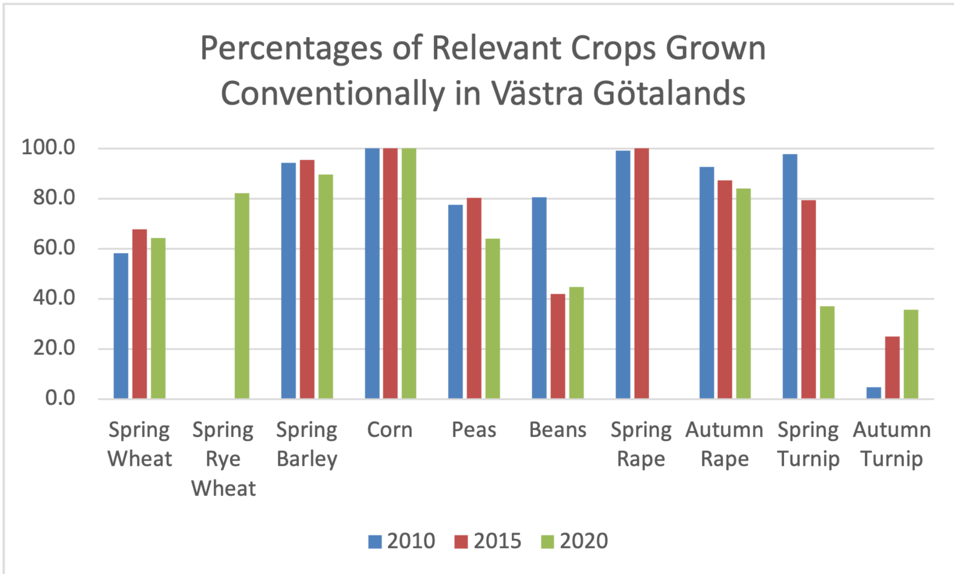


Figure 4: Percentages of Relevant Crops Grown Conventionally in Västra Götalands (Data sourced from Jordbruksverket)

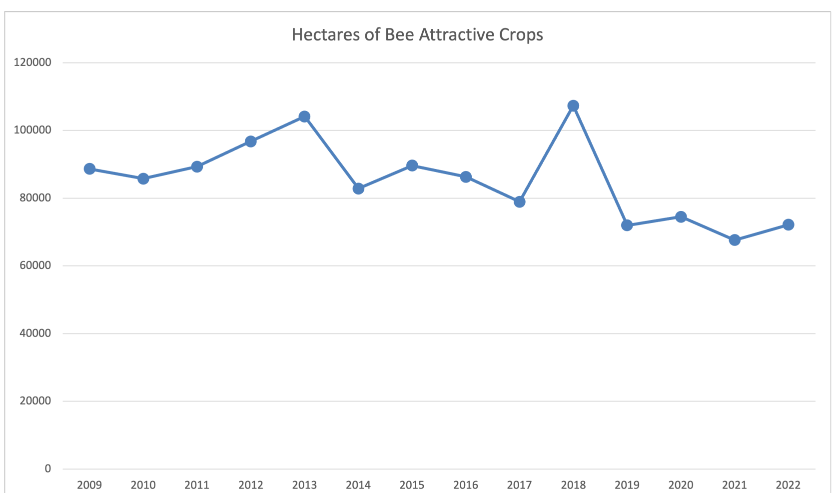


Figure 5: Hectares of bee-attractive Crops grown in Treatment Municipalities (Data sourced from Jordbruksverket)

demonstrated comprehension[14]. With these proportions, it is possible to calculate how many boys and girls took the national test in each municipality, which is important for proper weighting when conducting analyses and gender specific analyses. One thing to note is that proficiency was not holistically measured in both math and reading, but proficiency in each subcategory was recorded (e.g. interpreting graphs and tables, addition, subtraction, etc.) I created an average proficiency level that equally weighted the proficiencies in each of the subcategories. This average proficiency level was calculated for boys and girls together and separately. Additionally, the structure of the math test was not consistent through the years in this study. For instance, in some years, there were 7 subcategories, but in other years, there were 9. The titles of the subcategory changed sometimes too. With that said, the reading test subcategories are consistent throughout the sampled years.

Another education-related set of data from Skolverket described student-to-teacher ratios[15]. This data showed the student-to-teacher ratios for municipality run schools, privately run schools, and the two of them combined for each municipality for each year [16]. All student-to-teacher ratios and the calculations for the percentages of private schools were based on all schools, regardless of level, in the municipality for that year.

Yet another education related data set came from SCB on the educational

[14]Academic years 2019/2020 and 2020/2021 were omitted because of the COVID-19 pandemic

[15]Accessed: 6 May 2023, https://www.skolverket.se/skolutveckling/statistik/sok-statistik-om-forskola-skola-och-vuxenutbildning?sok=SokD&niva=K&omr=personal&exp=81&lasar=2021&uttag=null

[16]It should be noted that this data did not distinguish between primary and secondary schools

attainment for ages 16 to 74[17]. The data was broken down by year and municipality, and it showed how many people were in each education bracket (e.g. less than high school, high school, more than high school but no more than 2 years, etc). By summing together the number of individuals with more than a high school degree for each municipality in each year, I then divided the sum by the municipality's population for that year to figure out proportionally how many people strived to educate themselves beyond high school in each municipality for each year. Although this measure included 16 and 17 year olds, for the purposes of this study, they were considered adults. Additionally, this variable was transformed by being multiplied by 100 for a more easy interpretation of the coefficient in the regression tables.

From Brå, I sourced data on reported crime rates by municipality by year from 2006 through 2021[18]. I used this data because medical literature and Grönqvist et al's (2020) study suggest that this ban may impact criminal activity (Rice et al 2000). The data used is a rate per 100,000 persons[19]. For privacy reasons and for greater accuracy, annual municipal data was not able to be broken down into age groups nor gender. This measurement concerns reported crime and included all reportings of assault, sexual assault, defamation, theft, embezzlement, forgery, perjury, and treason to name several. I used crime reportings instead of convictions, which was what Grönqvist et al's (2020) study used, because data on convictions were not available at the municipal level.

[17] Accessed: 5 May 2023, https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__UF__UF0507/StudiedeltagandeF/

[18] Accessed: 25 April 2023, https://statistik.bra.se/solwebb/action/index

[19] Given that all of the municipalities are less than 100,000, and many are only around 20,000 people, one should keep this in mind when interpreting the results

In my analysis, I used population data for year and municipality which was sourced from SCB[20]. This was needed when weighting observations in my analysis as well as when calculating other control variables as a proportion with respect to population. From SCB, I also used annual median income for individuals 16 and older as a way to evaluate the wealth of a municipality[21]. The decision to include median income as a way to control for municipal wealth was inspired by Lai (2017) who controlled for regional GDP in his analysis.

I also used occupational data from SCB to determine proportionally how many people work in STEM jobs in each municipality as well as if a municipality has several police officers[22]. To determine the proportion of residents working in STEM jobs, I summed the count of all STEM related occupations for any given municipality in each year and divided it by the population. Additionally, this variable was transformed by being multiplied by 100 for easy interpretation of the coefficient in the regression tables. STEM occupations were determined manually by their SSYK occupational code and title (e.g. doctor, data engineer, etc). One potential issue was that for years before 2013, the definition for the SSYK occupational codes shifted. I did my best to make sure the selections in occupations reflected the occupational title. Often times, the title stayed the same, but the classification code changed. To the best of my ability, the data selected did not appear to have a noticeable

[20] Accessed: 27 April 2023, https://scb.se/hitta-statistik/statistik-efter-amne/befolkning/befolkningens-sammansattning/befolkningsstatistik/

[21] Accessed: 2 April 2023, https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__HE__HE0110__HE0110A/NetInk02/

[22] Accessed: 5 May 2023, https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__AM__AM0208__AM0208D/YREG58N/

discontinuity between 2013 and 2014.

For determining the number of police, I used the same occupational data that allowed me to determine the proportion of all STEM related occupations in each municipality. I created a dummy variable that equals one if a municipality has more than 15 police officers in a given year. Although the SSYK occupational code for police officers changed between 2013 and 2014, the title stayed the same.

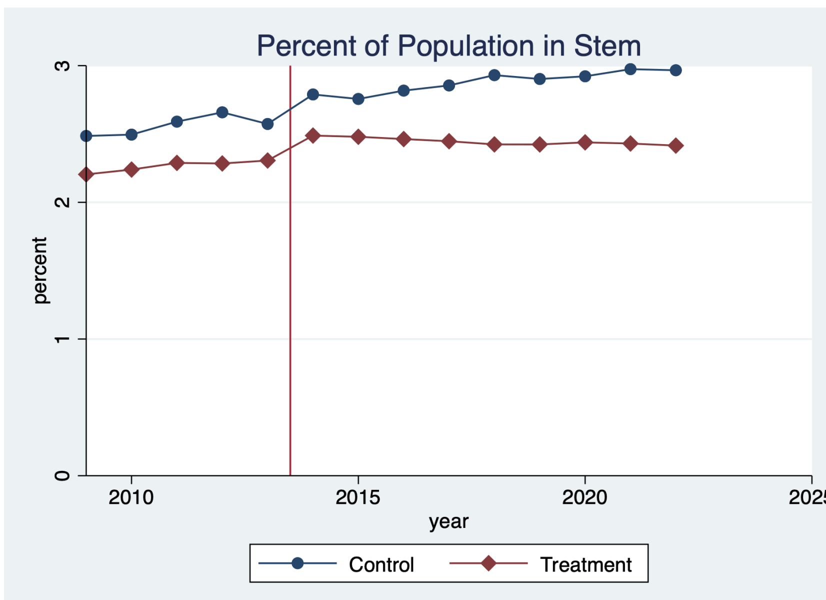


Figure 6: Percentage of adults working in STEM jobs (Line between years 2013 and 2014 when the data reflected updated occupational codes) (Data sourced from SCB)

I used several data sets from SCB to control for the variation each municipality displayed in the qualities and differences between rural and urban areas. The first set of data was yearly population density for each municipality[23]. The second was the number of houses and apartments in each municipality for each year[24] [25]. I then modified this data by dividing it by the municipality population to show the number of houses and apartments in proportion to the population. And thirdly, I used yearly gini coefficients for each municipality [26]. The gini coefficient was calculated using disposable income and capital gains. The data on the gini coefficient provided by SCB included only the years from 2012 to 2020. For the relevant years in the analysis, observations for the gini coefficients are missing for the years 2009, 2010, 2011, and 2021. I imputed years 2009 - 2011 with 2012's value and 2021 with 2020's value. I assumed that the imputed gini coefficient values would be relatively close enough to what they actually are for those years. Additionally, there are three non-imputed years/observations for the years leading up to and including the year in which the ban took effect. In studies involving cutoffs, such as a temporal event, it is preferable to just include data that is closest to the cutoff as data that is further away is more prone to biases. In this way, hopefully by having non-imputed data as the 3 closest years leading up to and including the ban, my analysis is safe from bias. Further, this is only one of several measures for capturing qualitative differences between rural and urban areas within a municipality. The shortcomings of using this variable as a control variable will not totally and detrimentally

[23]Accessed: 5 May 2023, https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__BE__BE0101__BE0101C/BefArealTathetKon/

[24]Accessed: 5 May 2023, https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__BO__BO0104__BO0104D/BO0104T04/

[25]Houses are defined as stand alone residential buildings with no more than two separate living units, and apartments are residential buildings with 3 or more living units in them

[26]Accessed: 5 May 2023, https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__HE__HE0110__HE0110H/TABIRH4/

impact my study as I used other measures to capture urban-rural differences within municipalities. Additionally, this variable was transformed by being multiplied by 100 to more easily interpret the coefficient in the regression tables.

The last set of data that I used was counting the number of households who rely on self-supplied drinking water[27]. This data is included because it follows along the lines of Lai's (2017) research that found a relationship between drinking contaminated water and adverse health effects. SCB provided data at the municipal level for most years on the number of residents who have publicly supplied water, self supplied water (such as from a well), seasonally supplied water (residents have access to both public and private), no water, and a total. By dividing the number of those who self supply their own water by the total, I calculated a proportion that I then used to determine which municipalities regularly had a large portion of residents supplying their own water. The years included in SCB's water supply data are 2005, 2010, and 2014 through 2020. For the relevant years in my analysis, I imputed the value for 2009 as the value from 2005; For 2011-2013, I used the value from 2010; and for 2021, I used the value from 2020. As before, I assume that the imputed values are close enough to the actual proportion of residents who self supplied their own water.

[27] Accessed: 10 March 2023, https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__MI__MI0902__MI0902C/MI0902T03/

| Variable | | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| total_crime | crime rate per 100,000 | 602 | 10131.7 | 2612.809 | 4846 | 22774 |
| tot_math | percent proficient in math | 473 | 88.97976 | 4.047121 | 74.37143 | 98.61111 |
| boys_math | percent boys proficient in math | 472 | 88.81418 | 4.305911 | 73.9 | 99.6 |
| tot_reading | percent proficient in reading | 473 | 92.8014 | 2.660537 | 82.225 | 98.725 |
| boys_reading | percent boys proficient in reading | 472 | 90.53652 | 3.665215 | 75.45 | 100 |
| bee_plant_~y | dummy variable for if a municipality is in the treatment or control | 602 | 0.5348837 | 0.4991964 | 0 | 1 |
| pct_bee_pl~8 | percentage of municipal land used to grow bee-attractive crops | 602 | 0.1170744 | 0.0478275 | 0.0293336 | 0.2900206 |
| income | median income in SEK | 559 | 248338.8 | 33764.62 | 181100 | 384000 |
| adults_in_~m | percent of adults with a STEM job | 602 | 3.179194 | 2.189739 | 0.9731945 | 15.61839 |
| density | inhabitants per sq km | 602 | 104.8148 | 99.77721 | 15.7 | 448.3 |
| houses_per~p | number of. Houses per person | 602 | 0.2854029 | 0.0622804 | 0.149105 | 0.4131896 |
| apt_per_pop | number of apartments per person | 602 | 0.1636998 | 0.0673067 | 0.0608541 | 0.34 |
| gini | gini | 602 | 26.7088 | 2.89931 | 21.9 | 40 |
| adults_mor~s | percent of adults with more than high school education | 602 | 21.02715 | 6.320117 | 10.34227 | 47.92809 |
| has_10pct_~l | dummy variable for if 10% or more schools are private | 602 | 0.2342193 | 0.4238621 | 0 | 1 |
| student_te~o | number of students per teacher | 473 | 11.91712 | 0.8770754 | 8.9 | 14.3 |
| has_severa~e | dummy variable for if a municipality has more than 15 police officers | 602 | 0.4501661 | 0.4979241 | 0 | 1 |
| is_ss_water | dummy variable for if 19% of residents or more self supply their own water | 602 | 0.3853821 | 0.4870902 | 0 | 1 |
| pop | municipal population | 602 | 31941.44 | 32157.66 | 5493 | 158653 |
| totalnumberofstudents | total number of students taking the 3rd grade national exam | 473 | 360.0338 | 350.5936 | 20 | 1839 |

Table 1: Summary of data

# 4 Methodology

To gain an understanding of the impact that the pesticide ban in 2013 had on crime rates as well as math and reading proficiency, I used a differences in differences design where I split the 38 municipalities into treatment and control groups based on the intensity with which they grew impacted crops. I selected crime rates, proportions of 3rd grade students who are proficient in math and reading, and 3rd grade boys who are proficient in math and reading as my dependent variables because previous research suggested that there could be impacts in criminal activity as well as cognitive and learning ability, especially among boys in particular (Grönqvist et al 2020; Rice et al 2000; Ding and Bao 2014). To increase the robustness of the analysis, I included several observable qualities as control variables. I also clustered robust standard errors at the municipal level since observations occurring within the same municipality are likely to correlate over time. Additionally, I included municipality fixed effects as well as year fixed effect to account for unique qualities that municipalities and years have. Lastly, I weighted observations by population when crime rates were the dependent variable, by total number of students when the total proportion of 3rd graders proficient in math and reading was the dependent variable, and by the number of boys when the proportion of boys proficient in math and reading was the dependent variable. I estimated the following model:

$$\begin{aligned} y_{i,t} =& c + (\sum_{j \in (m...0...n)} \gamma_j * D_{i,t-j}) + a_i + \delta_t + \beta * X_{i,t} + \epsilon_{i,t} \\ & s.t.\ j = t - \textit{Year ban took effect} \end{aligned} \tag{1}$$

$y_{i,t}$ represents the dependent variable, namely the schooling proficiency or the crime rate in year $t$ and in municipality $i$. $c$ is just the intercept. $(\sum_{j \in (m...n)} \gamma_j * D_{i,t-j})$ are the terms for the event study. $D_{i,t-j}$ is an indicator variable for the year that is $j$ periods before the event, which in this study is the year that the ban took effect. Additionally, one period is equivalent to one year. $\gamma_j$ is the coefficient of interest as this coefficient shows the effects of being in the treatment group for each period $j$. For when $j$ is less than 0, $\gamma_j$ shows the effect of being in the treatment group before the ban, and these coefficients can be used to investigate possible violations of the parallel trends assumption if values of $\gamma_j$ are statistically different from 0. When $j$ is greater than 0, $\gamma_j$ shows the effect of the ban in treatment municipalities. $m$ represents the earliest period before the ban that $j$ can take, as defined by the smallest value from $t - \textit{Year ban took effect}$. Similarly, $n$ represents the latest period after the ban that $j$ can take, as defined by the largest value from

$t -$ *Year ban took effect*. Further, *Year ban took effect* is the year in which the event of the study took place. In this study, the year in which the event took place usually refers to 2014 [28] (Miller 2023). $a_i$ and $\delta_t$ measure fixed effects for municipality and year respectively. $\beta$ is a vector of coefficients for $X_{i,t}$, which is a vector containing year and municipality specific control variables. And lastly, there is the error term $\epsilon_{i,t}$ .

In order to conduct my analysis, I needed to make several assumptions. One of the most critical assumptions was that of parallel trends which assumed that, in the absence of the ban, the outcome variables would evolve in a similar manner. This assumption is crucial because if the trends in the outcome variables are not expected to remain constant, then the estimation of the treatment will be biased. To evaluate this assumption, I performed a visual analysis of graphs plotting the outcome variable and an inspection of $\gamma_j$ coefficients corresponding to the years before the ban. **Tables 3, 4,** and **5** show the point estimates for the treatment by year effects and **Figures 12, 13,** and **14** show their corresponding coefficient plots. **Figures 7, 8, 9, 10,** and **11** show the treatment and control groups' average for the 5 dependant variable over time. After examining the graphs of the proportion of boys proficient in math and reading, proportion of boys and girls combined who are proficient in math and reading, and crime rates between control and treatment municipalities, the trends between the control group and the treatment group appeared to have maintained a fairly parallel relationship before the ban took effect in 2014. When inspecting the $\gamma_j$ coefficients for any pre-ban structural differences between treatment and control groups,

[28]for one sensitivity check, 2018 and 2019 are used as the time periods for when the event took place following the expansion of the ban

estimates of $\gamma_j$ before the ban were clustered around 0 for all 5 outcome variables which suggested that there were no structural differences and that the parallel trends assumption could be reasonably assumed[29]. It is important to use both methods because a small and insignificant change in one method may be regarded as a violation of the parallel trends depending on how strict the standards are (Roth,2022).

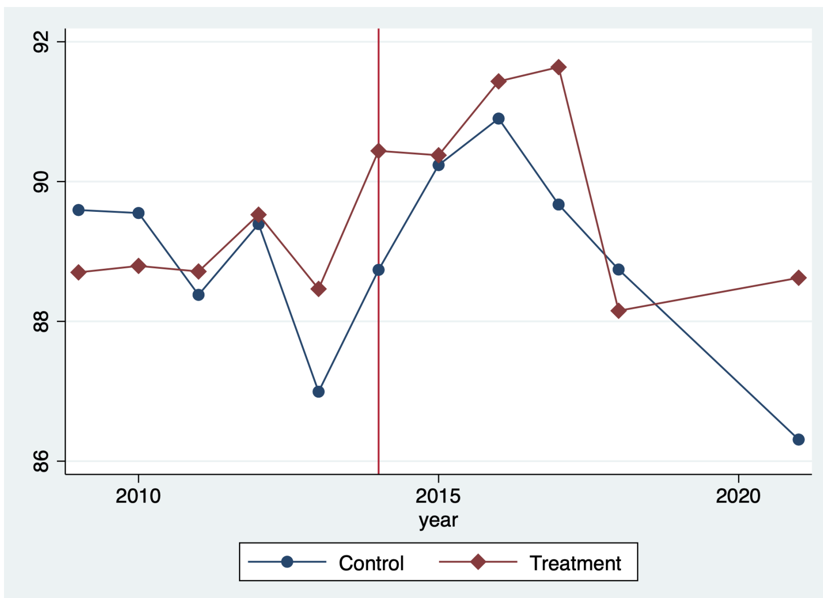


Figure 7: Average proportion of 3rd graders proficient in math for control and treatment municipalities

A second assumption is a less strict exchangeability or the unconfoundedness assumption. Besides the type of crop that assigns municipalities to either the control or treatment group, there cannot be any important differences between the control and treatment groups that could impact the

[29]The pre-trend analysis for proportion of students proficient in math however is potentially debatable as most pre-ban estimates are negative. That said, they are not statistically different from 0

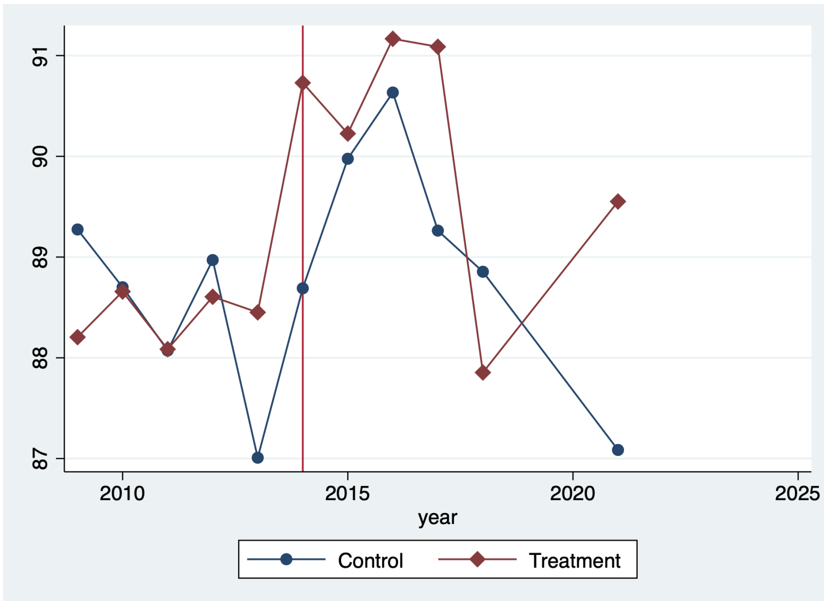


Figure 8: Average proportion of 3rd grade boys proficient in math for control and treatment municipalities

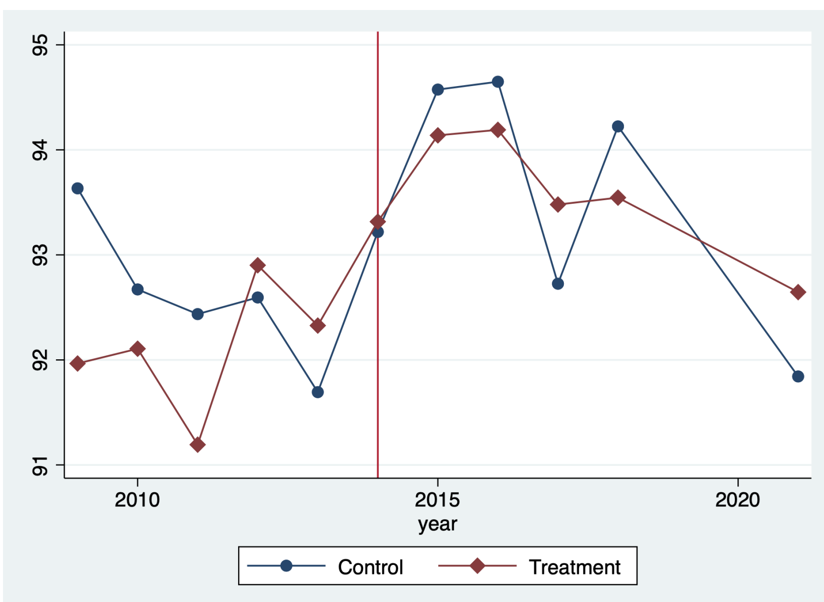


Figure 9: Average proportion of 3rd graders proficient in reading for control and treatment municipalities

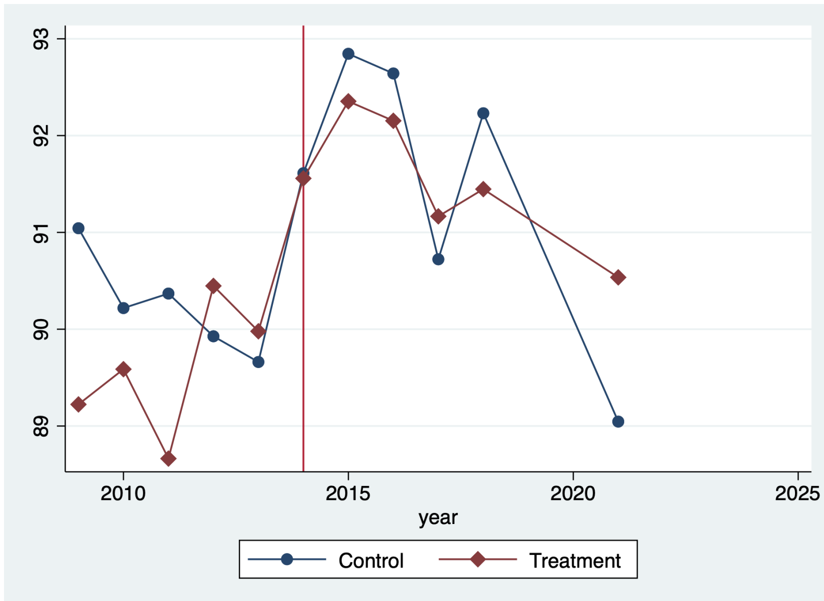


Figure 10: Average proportion of 3rd grade boys proficient in reading for control and treatment municipalities

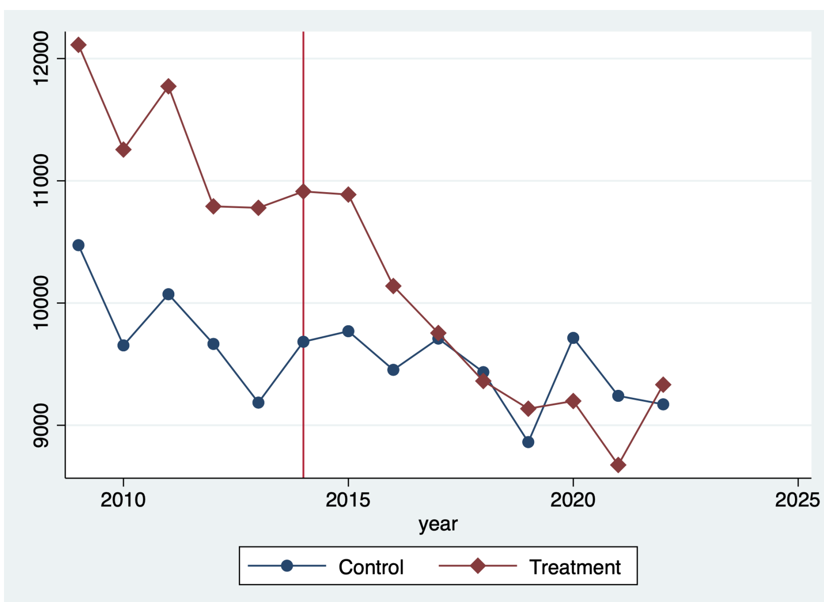


Figure 11: Average crime rates per 100,000 people for control and treatment municipalities

results. To assist in this, my model included several control variables that helped isolate the effect of the pesticide ban.

A third assumption is the Stable Unit Treatment Value Assumption (SUTVA). In terms of variation of treatment, it is reasonably assumed that all municipalities are subject to the same rules, and enforcement of the policy change does not vary among years and municipalities. And on a similar note, it is further assumed that farmers comply, but this compliance with the policy is difficult to verify. Additionally, it is assumed that there are no spillover effects between municipalities, namely young children who live in one municipality do not attend primary school in another and those who engage in criminal activity do not cross over into other municipalities.

A fourth assumption is that the control group is a good control. This is potentially an issue since all agricultural municipalities in Sweden grew some amount of crops affected by the ban. That said, I assume the effect of the ban to be negligible in control group municipalities because the municipal land area dedicated to growing crops impacted by the ban in control group municipalities is very small.

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Treatment | 168 | 0.1620214 | 0.0419953 | 0.08997 | 0.2900206 |
| Control | 136 | 0.0857569 | 0.0325587 | 0.034914 | 0.2137676 |

Table 2: Average percentage of bee-attractive crops grown in treatment groups vs control groups before 2014

A fifth assumption for my analysis is that Swedish farmers used neonicotinoid pesticides on their crops. As mentioned earlier, the EU fair trade agreement has made it difficult to track the sale and application of neonicotinoid pesticides. Although using conventional farming practices does not inherently imply the use of neonicotinoids, a farmer using neonicotinoids would be considered to utilize conventional farming practices. By looking at **Figures 3** and **4**, it can be seen that conventional farming is very common amongst farmers growing bee-attractive crops. Based on the Swedish agricultural literature discussing the ban and its impact on farmers who grow bee-attractive crops, it is reasonable to assume that it was commonly used on bee-attractive crops.

A sixth assumption is that a complete or near-complete removal of neonicotinoids is not necessary to see an acute impact of the policy. Given the newness of this policy, enough time has not passed to allow for the analysis of chronic conditions nor for a reliable and holistic comparison between children born before the ban and children born after. Acute impacts are the only impacts that can be seen at this time. Further, the ban in 2013 did not eliminate all uses of this pesticide, but rather significantly reduced its use and therefore its exposure to society as well. Some crops between 2014 and 2018 were still permitted to be protected by neonicotinoid pesticides, and currently, as of May 2023, emergency use of neonicotinoids is still permitted in Sweden.

A seventh assumption is that farmers did not switch their spring time crops because of the ban. For all farmers, it can be likely assumed that this ban did not encourage the growth of bee-attractive crops as the ban made the bee-attractive crops more susceptible to pests. Additionally, I worked with the assumption that farmers affected by the ban did not begin growing a replacement crop that is both typically treated with neonicotinoid pesticides and not included by the ban. Although it is certainly possible, it might not necessarily happen. As Lundin (2021) mentions, the use of pyrethroids in Sweden is still a viable option as pests have not developed resistance yet. Additionally, expensive and specialized equipment as well as crop schedules can make switching crops very difficult. Therefore, it is reasonably assumed that Swedish farmers did not exchange bee-attractive crops for other neonicotinoid treated crops as a result of the ban. This assumption is supported by **Figure 5**, which shows that after 2013, the amount of hectares used to grow bee-attractive crops has not decreased dramatically in treatment municipalities.

An eighth assumption is that the use of alternative pesticides have no detrimental impact on the surrounding population. In the medical literature, pyrethroids, which would be the Swedish farmers' substitute for neonicotinoids, is not associated with impacting cognitive ability nor criminal activity (Saillenfait 2015).

# 5 Results

## 5.1 Main Analysis

**Tables 3, 4,** and **5** show the results for math proficiency, reading proficiency, and crime rates respectively. **Figures 12, 13,** and **14** show the coefficient plots for the treatment group by year effects for math proficiency, reading proficiency, and crime rates respectively. For both total and boys specific math proficiency, there did not appear to be an impact from the ban. For the treatment by year effects on math proficiencies, point estimates after the ban range from -2.5 to 0.79, with a mix of positive and negative estimates that cluster around 0. Further, none of the treatment by year effects are statistically different from 0. For both total and boys specific reading proficiences, the ban did not appear to have an impact. After the ban, the point estimates for the treatment by year effects on the proportion of 3rd graders proficient in reading range from -1.2 and 1.4 with a mix of positive and negative estimates clustering around 0. Again, none of the treatment by year effects are statistically significant. Crime rates, however, did appear to be impacted by the ban, but it did not happen instantly. In 2015, point estimates for the treatment by year effects are not statistically significant, and the point estimates range from -49.7 to -103.4 depending on the control variable used. In 2016, the point estimates are again not statistically significant, and the point estimates range from -443.6 to -581.9, depending on the control variables used. In year 2017 and beyond, treatment by year point estimates range from -1778 to -720.7 with most clustering around -1000. Additionally, for crime, almost all treatment by year point estimates between 2017 and 2021 are statistically significant at the 5% level.

Some control factors to note are that the percentage of adults with more than just a high school education are sometimes statistically significant, depending on the regression. For math and reading, a one-percent increase in the proportion of adults with more than a highschool education results in about a 1% increase in the proportion of children proficient in math or reading. For crime, a 1% increase in proportion of adults with more than a high school education, crime rates are expected to decrease by about 900 crimes per 100,000 inhabitants.

As for the measures that are used to capture differences in contrasts between each municipalities' urban and rural areas, the coefficients are often small and often not statistically significant. That said, with statistical significance at the 10% level, a one person increase in density is associated with 0.1% increase in the proportion of boys proficient in math. Additionally, with statistical significance at the 5% level, a 0.01 increase in the gini coefficient is associated with a 0.48% decrease in the proportion of boys proficient in math.


Figure 12: Treatment by year effects when math is the dependent variable (note, above refers to the regression results corresponding to columns 1 and 2 in Table 3)

| VARIABLES | (1)<br>tot_math | (2)<br>boys_math | (3)<br>tot_math | (4)<br>boys_math | (5)<br>tot_math | (6)<br>boys_math |
|---|---|---|---|---|---|---|
| Treatment x Year 2009 | -1.542 | -2.193 | -1.732 | -2.536 | -1.586 | -2.193 |
| | (1.416) | (1.773) | (1.327) | (1.629) | (1.258) | (1.537) |
| Treatment x Year 2010 | -1.798 | -1.356 | -1.985 | -1.625 | -1.803 | -1.293 |
| | (1.365) | (1.469) | (1.265) | (1.319) | (1.221) | (1.278) |
| Treatment x Year 2011 | -1.057 | -1.546 | -1.217 | -1.763 | -1.034 | -1.449 |
| | (1.381) | (1.714) | (1.311) | (1.598) | (1.314) | (1.602) |
| Treatment x Year 2012 | -1.239 | -2.138 | -1.339 | -2.235 | -1.163 | -1.945 |
| | (1.398) | (1.673) | (1.344) | (1.539) | (1.303) | (1.527) |
| Treatment x Year 2013 | 0.112 | -0.319 | 0.00912 | -0.457 | 0.0692 | -0.389 |
| | (1.559) | (1.661) | (1.506) | (1.574) | (1.533) | (1.636) |
| Treatment x Year 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (0) | (0) | (0) | (0) | (0) | (0) |
| Treatment x Year 2015 | -1.828 | -1.854 | -1.765 | -1.759 | -1.773 | -1.737 |
| | (1.682) | (1.859) | (1.722) | (1.922) | (1.722) | (1.907) |
| Treatment x Year 2016 | -1.072 | -1.786 | -0.881 | -1.473 | -0.765 | -1.260 |
| | (1.204) | (1.250) | (1.280) | (1.375) | (1.276) | (1.369) |
| Treatment x Year 2017 | 0.162 | -0.762 | 0.454 | -0.287 | 0.613 | -0.000835 |
| | (1.160) | (1.272) | (1.247) | (1.429) | (1.254) | (1.363) |
| Treatment x Year 2018 | -2.554* | -3.656** | -2.232 | -3.104* | -2.064 | -2.819* |
| | (1.411) | (1.622) | (1.495) | (1.786) | (1.452) | (1.654) |
| Treatment x Year 2021 | 0.274 | -0.576 | 0.513 | -0.120 | 0.785 | 0.318 |
| | (1.222) | (1.383) | (1.313) | (1.497) | (1.279) | (1.401) |
| income | 3.37e-05 | -2.66e-05 | 7.84e-05 | 3.02e-05 | 9.67e-05* | 8.63e-05 |
| | (7.17e-05) | (8.70e-05) | (6.08e-05) | (8.13e-05) | (5.26e-05) | (7.23e-05) |
| adults_in_stem | -0.791 | -0.975 | -0.794 | -0.978 | -0.970* | -1.352* |
| | (0.536) | (0.823) | (0.528) | (0.768) | (0.503) | (0.729) |
| adults_more_than_hs | 1.267* | 1.487* | 1.175 | 1.297 | 1.054 | 1.107 |
| | (0.706) | (0.769) | (0.711) | (0.856) | (0.735) | (0.830) |
| has_10pct_priv_school | 0.435 | 0.0888 | 0.387 | 0.122 | 0.435 | 0.0913 |
| | (0.447) | (0.453) | (0.428) | (0.450) | (0.427) | (0.440) |
| student_teacher_ratio | -0.291 | -0.452 | -0.243 | -0.346 | -0.222 | -0.334 |
| | (0.275) | (0.290) | (0.265) | (0.284) | (0.264) | (0.294) |
| houses_per_pop | | | -38.22 | -48.24 | | |
| | | | (42.67) | (57.68) | | |
| apt_per_pop | | | -10.43 | 16.94 | | |
| | | | (36.68) | (50.92) | | |
| density | 0.0586 | 0.100* | | | | |
| | (0.0482) | (0.0567) | | | | |
| gini | | | | | -0.281 | -0.477** |
| | | | | | (0.193) | (0.200) |
| Constant | 53.76*** | 61.46*** | 63.39** | 72.99*** | 56.73*** | 65.83*** |
| | (15.38) | (18.79) | (23.44) | (24.76) | (15.78) | (18.96) |
| Observations | 418 | 395 | 418 | 395 | 418 | 395 |
| R-squared | 0.237 | 0.196 | 0.234 | 0.184 | 0.236 | 0.194 |
| Number of Municipalities | 38 | 36 | 38 | 36 | 38 | 36 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Math proficiencies for total and for boys with different control variables

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| VARIABLES | tot_reading | boys_reading | tot_reading | boys_reading | tot_reading | boys_reading |
| Treatment x Year 2009 | -1.449 | -1.564 | -1.587 | -1.701 | -1.567 | -1.648 |
| | (1.225) | (1.697) | (1.218) | (1.668) | (1.201) | (1.654) |
| Treatment x Year 2010 | -0.421 | -0.381 | -0.592 | -0.540 | -0.501 | -0.429 |
| | (0.847) | (1.136) | (0.883) | (1.141) | (0.860) | (1.150) |
| Treatment x Year 2011 | -1.253 | -1.480 | -1.413 | -1.631 | -1.304 | -1.505 |
| | (1.174) | (1.787) | (1.172) | (1.754) | (1.183) | (1.781) |
| Treatment x Year 2012 | 0.174 | 0.572 | 0.0651 | 0.498 | 0.159 | 0.589 |
| | (1.014) | (1.482) | (1.032) | (1.461) | (1.000) | (1.457) |
| Treatment x Year 2013 | 0.675 | 0.389 | 0.579 | 0.304 | 0.620 | 0.337 |
| | (1.179) | (1.700) | (1.173) | (1.652) | (1.192) | (1.701) |
| Treatment x Year 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (0) | (0) | (0) | (0) | (0) | (0) |
| Treatment x Year 2015 | -0.801 | -0.564 | -0.746 | -0.513 | -0.760 | -0.513 |
| | (0.995) | (1.532) | (0.995) | (1.539) | (0.988) | (1.525) |
| Treatment x Year 2016 | -0.788 | -0.769 | -0.643 | -0.644 | -0.607 | -0.567 |
| | (0.847) | (1.106) | (0.820) | (1.095) | (0.857) | (1.145) |
| Treatment x Year 2017 | 0.409 | 0.120 | 0.614 | 0.264 | 0.700 | 0.434 |
| | (1.060) | (1.406) | (1.002) | (1.384) | (1.039) | (1.410) |
| Treatment x Year 2018 | -1.155 | -1.212 | -0.937 | -1.050 | -0.828 | -0.858 |
| | (1.012) | (1.603) | (0.972) | (1.620) | (0.978) | (1.566) |
| Treatment x Year 2021 | 0.533 | 1.050 | 0.633 | 1.048 | 0.874 | 1.427 |
| | (0.859) | (1.380) | (0.781) | (1.366) | (0.791) | (1.318) |
| adults_in_stem | -0.701 | -1.173* | -0.645 | -0.988 | -0.824* | -1.325** |
| | (0.423) | (0.655) | (0.427) | (0.665) | (0.427) | (0.636) |
| income | -3.10e-05 | -4.42e-05 | 6.68e-06 | -2.21e-05 | 9.21e-06 | 5.75e-07 |
| | (5.83e-05) | (6.44e-05) | (3.74e-05) | (5.68e-05) | (4.10e-05) | (5.50e-05) |
| adults_more_than_hs | 0.879 | 0.787 | 0.835 | 0.776 | 0.755 | 0.634 |
| | (0.554) | (0.686) | (0.526) | (0.661) | (0.573) | (0.694) |
| has_10pct_priv_school | -0.260 | -0.381 | -0.335 | -0.399 | -0.266 | -0.386 |
| | (0.309) | (0.372) | (0.293) | (0.397) | (0.307) | (0.370) |
| student_teacher_ratio | -0.274 | -0.360 | -0.259 | -0.354 | -0.213 | -0.298 |
| | (0.190) | (0.262) | (0.198) | (0.264) | (0.211) | (0.274) |
| houses_per_pop | | | -49.41 | -65.89 | | |
| | | | (34.18) | (58.28) | | |
| apt_per_pop | | | -19.84 | -1.949 | | |
| | | | (28.35) | (37.70) | | |
| density | 0.0452 | 0.0467 | | | | |
| | (0.0424) | (0.0439) | | | | |
| gini | | | | | -0.0731 | -0.113 |
| | | | | | (0.164) | (0.198) |
| Constant | 82.43*** | 88.01*** | 96.01*** | 106.5*** | 82.05*** | 88.42*** |
| | (10.51) | (14.91) | (16.41) | (20.66) | (10.71) | (14.13) |
| | | | | | | |
| Observations | 418 | 395 | 418 | 395 | 418 | 395 |
| R-squared | 0.248 | 0.212 | 0.250 | 0.214 | 0.242 | 0.209 |
| Number of Municipalities | 38 | 36 | 38 | 36 | 38 | 36 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Reading proficiencies for total and for boys with different control variables


Figure 13: Treatment by year effects when reading is the dependent variable (note, above refers to the regression results corresponding to columns 1 and 2 in Table 4)

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | total_crime | total_crime | total_crime |
| Treatment x Year 2009 | 132.3 | 215.6 | 163.8 |
| | (487.6) | (458.5) | (473.5) |
| Treatment x Year 2010 | 140.5 | 219.3 | 155.0 |
| | (382.3) | (373.9) | (381.4) |
| Treatment x Year 2011 | 284.2 | 362.6 | 290.9 |
| | (507.7) | (462.4) | (486.5) |
| Treatment x Year 2012 | -223.2 | -157.2 | -242.1 |
| | (420.4) | (451.6) | (442.8) |
| Treatment x Year 2013 | 237.8 | 276.6 | 258.7 |
| | (361.7) | (385.9) | (378.1) |
| Treatment x Year 2014 | 0 | 0 | 0 |
| | (0) | (0) | (0) |
| Treatment x Year 2015 | -49.73 | -103.4 | -82.18 |
| | (441.2) | (434.7) | (433.4) |
| Treatment x Year 2016 | -443.6 | -568.7 | -581.9 |
| | (411.2) | (393.5) | (404.4) |
| Treatment x Year 2017 | -998.6** | -1,209*** | -1,200*** |
| | (396.9) | (345.8) | (348.3) |
| Treatment x Year 2018 | -1,070** | -1,329*** | -1,298*** |
| | (468.6) | (452.0) | (446.2) |
| Treatment x Year 2019 | -720.7* | -975.4** | -952.6** |
| | (385.8) | (412.4) | (415.2) |
| Treatment x Year 2020 | -1,490*** | -1,778*** | -1,737*** |
| | (473.0) | (468.1) | (449.7) |
| Treatment x Year 2021 | -1,468*** | -1,766*** | -1,710*** |
| | (511.0) | (490.0) | (501.4) |
| adults_more_than_hs | -939.0*** | -891.0** | -878.4** |
| | (324.5) | (332.1) | (326.7) |
| income | 0.0212 | -0.0140 | -0.00572 |
| | (0.0296) | (0.0169) | (0.0163) |
| adults_in_stem | 74.43 | 244.9 | 157.4 |
| | (233.3) | (259.3) | (247.0) |
| houses_per_pop | | -13,412 | |
| | | (14,114) | |
| apt_per_pop | | 18,211 | |
| | | (20,125) | |
| has_several_police | 355.0 | 383.8 | 366.0 |
| | (287.7) | (261.7) | (247.4) |
| density | -28.37 | | |
| | (26.58) | | |
| gini | | | 89.65 |
| | | | (61.65) |
| Constant | 27,317*** | 32,105*** | 26,881*** |
| | (6,071) | (7,252) | (5,838) |
| | | | |
| Observations | 494 | 494 | 494 |
| R-squared | 0.451 | 0.450 | 0.447 |
| Number of Municipalities | 38 | 38 | 38 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1



Table 5: Crime with different control variables

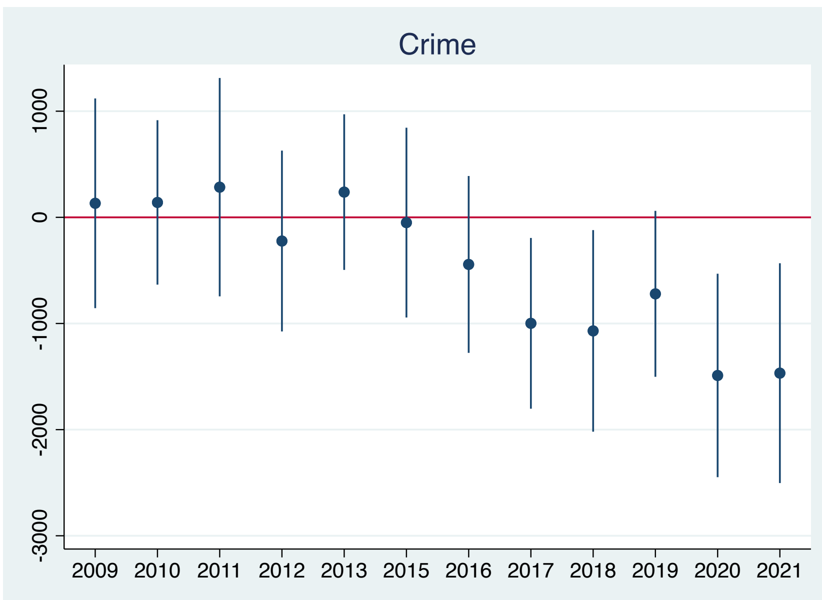


Figure 14: Treatment by year effects when crime is the dependent variable (note, above refers to the regression results corresponding to column 1 in Table 5)

## 5.2 Sensitivity Checks

In addition to the main specification, I also ran regressions on math proficiency, reading proficiency, and crime rates with alternative specifications. The first alternative specification follows inspiration from Lai's (2017) study. In this specification, the treatment group is defined as having both a significant proportion of land used to grow bee-attractive crops as well as a significant proportion of the population supplying their own water. This specification follows the idea that in the absence of a public water supply system that cleans and purifies water, residents may be drinking water contaminated with neonicotinoid pesticides (Lai 2017). The second alternative specification includes the 5 populous municipalities that were formally excluded making the number of municipalities in the sample 43. The third alternative specification runs the same regression as the main regression but unweighted. The fourth alternative specification is based off of the policy change that occurred in 2018 when the EU extended the ban to all outdoor crops. For the specification based on the 2018 expanded ban, municipalities needed to have at least 35% of total land dedicated to growing outdoor crops for 10 out of the 13 years between 2006 and 2017. Although the ban was put into effect in December 2018, the school proficiencies' reference year is 2018 because the COVID-19 pandemic prevented students from taking the national tests in the 2019/2020 and 2020/2021 academic years. For crime, the reference year is 2019. Raw mean plots of the dependent variable used for visually analyzing the parallel trends assumption, treatment by year coefficient plots, and regression tables for all of the alternate specifications can be found in the appendix. A fifth and final alternative specification that I conducted was restricting the control group municipalities to only those that used less than 10% of their municipal land to grow bee-attractive crops for any year between 2006 and 2014. This specification was made to address the potential issue that arose from the fact that all municipalities in the control group grew some amount of bee-attractive crops for at least one year between 2006 and 2014. This 5th specification keeps the composition of treatment group municipalities the same while refining the control group further. Two downsides to this refinement are that 1) it is imperfect because no municipality in this study had never grown bee-attractive crops, and that 2) there are only 5 municipalities in the control group, which may lead to a lack of precision and insufficient statistical power to detect a difference (Hutchins et al 2015). A table showing the mean percentage of land used to grow bee-attractive crops between the treatment and control can be found in the appendix.

For both total and boy specific math proficiency, the parallel trends assumption does not appear to hold for any of the alternative specifications. Despite the fact that none of the point estimates for treatment by year effects were statistically different from 0, the values were mostly negative, ranging from -2.91 to 0.76 and with many around -1.25 for the time periods before the ban. Graphical analysis also support this violation of parallel trends. The one exception to this is for the 2018 specification as there is a nice balance of positive and negative values close to 0. For the 2018 specification, there could be very small increases in math proficiency as the one and only point estimate is 0.8 for total math and 0.12 for boys-specific math. That being said, these point estimates after the ban took effect are not statistically different from 0.

After analyzing treatment by year point estimates as well as graphical analyses of the alternative specifications for reading, it appeared that the parallel trends assumption was maintained overall as there were no noticeable pre-ban trends[30]. For the coefficients of interest after the ban took place, it appeared that the ban had no impact on reading, with the possible exception for the specification where treatment group municipalities are additionally required to have large portions of their population supplying their own water. Here, there could be a small positive impact on reading proficiency, but it is difficult to tell [31]. All point estimates are positive after the ban, but most are not statistically different from 0. Only the point estimates in 2017 of 1.95 for 3rd graders as a whole and 2.2 for boys specifically are statistically significant at the 5% and 10% level, respectively. This indicated an increase of 1.95% in the proportion of 3rd grade students proficient in reading and an increase of 2.2% for boys in particular.

Graphical interpretation as well as analysis of pre-ban trends suggested that the parallel trends assumption holds for all of the alternative specifications when crime rates are the dependent variable, with the exception of the 2018 specification for crime rates. For the coefficients of interest, the ban appeared to have decreased crime, just like the primary specification.

[30]In the Treatment by year effects before the ban took place for when the control group consisted of municipalities that have never used 10% or more land to grow bee-attractive crops, the 2012 year effect for being in the treatment group was positive and statistically significant. That being said, this could be an outlier though a visual analysis of the raw means graphs suggest a structural difference between the mean and control groups.

[31]It should be noted that in Lai's study based in China, residents drank surface water where as in Sweden, it is much more likely that residents drank from wells that are tested for potability.

That being said, unlike the primary specification, with the exception to the unweighted specification, most of the treatment by year effects for the years after 2017 are not statistically significant.

Overall, the results for the alternative specifications cannot be used for reliable estimations when analyzing the effect that the ban had on the proportion of 3rd graders proficienct in math as it could not be guaranteed that there were no structural differences between treatment and control groups. However, it could be reasonably assumed after looking at the treatment by year effects before the ban as well as graphical analyses of the raw means that there were no structural differences when analyzing the proportion of 3rd graders proficient in reading and crime rates. The alternative specifications had similar results to the primary specification in that it appeared that reading proficiency was not impacted but crime was.

For the control variables, the alternate specifications share similar results to the primary specifications. Increasing the proportion of adults with more than just a high school education is associated with an increase in reading proficiency as well as a decrease in crime. Likewise, increasing population density is associated with lower rates of crime.

# 6 Discussion

## 6.1 Interpretation

Overall, the results of this study suggest that the proportion of young students who demonstrate a proficient understanding of math and reading showed no change after the ban, but crime rates did. Between the years 2017 and

2021, when the point estimates were statistically significant, instances of reported crimes decreased cumulatively by about 5700 instances per 100,000 in treatment group municipalities. Keep in mind that many of the municipalities have populations of 20,000 people so this result should be seen as reducing reported crimes by roughly 1200 instances per 20,000 people. The decrease in crime rates was not immediate, but the rates steadily decreased starting in the year after the ban took effect. One possible reason for non-immediate impact was because of the persisting presence of neonicotinoids in the surrounding environment despite the ban. The half-life of neonicotinoids is rather variable, ranging from 1 month to 3.5 years. It could very well be that even after the ban was in effect, neonicotinoids were still present in the environment due to their potentially long half-life. As the amount of neonicotinoids decayed over the years, the effect of policy likely increased.

The findings regarding crime rates is consistent with previous literature that connects neurotoxin exposure to increased aggression and criminal activity. However, it is surprising that school proficiency appears to be unaffected. There are several potential reasons for this, with one possiblility being that this particular neurotoxin impacts people's aggression and propensity for crime more than their cognitive capacity. Further research in the science community would be needed to verify this specific and targeted impact of neonicotinoids, however.

Another possible explanation for the effect seen in crime but not children's proficiency is that adults who committed crimes had more exposure to the neonicotinoid pesticide than the children. My research relies on the assumption that residents are constantly exposed to micro amounts of neonicotinoid pesticides because they live in an agricultural area. It could be that, before the ban, children in the treatment group were not exposed long enough by the 3rd grade to develop a cognitive impairment, resulting in no difference when comparing treatment and control groups after the ban. For adults however, who have been exposed to micro amounts of the pesticide for a lot longer, they might have had enough exposure such that the ban had an impact. These possibilities, although possible, are not likely in my opinion and possibly warrant further research. Children are a vulnerable demographic, and given that the exposure is likely small, it is more likely that children would show effects rather than adults.

Perhaps this neurotoxin does impact cognitive abilities, but the data and methods used in my research are not able to capture its effect. Firstly, because data is aggregated at the municipal level, small nuances that are only visable at the household or neighborhood level are likely lost. Secondly, since children are very vulnerable to pesticides, the control group municipalities could be viewed as a bad control. As mentioned earlier, all municipalities in the study grow some amount of bee-attractive crops, and it was the intensity at which each municipality grew these crops that placed them in either the control or treatment group. Due to children's vulnerability and the toxicity of the pesticide, it is possible that my treatment and control groups are not suitable for a proper comparison. Thirdly, it is also possible that the impacts of the policy are very small. This idea is potentially supported by the regression specification inspired by Lai's study with reading proficiency as the outcome. Despite not being statistically different from 0, it could suggest that there was some small effect because most point estimates in this specification were above 0.

More likely in my opinion, however, the impact in cognitive ability was possibly not observed because the degree to which children understand a school subject was not observed. The proportions of students who reached the threshold to be considered proficient saw no noticeable change, but it could be that prior to the ban, students were just clearing the threshold whereas after the ban, students in the treatment groups are clearing the threshold easily. Along a similar note, given that the proportions of students who are proficient are consistently high throughout the sample, it is possible that the threshold to be considered proficient is low, and despite cognitive impairment, most children in the time before the ban were able to be considered proficient.

The idea that the Swedish schooling system has relatively low academic standards for 3rd grade students is backed by previous research. The quality of Swedish education appears to be degrading. This has been measured with international tests such as TMISS and PISA scores (Henrekson and Wennström 2022). Swedes today are demonstrating a lower comprehension of math, science, and reading compared to Sweden's international peers as well as older Swedish cohorts[32]. Therefore, it is possible that the improvements in cognitive ability from the ban are outdone by the lackluster quality of schooling. It also should be noted that because children start school at different ages, and curricula also varies between countries, the exposure to certain subjects is not the same. Along this line, what Skolverket deems suf-

[32]That said, comparing scores for reading may be problematic since translations of the original test to the test takers' native language may not be fair to compare (Asil and Brown 2015)

ficient for a Swedish 3rd grade child in math and reading may not be rigorous at all. Perhaps using 3rd grade proficiency measures is not an effective way to evaluate cognitive ability in young Swedish children.

## 6.2 Limitations

One limitation is that I used data aggregated on the municipal level compared to a more granular level of aggregation. As mentioned earlier, each municipality has differt qualitative divides between urban and rural areas. Although attempts were made to control for this characteristic in this analysis, they are imperfect controls. Data aggregated at the household or even neighborhood level would be preferable as the contrast between family members or neighbors would be significantly less than the contrasts between individuals from different parts of the same municipality.

Another possible limitation of this study is that the estimation of the treatment effect may be biased because the treatment group mostly has counties from Skåne. Although the control group has a mix of municipalities from various counties, the heavy dependency on municipalities from Skåne in the treatment group could mean that what is estimated is influenced by county-specific differences.

Another possible limitation was that the data from Brå was unable to be broken down by age. Although analyses at all ages is useful, it is unclear whether crime is reduced for all ages or if a specific age group is driving the age. If crime among young adults is driving the observed decrease, then this fits with the previous literature on the effects of neurotoxins on aggressive and criminal behavior for young people with developing bodies. If crime among middle aged individuals is driving the change, then further research would be needed to understand if there is a connection between this pesticide and developed adults' behavior.

One possible confounder is that the Swedish Police underwent a structural and organizational change in 2015. The change was intended to clarify a hierarchical structure and to properly allocate resources efficiently. This change was designed to improve understanding of jurisdiction as well as to effectively assign or mobilize resources where they are needed. In a review of the police reform, Cameron (2017) notes that there are some transitional complications in administration and coordination, and that the time needed for a full transition was underestimated. These changes, to the best of my ability, do not appear to impact the rate at which crime would be reported, or specifically impact the rate at which crime would be reported in treatment group municipalities any differently from control municipalities.

Another limitation of the study is that the time frame is rather limited. When comparing it to Grönqvist et al's (2020) study, I have a significantly smaller time frame. My study encompases 17 years of data whereas Grönqvist et al were able to track two cohorts of children born over a decade apart for their entire childhood and early adult career. It is for this reason that I cannot examine long term impacts, of which the medical literature suggests there are many (Cimino et al 2017; Ding and Bao 2013; Rice et al 2000). It is very possible that there are implications of the ban that I am missing because not enough time has passed for these effects to noticeably reveal themselves or even manifest within the children.

Another limitation of this study is that it does not compare exposure to non-exposure. Again, comparing my analysis to Grönqvist et al's (2020), they compared cohorts of individuals that had exposure as children to cohorts of invidiuals that had no childhood exposure. My treatment group did not experience a complete removal of neonicotinoid pesticides as neonicotinoids have unpredictable half-lives, neonicotinoids were permitted on other plants, and emergency use of neonicotinoids were permitted in Sweden. It is therefore likely that my study does not capture the full effect that could be seen if neonicotinoids were completely removed.

# 7 Conclusion

This study provides weak but potentially suggestive evidence that the 2013 neonicotinoid pesticide ban may have had an impact on the well-being of rural Swedish communities. Although short-term beneficial impacts were not reflected in improved rates of proficiency in math and reading among 3rd grade children, crime rates do appear to decrease shortly after the ban. Further research should be done to better understand the effects of neonicotinoids on humans.

Agriculture is already an important industry for global society, and its importance is only going to increase as the population continues to grow and climate change becomes a greater threat. For this reason, it is vitally important to identify the best agricultural practices, not only for the sake of the environment, but also for communities and governments all over the world. It is common and well-documented that farmers who fall into myopic traps when using pesticides on their crops suffer because of the short-and long-term consequences. As this paper suggests, it is not only farmers who can benefit from the abstained use of pesticides, but their surrounding community can also benefit. In this way, it is in the societies' and the governments' best interest to design policies that support farmers in transitioning towards more organic practices because transition costs are high, the rewards are not often immediately received, and both farmers and their communities would be better off.

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# 9 Appendix

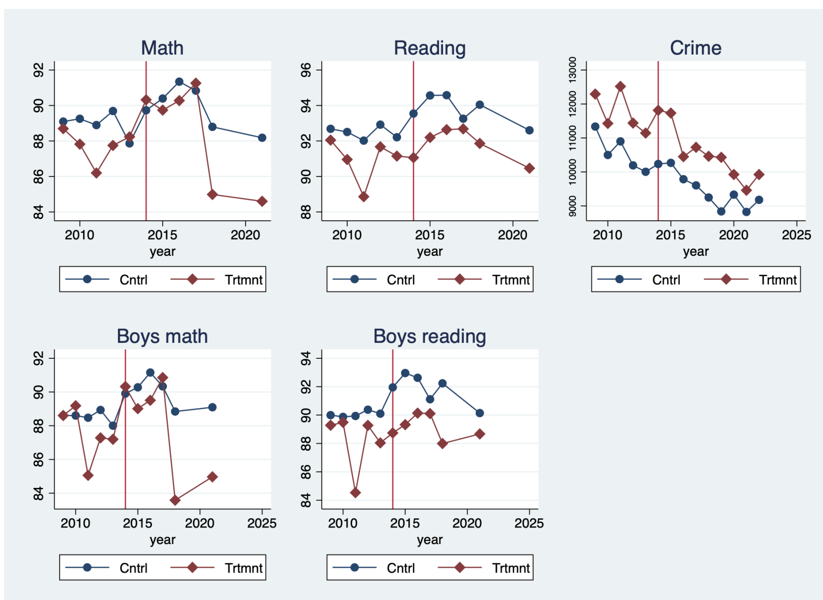


Figure 15: Raw mean for dependent variables when treatment group is defined by proportionally growing large amounts of bee-attractive plants and a large proportion of residents supplying their own water

| Control | Treatment |
|---|---|
| BORGHOLM | BJUV |
| BÅSTAD | ENKÖPING |
| ESSUNGA | ESLÖV |
| FALKÖPING | HÖGANÄS |
| GRÄSTORP | KUMLA |
| GÖTENE | KUNGSÖR |
| HALLSTAHAMMAR | KÄVLINGE |
| HJO | LANDSKRONA |
| HÖRBY | LOMMA |
| LIDKÖPING | SIMRISHAMN |
| MELLERUD | SJÖBO |
| MJÖLBY | SKURUP |
| SKARA | STAFFANSTORP |
| SVEDALA | SVALÖV |
| VARA | SÖLVESBORG |
| VÄNERSBORG | TOMELILLA |
| ÄNGELHOLM | TRELLEBORG |
| | VADSTENA |
| | VELLINGE |
| | YSTAD |
| | ÅSTORP |
| | |
| Big Municipalities | |
| KRISTIANSTAD | HELSINGBORG |
| LUND | VÄSTERÅS |
| SKÖVDE | |

Table 6: List of municipalities in control and treatment groups for main specification and with large populated municipalities

| Control | Control cont. | Treatment |
|---|---|---|
| BJUV | MELLERUD | ENKÖPING |
| BORGHOLM | MJÖLBY | KUNGSÖR |
| BÅSTAD | SIMRISHAMN | SJÖBO |
| ESLÖV | SKARA | SVALÖV |
| ESSUNGA | SKURUP | TOMELILLA |
| FALKÖPING | STAFFANSTORP | |
| GRÄSTORP | SVEDALA | |
| GÖTENE | SÖLVESBORG | |
| HALLSTAHAMMAR | TRELLEBORG | |
| HJO | VADSTENA | |
| HÖGANÄS | VARA | |
| HÖRBY | VELLINGE | |
| KUMLA | VÄNERSBORG | |
| KÄVLINGE | YSTAD | |
| LANDSKRONA | ÄNGELHOLM | |
| LIDKÖPING | ÅSTORP | |
| LOMMA | | |

Table 7: List of municipalities in control and treatment groups with additional self-supplied water condition

| Control | Treatment | Treatment cont. |
|---|---|---|
| BORGHOLM | BJUV | SKURUP |
| FALKÖPING | ENKÖPING | STAFFANSTORP |
| HJO | ESLÖV | SVALÖV |
| HÖRBY | HÖGANÄS | SÖLVESBORG |
| MELLERUD | KUMLA | TOMELILLA |
| | KUNGSÖR | TRELLEBORG |
| | KÄVLINGE | VADSTENA |
| | LANDSKRONA | VELLINGE |
| | LOMMA | YSTAD |
| | SIMRISHAMN | ÅSTORP |
| | SJÖBO | |

Table 8: List of municipalities in control and treatment groups with control group municipalities having less than 10% of land used to grow bee-attractive crops for every year between 2006 and 2014

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Treatment | 168 | 0.1620214 | 0.0419953 | 0.08997 | 0.2900206 |
| Control | 40 | 0.0611797 | 0.0178443 | 0.034914 | 0.0988003 |

Table 9: Average percentage of land used to grow bee-attractive plants between 2006 and 2014 for control group and treatment group municipalities with control group municipalities having less than 10% of land used to grow bee-attractive crops for every year between 2006 and 2014

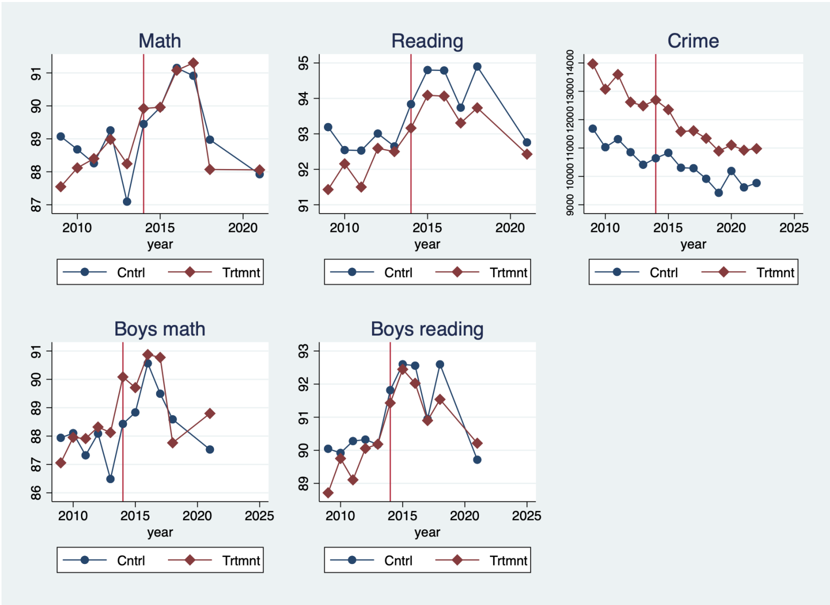


Figure 16: Raw mean for dependent variables when the 5 very populated municipalities are included

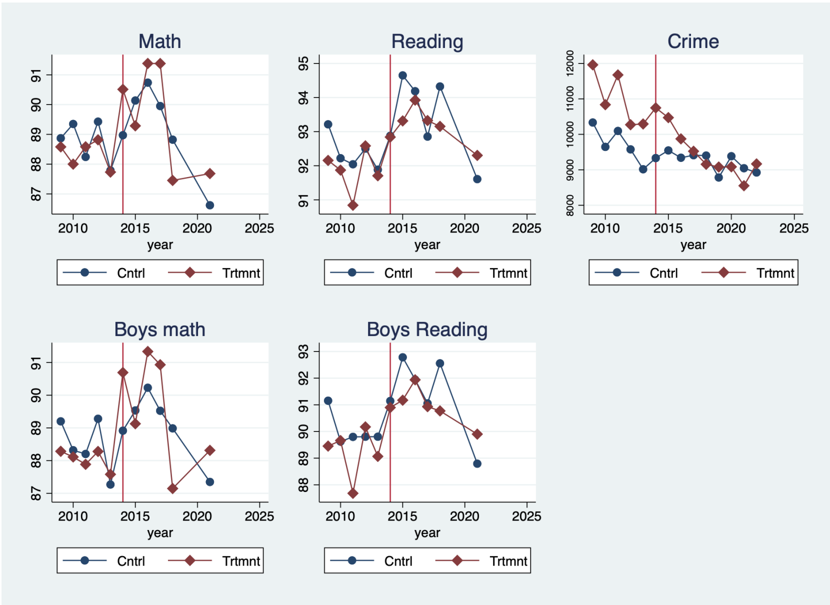


Figure 17: Raw mean for dependent variables when analysis is unweighted

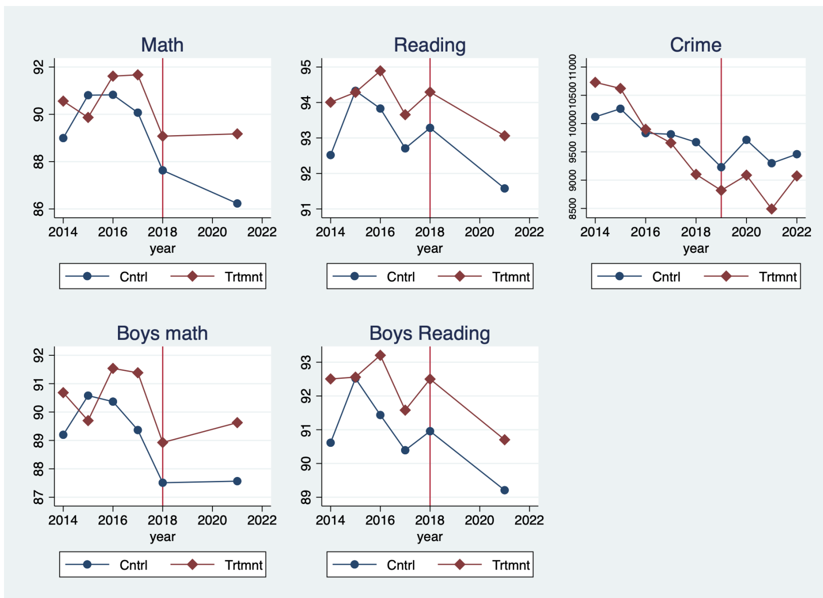


Figure 18: Raw mean for dependent variables when treatment group is defined by all crops following the 2018 policy change

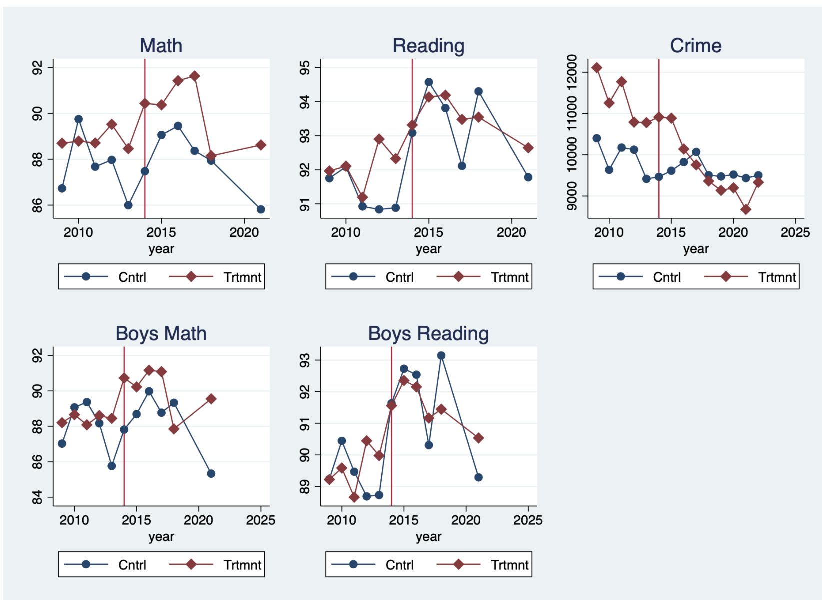


Figure 19: Raw mean for dependent variables when control group is defined as having less than 10% land used to grow bee-attractive crops for every year before 2014


Figure 20: Treatment by year effects when houses per population and apartments per population control variables are included


Figure 21: Treatment by year effects when gini control variable is included


Figure 22: Treatment by year effects when the treatment group is defined by proportionally growing large amounts of bee-attractive plants and a large proportion of residents supplying their own water


Figure 23: Treatment by year effects when analysis includes the 5 largely populated municipalities

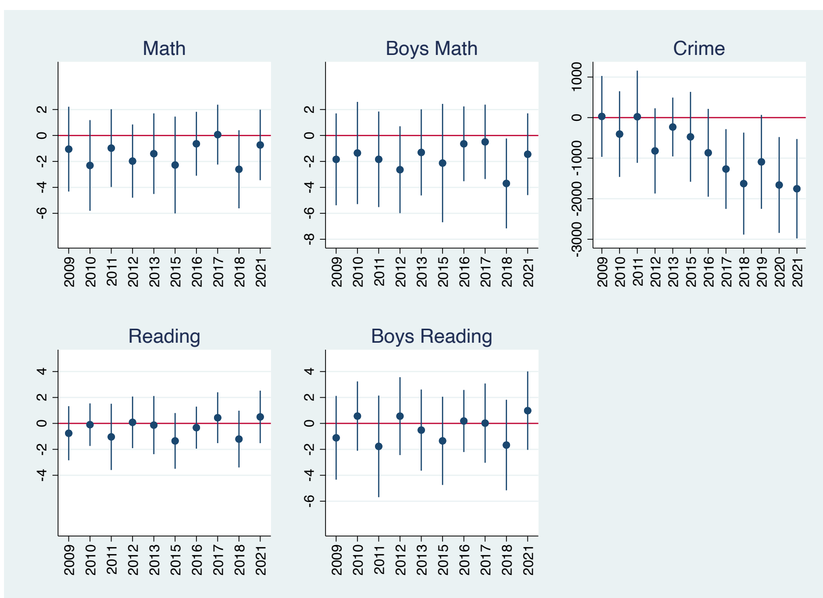


Figure 24: Treatment by year effects when analysis is unweighted

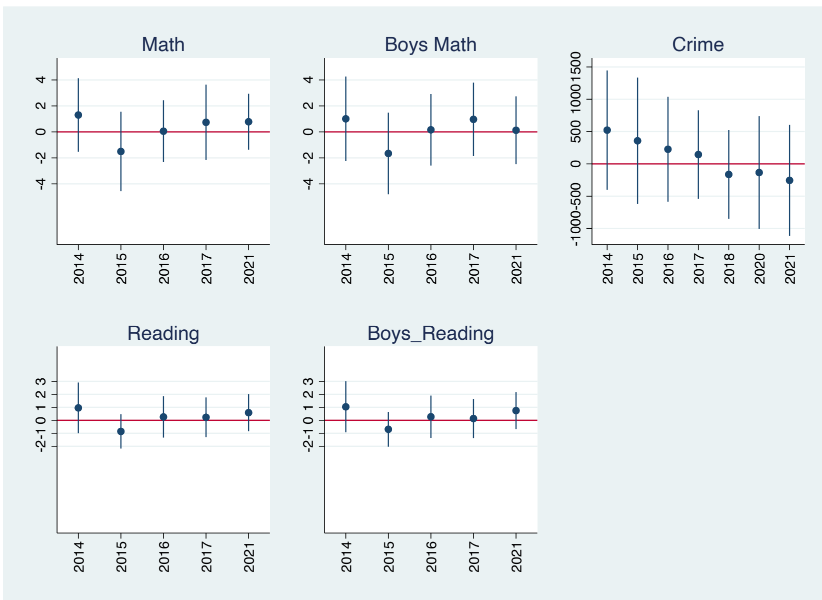


Figure 25: Treatment by year effects when treatment group is defined by all crops following the 2018 policy change


Figure 26: Treatment by year effects when control group are municipalities that have no more than 10% land used to grow bee-attractive crops for every year before 2014

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| VARIABLES | tot_math | boys_math | tot_math | boys_math | tot_math | boys_math |
| Treatment x Year 2009 | -0.817 | -0.702 | -1.691 | -2.200 | -1.051 | -1.838 |
| | (1.626) | (2.299) | (1.116) | (1.551) | (1.613) | (1.747) |
| Treatment x Year 2010 | -2.130 | 0.200 | -0.883 | -1.554 | -2.309 | -1.349 |
| | (1.488) | (1.926) | (1.077) | (1.314) | (1.725) | (1.945) |
| Treatment x Year 2011 | -3.493** | -4.109** | -0.263 | -0.991 | -0.973 | -1.836 |
| | (1.462) | (1.913) | (1.030) | (1.240) | (1.480) | (1.818) |
| Treatment x Year 2012 | -2.429 | -2.271 | -0.770 | -1.395 | -1.974 | -2.636 |
| | (1.946) | (2.148) | (1.078) | (1.274) | (1.393) | (1.653) |
| Treatment x Year 2013 | -0.175 | -1.401 | 0.800 | 0.0103 | -1.403 | -1.303 |
| | (2.090) | (2.392) | (1.035) | (1.331) | (1.534) | (1.638) |
| Treatment x Year 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (0) | (0) | (0) | (0) | (0) | (0) |
| Treatment x Year 2015 | -1.443 | -1.587 | -0.790 | -0.964 | -2.275 | -2.125 |
| | (2.194) | (2.505) | (1.105) | (1.479) | (1.842) | (2.252) |
| Treatment x Year 2016 | -1.548 | -1.780 | -0.789 | -1.570 | -0.637 | -0.641 |
| | (1.242) | (1.279) | (0.870) | (1.095) | (1.216) | (1.423) |
| Treatment x Year 2017 | 0.184 | 0.292 | -0.265 | -0.705 | 0.0673 | -0.489 |
| | (1.278) | (1.713) | (0.924) | (1.235) | (1.139) | (1.415) |
| Treatment x Year 2018 | -3.573** | -4.761** | -1.690 | -2.791** | -2.604* | -3.696** |
| | (1.562) | (2.099) | (1.075) | (1.258) | (1.486) | (1.710) |
| Treatment x Year 2021 | -2.830* | -3.280* | -0.602 | -0.950 | -0.729 | -1.444 |
| | (1.441) | (1.845) | (0.961) | (1.232) | (1.341) | (1.555) |
| income | 3.38e-05 | -1.63e-05 | 2.93e-05 | 1.40e-05 | 6.12e-05 | 2.69e-05 |
| | (6.93e-05) | (8.82e-05) | (4.31e-05) | (6.92e-05) | (7.69e-05) | (8.53e-05) |
| adults_in_stem | -0.803 | -0.951 | -0.289 | -0.182 | -0.541 | -1.061 |
| | (0.528) | (0.796) | (0.302) | (0.605) | (0.640) | (0.731) |
| density | 0.0625 | 0.0857 | 0.0302 | 0.0264 | 0.0335 | 0.0783 |
| | (0.0429) | (0.0509) | (0.0250) | (0.0330) | (0.0540) | (0.0640) |
| adults_more_than_hs | 1.254* | 1.289* | 0.440 | 0.531 | 1.586* | 1.455* |
| | (0.644) | (0.739) | (0.594) | (0.825) | (0.852) | (0.785) |
| has_10pct_priv_school | 0.691 | 0.442 | 0.644* | 0.756* | 0.444 | 0.256 |
| | (0.522) | (0.509) | (0.344) | (0.429) | (0.553) | (0.529) |
| student_teacher_ratio | -0.224 | -0.411 | -0.0791 | -0.118 | -0.445 | -0.636* |
| | (0.281) | (0.287) | (0.260) | (0.322) | (0.336) | (0.368) |
| Constant | 52.71*** | 64.18*** | 69.32*** | 72.13*** | 47.93** | 58.30*** |
| | (16.64) | (19.63) | (16.80) | (21.58) | (22.28) | (18.47) |
| Observations | 418 | 395 | 473 | 439 | 418 | 417 |
| R-squared | 0.232 | 0.201 | 0.264 | 0.210 | 0.195 | 0.161 |
| Number of Municipalities | 38 | 36 | 43 | 40 | 38 | 38 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Regression results for math proficiency following the alternate specifications. Columns 1 and 2 are when the treatment group is defined by proportionally growing large amounts of bee-attractive plants and a large proportion of residents supply their own water. Columns 3 and 4 are for when the 5 very populated municipalities are included. Columns 5 and 6 are for when the regression results are unweighted

| VARIABLES | (1) tot_reading | (2) boys_reading | (3) tot_reading | (4) boys_reading | (5) tot_reading | (6) boys_reading |
|---|---|---|---|---|---|---|
| Treatment x Year 2009 | 1.513 | 2.064 | -0.998 | -0.694 | -0.758 | -1.109 |
| | (1.113) | (1.710) | (0.943) | (1.324) | (1.029) | (1.594) |
| Treatment x Year 2010 | 0.679 | 2.691** | 0.344 | 0.450 | -0.0966 | 0.565 |
| | (0.836) | (1.137) | (0.720) | (0.964) | (0.809) | (1.319) |
| Treatment x Year 2011 | -0.912 | -2.457 | -0.320 | -0.599 | -1.039 | -1.770 |
| | (1.513) | (2.350) | (0.794) | (1.291) | (1.260) | (1.934) |
| Treatment x Year 2012 | 0.960 | 1.884 | 0.222 | 0.240 | 0.0826 | 0.561 |
| | (1.212) | (1.530) | (0.680) | (1.070) | (0.982) | (1.482) |
| Treatment x Year 2013 | 1.282 | 0.940 | 0.613 | 0.535 | -0.130 | -0.515 |
| | (1.826) | (3.190) | (0.776) | (1.284) | (1.106) | (1.544) |
| Treatment x Year 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | (0) | (0) | (0) | (0) | (0) | (0) |
| Treatment x Year 2015 | 0.00850 | -0.429 | -0.233 | 0.156 | -1.349 | -1.344 |
| | (1.325) | (1.690) | (0.651) | (1.166) | (1.061) | (1.678) |
| Treatment x Year 2016 | 0.558 | 0.828 | -0.221 | -0.272 | -0.326 | 0.186 |
| | (0.762) | (0.840) | (0.608) | (0.878) | (0.800) | (1.181) |
| Treatment x Year 2017 | 1.945** | 2.212* | 0.00541 | 0.130 | 0.440 | 0.0211 |
| | (0.801) | (1.168) | (0.671) | (1.041) | (0.967) | (1.508) |
| Treatment x Year 2018 | 0.827 | -0.427 | -0.762 | -0.880 | -1.208 | -1.668 |
| | (0.889) | (1.460) | (0.693) | (1.200) | (1.080) | (1.722) |
| Treatment x Year 2021 | 1.395 | 2.595 | 0.149 | 0.529 | 0.502 | 0.984 |
| | (1.398) | (2.116) | (0.625) | (1.165) | (0.999) | (1.492) |
| adults_in_stem | -0.746* | -1.216* | -0.0631 | -0.279 | -0.480 | -1.183** |
| | (0.430) | (0.636) | (0.179) | (0.403) | (0.452) | (0.573) |
| income | -2.64e-05 | -3.84e-05 | -1.81e-05 | -2.15e-05 | -1.09e-05 | -4.33e-06 |
| | (5.71e-05) | (6.19e-05) | (3.62e-05) | (4.76e-05) | (5.46e-05) | (6.23e-05) |
| adults_more_than_hs | 1.077** | 1.116* | 0.405 | 0.586 | 1.079** | 0.995 |
| | (0.523) | (0.646) | (0.437) | (0.627) | (0.498) | (0.642) |
| has_10pct_priv_school | -0.0995 | -0.106 | 0.182 | 0.176 | -0.327 | -0.0773 |
| | (0.357) | (0.418) | (0.227) | (0.337) | (0.394) | (0.428) |
| student_teacher_ratio | -0.286 | -0.375 | -0.163 | -0.192 | -0.300* | -0.371 |
| | (0.201) | (0.268) | (0.224) | (0.270) | (0.172) | (0.231) |
| density | 0.0542 | 0.0565 | 0.0238* | 0.0135 | 0.0278 | 0.0266 |
| | (0.0379) | (0.0347) | (0.0136) | (0.0214) | (0.0418) | (0.0451) |
| Constant | 76.35*** | 78.73*** | 86.45*** | 85.00*** | 76.75*** | 77.71*** |
| | (11.14) | (15.86) | (12.66) | (15.79) | (10.77) | (13.86) |
| | | | | | | |
| Observations | 418 | 395 | 473 | 439 | 418 | 417 |
| R-squared | 0.232 | 0.224 | 0.271 | 0.234 | 0.198 | 0.168 |
| Number of Municipalities | 38 | 36 | 43 | 40 | 38 | 38 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Regression results for reading proficiency following the alternate specifications. Columns 1 and 2 are when the treatment group is defined by proportionally growing large amounts of bee-attractive plants and a large proportion of residents supply their own water. Columns 3 and 4 are for when the 5 very populated municipalities are included. Columns 5 and 6 are for when the regression results are unweighted

| VARIABLES | (1)<br>total_crime | (2)<br>total_crime | (3)<br>total_crime |
|---|---|---|---|
| Treatment x Year 2009 | -317.4 | 118.0 | 29.45 |
| | (854.3) | (516.8) | (492.3) |
| Treatment x Year 2010 | -441.8 | -100.6 | -405.9 |
| | (1,074) | (559.7) | (521.5) |
| Treatment x Year 2011 | 208.7 | 158.1 | 21.73 |
| | (986.1) | (478.3) | (561.0) |
| Treatment x Year 2012 | -105.3 | -338.5 | -820.9 |
| | (911.8) | (462.6) | (518.6) |
| Treatment x Year 2013 | -353.2 | -50.82 | -231.8 |
| | (519.8) | (257.5) | (358.1) |
| Treatment x Year 2014 | 0 | 0 | 0 |
| | (0) | (0) | (0) |
| Treatment x Year 2015 | -101.9 | -401.0 | -473.7 |
| | (1,015) | (359.2) | (547.2) |
| Treatment x Year 2016 | -1,084 | -501.4 | -867.6 |
| | (898.9) | (430.5) | (534.6) |
| Treatment x Year 2017 | -574.0 | -353.4 | -1,268** |
| | (923.8) | (632.1) | (485.2) |
| Treatment x Year 2018 | -768.4 | -166.6 | -1,627** |
| | (1,190) | (659.3) | (620.6) |
| Treatment x Year 2019 | -486.5 | -119.4 | -1,091* |
| | (880.3) | (629.4) | (571.7) |
| Treatment x Year 2020 | -1,709* | -671.3 | -1,662*** |
| | (969.5) | (696.4) | (583.4) |
| Treatment x Year 2021 | -1,716 | -289.7 | -1,754*** |
| | (1,041) | (916.4) | (604.9) |
| adults_more_than_hs | -1,301*** | -127.9 | -856.6*** |
| | (328.8) | (380.6) | (299.5) |
| income | 0.0407* | 0.0342* | 0.00669 |
| | (0.0240) | (0.0186) | (0.0287) |
| adults_in_stem | 146.0 | 115.6 | 82.52 |
| | (301.7) | (107.4) | (263.1) |
| density | -62.88*** | -48.37*** | -14.47 |
| | (21.23) | (12.62) | (24.39) |
| has_several_police | 300.8 | 189.8 | 470.0 |
| | (328.0) | (300.4) | (304.6) |
| Constant | 33,646*** | 13,389 | 26,204*** |
| | (8,010) | (9,651) | (5,926) |
| | | | |
| Observations | 494 | 559 | 494 |
| R-squared | 0.428 | 0.510 | 0.380 |
| Number of Municipalities | 38 | 43 | 38 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Regression results for crime rates following the alternate specifications. Column 1 is when the treatment group is defined by proportionally growing large amounts of bee-attractive plants and a large proportion of residents supply their own water. Column 2 is for when the 5 very populated municipalities are included. Column 3 is for when the regression results are unweighted

| VARIABLES | (1)<br>tot_math | (2)<br>tot_reading | (3)<br>boys_math | (4)<br>tot_reading | (1)<br>total_crime |
|---|---|---|---|---|---|
| Treatment x Year 2014 | 1.301 | 0.953 | 1.007 | 1.035 | 522.5 |
| | (1.397) | (0.964) | (1.604) | (0.968) | (455.6) |
| Treatment x Year 2015 | -1.507 | -0.856 | -1.660 | -0.693 | 357.7 |
| | (1.510) | (0.653) | (1.549) | (0.661) | (482.7) |
| Treatment x Year 2016 | 0.0545 | 0.259 | 0.161 | 0.271 | 226.6 |
| | (1.175) | (0.786) | (1.355) | (0.802) | (400.3) |
| Treatment x Year 2017 | 0.736 | 0.230 | 0.965 | 0.136 | 144.3 |
| | (1.433) | (0.753) | (1.395) | (0.742) | (338.1) |
| Treatment x Year 2018 | 0 | 0 | 0 | 0 | -163.3 |
| | (0) | (0) | (0) | (0) | (338.3) |
| Treatment x Year 2019 | | | | | 0 |
| | | | | | (0) |
| Treatment x Year 2020 | | | | | -134.0 |
| | | | | | (430.3) |
| Treatment x Year 2021 | 0.783 | 0.586 | 0.124 | 0.745 | -255.2 |
| | (1.062) | (0.707) | (1.287) | (0.701) | (423.5) |
| adults_more_than_hs | 2.085* | 0.608 | 2.645** | 0.651 | -701.9 |
| | (1.131) | (0.584) | (1.263) | (0.613) | (488.9) |
| income | 2.13e-06 | -8.97e-05 | -3.95e-05 | -0.000111* | 0.0433 |
| | (0.000103) | (5.69e-05) | (0.000114) | (5.71e-05) | (0.0369) |
| adults_in_stem | -0.625 | -0.0765 | 0.0817 | 0.0118 | 187.9 |
| | (1.291) | (0.904) | (1.244) | (0.910) | (511.2) |
| density | 0.151** | 0.0434 | 0.138* | 0.0544 | -67.27* |
| | (0.0638) | (0.0471) | (0.0728) | (0.0476) | (33.80) |
| has_10pct_priv_school | 0.236 | -0.629 | -0.262 | -0.630 | |
| | (0.603) | (0.463) | (0.570) | (0.492) | |
| student_teacher_ratio | -0.854* | -0.295 | -1.236** | -0.324 | |
| | (0.423) | (0.292) | (0.528) | (0.308) | |
| has_several_police | | | | | 281.0 |
| | | | | | (280.6) |
| Constant | 35.09 | 103.9*** | 38.13 | 107.6*** | 19,264 |
| | (23.20) | (15.21) | (30.23) | (15.16) | (14,718) |
| | | | | | |
| Observations | 228 | 228 | 216 | 216 | 304 |
| Number of Municipalities | 38 | 38 | 36 | 36 | 38 |
| R-squared | 0.307 | 0.224 | 0.208 | 0.234 | 0.344 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Regression results when following the 2018 policy change. Columns 1 and 3 are for when total math proficiency and boys proficiency respectively are the dependent variables. Columns 2 and 4 are for when total reading proficiency and boys reading proficiency respectively are the dependent variables. Column 5 is for when crime rates is the dependent variable

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| VARIABLES | tot_math | tot_reading | boys_math | boys_reading | total_crime |
| Treatment x Year 2009 | 0.763 | 0.903 | 0.0635 | 0.916 | -365.0 |
| | (2.111) | (1.494) | (2.207) | (2.223) | (724.0) |
| Treatment x Year 2010 | -2.549* | 0.736 | -1.659 | 0.157 | -399.9 |
| | (1.385) | (0.712) | (2.266) | (1.288) | (727.6) |
| Treatment x Year 2011 | -1.583 | 0.518 | -2.913 | 0.133 | -247.4 |
| | (1.941) | (1.193) | (1.907) | (1.779) | (832.9) |
| Treatment x Year 2012 | -0.763 | 2.155*** | -1.562 | 2.378*** | -967.9 |
| | (1.166) | (0.670) | (1.282) | (0.672) | (738.9) |
| Treatment x Year 2013 | 0.258 | 1.788 | 0.332 | 1.716 | -51.58 |
| | (2.032) | (1.584) | (2.309) | (1.711) | (436.7) |
| Treatment x Year 2014 | 0 | 0 | 0 | 0 | 0 |
| | (0) | (0) | (0) | (0) | (0) |
| Treatment x Year 2015 | -1.879 | -0.652 | -1.266 | -0.154 | -251.2 |
| | (1.393) | (1.095) | (1.633) | (1.808) | (377.5) |
| Treatment x Year 2016 | -1.243 | -0.0785 | -1.823* | -0.252 | -1,168* |
| | (1.045) | (1.079) | (1.007) | (1.508) | (575.1) |
| Treatment x Year 2017 | -0.0186 | 0.985 | -1.177 | 0.749 | -1,618*** |
| | (0.887) | (1.052) | (1.562) | (1.608) | (347.1) |
| Treatment x Year 2018 | -3.868 | -1.590 | -5.211* | -2.087 | -1,421** |
| | (2.520) | (1.147) | (2.694) | (1.656) | (656.9) |
| Treatment x Year 2019 | | | | | -1,544* |
| | | | | | (797.5) |
| Treatment x Year 2020 | | | | | -1,486 |
| | | | | | (961.8) |
| Treatment x Year 2021 | -0.854 | 0.364 | 0.404 | 1.140 | -1,884** |
| | (1.373) | (1.327) | (1.711) | (1.806) | (784.0) |
| adults_more_than_hs | 0.967 | 0.646 | 1.327 | 0.628 | -1,085** |
| | (0.846) | (0.684) | (0.987) | (0.886) | (392.4) |
| income | -2.67e-05 | -4.64e-05 | -9.30e-05 | -6.60e-05 | 0.0387 |
| | (5.57e-05) | (6.12e-05) | (7.48e-05) | (6.65e-05) | (0.0315) |
| adults_in_stem | -1.303** | -1.180** | -1.803* | -1.717** | 48.13 |
| | (0.626) | (0.452) | (0.954) | (0.753) | (313.9) |
| density | 0.0834** | 0.0491 | 0.123** | 0.0480 | -33.02 |
| | (0.0391) | (0.0419) | (0.0452) | (0.0413) | (26.27) |
| has_several_police | | | | | 210.9 |
| | | | | | (387.6) |
| has_10pct_priv_school | 0.750* | 0.106 | 0.461 | -0.213 | |
| | (0.384) | (0.321) | (0.459) | (0.425) | |
| student_teacher_ratio | -4.29e-05 | 0.166 | 0.00973 | 0.0791 | |
| | (0.363) | (0.190) | (0.348) | (0.358) | |
| Constant | 67.30*** | 84.86*** | 71.54** | 90.91*** | 28,139*** |
| | (19.75) | (14.11) | (26.42) | (21.65) | (8,271) |
| | | | | | |
| Observations | 286 | 286 | 264 | 264 | 338 |
| R-squared | 0.262 | 0.283 | 0.272 | 0.247 | 0.508 |
| Number of Municipalities | 26 | 26 | 24 | 24 | 26 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: Regression results when the control group is defined as municipalities that have less than 10% of land used to grow bee-attractive crops for every year before 2014. Columns 1 and 3 are for when total math proficiency and boys proficiency respectively are the dependent variables. Columns 2 and 4 are for when total reading proficiency and boys reading proficiency respectively are the dependent variables. Column 5 is for when crime rates is the dependent variable