Nitrogen Regulations and Housing Development in the Netherlands: A Quantitative Analysis

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Abstract

As the Netherlands struggles with a housing crisis, nitrogen regulations, aimed at protecting Natura 2000 sites, have been accused of impeding housing development. However, existing studies on the topic have found contrasting results. Therefore, this study aims to provide an overarching, longitudinal analysis to clarify the true impact of nitrogen regulations on housing development in the Netherlands from 2015 to 2022. Linear mixed regression models were used to investigate the effect of municipalities' average distance to N2000 sites and coverage of 2 buffer zones around these sites on building permits and newly constructed housing.

The results indicate significant decreases in both building permits and newly constructed housing within 1250 meters of the Natura 2000 sites, with these decreases being particularly pronounced following the revocation of Program Approach Nitrogen (PAS). Regarding coverage, significant decreases in newly constructed housing were observed from 2020 to 2022 in the highest coverage categories (both 1250- and 2500-meter buffer zones), while building permits did not show a significant decrease. The construction exemption introduced in late 2021 permitted some construction to occur closer to these sites. A mitigating effect of change in agricultural nitrogen emissions on housing development was not found.

In conclusion, nitrogen regulations have significantly altered the spatial distribution of housing development, however, the affected area is at a closer distance to the N2000 sites than was concluded in previous literature (i.e. EIB, 2023; Rouwendal, 2023). Overall, it seems that the nitrogen regulations have not been a major contributor to the housing crisis in the Netherlands, as their impact has primarily been on the spatial distribution of housing development rather than the total quantity.

Keywords: Nitrogen regulations, Natura 2000, Environmental regulations, Housing development

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1. Introduction

While the Netherlands is facing a housing crisis, marked by a shortage of approximately 390.000 homes, nitrogen regulations have been accused of being a contributing factor to this shortage in housing supply (BZK, 2023). The regulations imposed on the construction sector aim to decrease nitrogen emission in construction projects to protect Natura 2000 nature reserves, as these reserves were experiencing biodiversity loss due to increased nitrogen depositions, leading to a decline in their health and resilience (Staatsbosbeheer, n.d.).

While several studies have investigated the effects of nitrogen regulations on housing development, findings have proven mixed results. The Economic Institute for Construction (EIB) predicted a decline in construction projects in both their 2019 and 2023 studies. Similarly, ABN AMRO (2020) observed a decrease in housing construction within 5 km of Natura 2000 sites and a slight increase between 5 and 10 km from Natura 2000 sites between 2019 and 2020. However, a longitudinal study by Rouwendal (2023) found no significant decrease in granted building permits after the nitrogen regulations became more stringent in 2019. He did find a slight change in the spatial distribution of housing development, with an increase in building permits in municipalities that were 0-40% covered by Natura 2000 sites, arguing that housing development shifted slightly further from the Natura 2000 sites.

Given the conflicting findings regarding the impact of nitrogen regulations on housing development, it is evident that a comprehensive study is required. Understanding the true impact of nitrogen regulations on housing development is crucial for stakeholders in the housing development sector and future decision-making regarding nitrogen regulations. Therefore, an overarching, longitudinal analysis is required to grasp the full extent of the impact of nitrogen regulations on housing development in the Netherlands.

Internationally, other studies on the effects of environmental regulations on housing development have found that, generally, environmental regulations cause a decrease in housing construction in the regulated areas compared to neighbouring unregulated areas (Sims & Schuetz, 2009; Zabel & Paterson, 2006). However, these studies focused strongly on the United States, and little is known about the effects of environmental regulations in the Dutch or European housing market and regulatory environment. Therefore, this study aims to not only explore the role of nitrogen regulations in the shortage of housing supply in the Netherlands, but also to contribute to the understanding of the effects of environmental regulations on housing development in European, particularly Dutch, context. The following research question has been answered in this paper:

To what extent have nitrogen regulations affected the development of houses in the Netherlands from 2015 to 2022?

It is hypothesized that nitrogen regulations have affected the distribution of housing development throughout the Netherlands. Thus, it is expected to witness a decrease in housing development, observable in both building permits and new housing units near Natura 2000 sites where nitrogen regulations are most stringent, and an increase farther from the sites.

This paper is structured as follows. Section 2 starts with an outline of the context of nitrogen, nitrogen regulations and the protected Natura 2000 sites. Secondly, through analysis of studies on the effects of nitrogen regulation, studies on regulations that have similar effects have been sought and analysed to be able to compare and assist in forming hypotheses and expectations on the case of nitrogen regulations. Section 3 provides an overview of the method of data collection and analysis that consists of statistical analysis using a linear mixed effects regression model. Section 4 presents the results of the analysis. Section 5 states the conclusions of the paper. Lastly, section 6 discusses the results by comparing them with existing literature and aims to explain the results. Moreover, it considers the implications of nitrogen regulations and housing development.

2. Theoretical Framework

2.1. Background

2.1.1. Nitrogen and nitrogen deposition

Nitrogen is an element most commonly found in the atmosphere, which consists of almost 80% of nitrogen. However, in most terrestrial ecosystems, nitrogen is naturally not abundantly present, and since it does have a crucial role in the development of organisms, it has a controlling role in the composition, diversity, dynamics and functioning of these ecosystems, where species are adapted to surviving in low nitrogen conditions, which is why alteration of nitrogen values in an ecosystem could seriously affect the functioning of this ecosystem (Vitousek et al., 1997). The main effects include eutrophication, meaning that nitrogen accumulates in the soil which can cause rare and specialised species to be outcompeted by more general species, leading to a reduction in the biodiversity of the ecosystem. Another common effect is the process of acidification of the soil, which causes toxic conditions in the soil. Additionally, high nitrogen levels lower the resiliency of plant species to events such as disease or heat (Bobbink, 2021).

In the Netherlands, there are five main economic sectors responsible for nitrogen depositions: (1) the agricultural sector, where nitrogen is being emitted by animals (cattle, pigs, chickens, and other animals) and through the use, storage, and processing of manure and fertiliser, (2) the mobility sector, consisting of the shipping industry, fishing industry, mobile equipment, road traffic, aviation, and rail, (3) industry and energy, and lastly, and also the focus of this paper, nitrogen emission from (4) households, services, and construction (RIVM, 2023). The 2 types of nitrogen that are emitted and can affect the functioning of ecosystems are ammonia (NH_3) and nitrogen oxides (NO and NO_2) (RIVM, 2023). The biggest contributor to ammonia emissions in the Netherlands has been the agricultural sector. As for the emission of nitrogen oxides, the greatest contributor to the emissions is the mobility sector (RIVM, 2023). Table 1 lists the emissions per sector in 2021.

Table 1: shows the emission per type and per sector for the year 2021. Data source: Rijksinstituut voor Volksgezondheid en Milieu (RIVM). (2023). Monitor stikstofdepositie in Natura 2000-gebieden 2023: Monitoring van de Wet stikstofreductie en natuurverbetering. RIVM-rapport 2023-0239

Sector	Ammonia (kton)	Nitrogen oxides (kton)
Industry	2,8	29,1
Energy	0,0	13,2
Mobility	3,3	217,2
Households	5,8	7,3
Services and construction	5,2	4,6
Agriculture	104,8	37,0
Total	**122**	**308**

2.1.2. Natura 2000

Natura 2000 sites are part of the Natura 2000 (N2000) network, which has been established by the European Union (EU) to protect biodiversity in its member states. It is an ecological network of protected areas, aimed at ensuring the preservation, maintenance and, if necessary, restoration of native species abundance and habitats in the EU (EEA, n.d.). The N2000 sites have been allocated based on the Birds and Habitat Directive. The Birds Directive was implemented in 1979 and mandated member states of the EU to ensure the maintenance or restoration of the population of European native bird species and provide a diverse and healthy habitat for these species. The Habitat Directive followed the Birds Directive in 1992 and aims at more generally maintaining or restoring biodiversity in the EU (LNV, 2023).

In the Netherlands, there are currently 162 N2000 sites (figure 1) (LNV, n.d.). Of these sites, 131 have been classified as nitrogen-sensitive/vulnerable sites, meaning that the amount of nitrogen deposition that the site can handle while remaining healthy is naturally low compared to average deposition values in the Netherlands (RIVM, 2023).

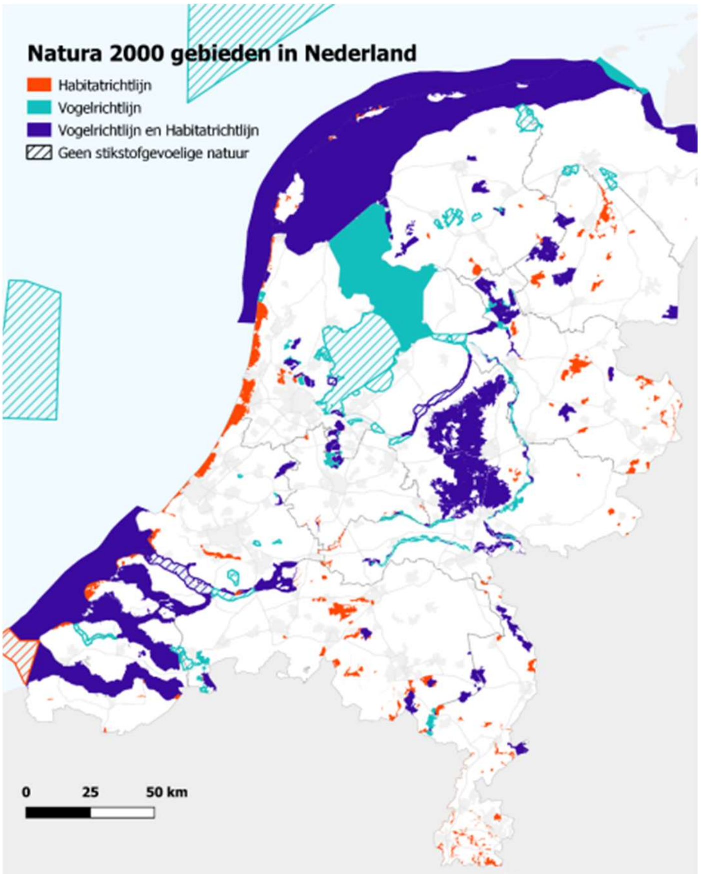


Figure 1: shows the Natura 2000 sites in the Netherlands. Source: Rijksinstituut voor Volksgezondheid en Milieu (RIVM). (2023). Monitor stikstofdepositie in Natura 2000-gebieden 2023: Monitoring van de Wet stikstofreductie en natuurverbetering. RIVM-rapport 2023-0239

2.1.3. Nitrogen Regulations

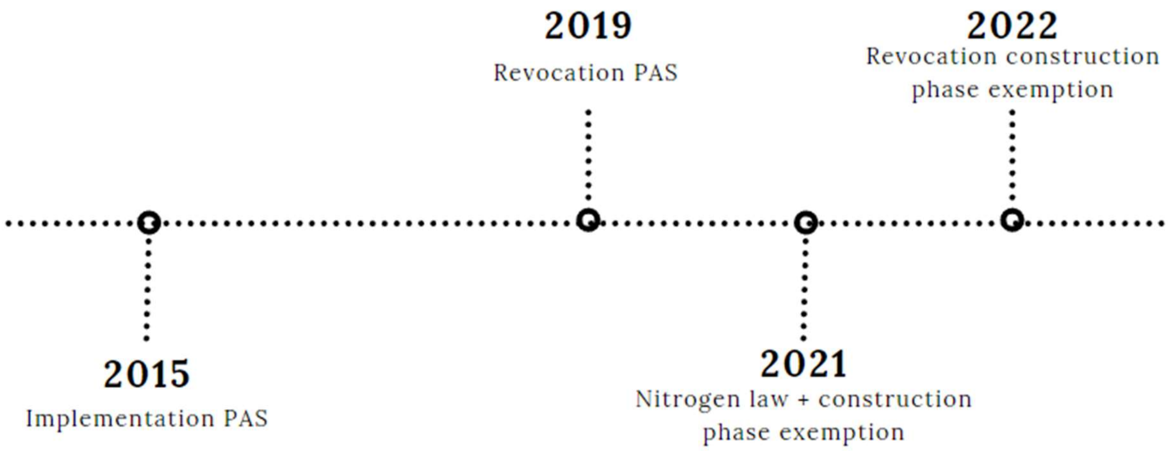


Figure 2: timeline of important events in nitrogen regulations history

In the history of the nitrogen policies, there are four moments where the regulations were changed, as outlined in figure 2. Firstly, in 2015, Program Approach Nitrogen (*Programma Aanpak Stikstof*, PAS) was implemented to protect the N2000 sites. The goal of PAS was to decrease nitrogen levels to strengthen the N2000 sites, while still permitting economic development. During the time PAS was implemented, measures aimed at improving N2000 sites and reducing nitrogen levels allowed certain nitrogen-emitting activities, such as construction or expansions of cattle sheds, near the sites to continue (De Vries, 2020; RIVM, 2019). Thus, projects were permitted to emit nitrogen with the assurance that other activities would offset these emissions. However, these reductions in emissions were not guaranteed, leading to the Council of State deciding in 2019 that PAS was an unreliable foundation for granting permits for projects that emitted nitrogen and revoking the program (RIVM, 2022).

Therefore, from 2019 onward, a permit was only granted if the project did not deposit any nitrogen to an area within a N2000 site that exceeded the determined critical deposition value, which is a value depicting the maximum amount of nitrogen the area can handle without declining in health (De Vries, 2020; RIVM, 2022). As the calculations did not include assumed future decreases in nitrogen depositions anymore, this regulation was much stricter than during PAS. This is seen as the start of the Dutch nitrogen crisis as building permits and pending zoning plans had to be reevaluated and delays in projects started (RIVM, 2022).

Regarding construction, the nitrogen emission needed to be calculated for two phases: (1) the construction phase and (2) the usage phase, which is the period of time after construction is finished and the completed structure is used. If the pre-assessment concluded that the project would cause a deposition of nitrogen in a vulnerable N2000 site, an environmental impact assessment (*"Passende beoordeling")* would be required to determine whether the project would cause damage to the N2000 site (BIJ12, n.d.). While the specific depositions that were allowed during both phases differed during and after PAS, this procedure was the same for both periods of time (De Vries, 2020). However, in 2021 the new nitrogen law changed this procedure: the new law included a "construction exemption" (*bouwvrijstelling*), which allowed construction projects to only consider the nitrogen deposition in the usage phase, excluding the construction phase from the calculation. The intention behind this exclusion was to make it easier to obtain a building permit and, consequently, stimulate construction. However, in 2022 this exemption was revoked, and the construction sector was once again required to calculate the deposition for both the construction and the usage phase of the project (Raad Van State, 2022).

In addition to nitrogen regulations targeting the construction sector, the Dutch government has implemented policies aimed at reducing emissions from the agricultural sector, which is the largest contributor to nitrogen depositions in the Netherlands (RIVM, 2023). Although the focus of this paper is not on agricultural regulations, a brief overview is provided to contextualise their potential moderating effect. Following the revocation of PAS in 2019, the Dutch government implemented an emergency law to address nitrogen emissions in an attempt to allow nitrogen-emitting projects to continue by reducing nitrogen emissions from other sources (PBL, 2024). One of these measures was targeted at the mobility sector and consisted of a reduction of the speed limit on highways (PBL, 2024). The regulations for the agricultural sector implemented in 2019 included increased subsidies to reduce the number of pigs, which resulted in a decrease in pigs in the Netherlands of over 500.000 from 2019 to 2022, and the intention to make requirements on the amount of protein in cow feed, which was later implemented through the program "Cow and Protein" (*Koe en Eiwit)* (CE Delft, 2023, LNV, 2019). Further regulations introduced in 2020 aimed at reducing nitrogen emissions included increased budgets for reducing livestock numbers and promoting technological innovations. In 2022, additional measures expanded these efforts, including further increases in subsidies for reducing the number of pigs, additional stable innovation requirements, stricter fertiliser use regulations and a plan to buy out the largest nitrogen emitters (PBL, 2024).

2.2. Literature Review

2.2.1. Nitrogen Regulations and Housing Development

Even though the focus of this paper is on nitrogen regulations that aim to protect N2000 sites, this literature review also incorporates studies on other types of environmental regulations or regulatory constraints of housing development that have similar effects as nitrogen regulations. In order to do that, it first needs to be determined what research has proven so far to be the effects of the nitrogen regulations.

Firstly, a study by the EIB (2019) on the effect of the change of nitrogen regulations in 2019 predicted that the regulations would cause delays varying from 3 months to 12 months depending on the distance of the project to the closest N2000 site, with the highest predicted delays closest to the N2000 sites. These delays were due to capacity problems at companies and municipalities responsible for performing and assessing the environmental impact assessments. A predicted 10.000 housing development projects, consisting of an estimated 400.000 homes, were expected to be affected by this regulatory change, resulting in an estimated production loss of about 2 billion euros. However, it is noteworthy that these delay estimates appear speculative, as the study refers to previous research conducted by the same institution and these studies were conducted before the 2019 change in nitrogen regulations and were limited to the provinces of Overijssel and Noord-Holland, focusing on assessing the feasibility of implementing provincial capacity plans. Therefore, accurately estimating delays caused by nitrogen regulations after 2019 based on these studies seems challenging.

The EIB conducted another study on the effects of the nitrogen regulations in 2023. Again, the EIB concluded that as a result of nitrogen regulations the development times of construction was increased. Ranging from several weeks up to six months depending on whether an environmental impact assessment was necessary for the project or if a pre-assessment sufficed, which depended on the project size and distance to the N2000 sites. The estimates were based on conversations with construction companies and surveys. Additionally, the EIB (2023) predicted an increase in development costs, resulting from the direct costs of the pre-assessment and impact assessments, as well as costs associated with the delays. The estimates of the costs are based on conversations with experts, who are not referenced or mentioned in the article. However, as several years has passed since the change in nitrogen regulations and thus more information was available on development times and costs associated with nitrogen regulations, it is assumable that the estimates are more accurate in this study as opposed to the EIB study from 2019. Therefore, it is concluded that the main effects of nitrogen regulations are an increase in development costs and time. The following section will elaborate on those effects.

Thus far, studies on the effects of nitrogen regulations on housing development have been limited but have shown less severe effects than were predicted by the EIB. Rouwendal (2023) for instance, did not find a significant difference in building permits between municipalities within 2500 meters of N2000 sites and municipalities farther than 2500 meters after the revocation of PAS. However, he did find a significant increase in building permits in municipalities that were covered by less than 40% by this zone within he argued nitrogen regulations were in place (<2500 meters from the N2000 sites), but no significant increase or decrease in municipalities with a higher coverage than 40%.

Conversely, ABN AMRO (2020) reported a 7.2% decrease in housing construction from the start of 2019 to the start of 2020 within 0-5 km of N2000 sites, an increase of 1.0% in housing construction at 5-10 km, and a decrease of 4.1% at distances greater than 10 km from N2000 sites. Therefore, whether nitrogen regulations affect housing development, to what degree, or at what exact distances, remains uncertain, with Rouwendal speculating negative effects should be within 2.5 km and ABN AMRO within 5 km. Both studies, however, suggest a potential shift in housing development towards areas with less stringent or no nitrogen regulations.

2.2.2. Development Time

Even though an increase in development time is often associated with an increase in development costs, this section explores additional effects of increased development times. Given that most of the cases discussed in the next section involve both increased development costs and time, the effects of delays will first be examined independently before delving into their combined impact on housing development.

In the context of environmental regulations, a common requirement for obtaining a permit is doing an environmental impact assessment, in which it is investigated whether the development of the project will have negative externalities on the surrounding natural environment. Environmental impact assessments cause expectable delays, which increase costs for the developers through increased holding costs as well as the direct cost of performing the assessment (Kiel, 2005). However, environmental regulations could also lead to unexpected delays, when, for instance, plan modifications are required to reduce potential negative externalities or when the developer is faced with lawsuits from neighbours and environmental activists, further increasing development times and costs as well as creating uncertainty (Kiel, 2005; Schill, 2005). Additionally, the administrative processes associated with obtaining a permit can cause delays, especially when developers have to deal with multiple governmental agencies (Schill, 2005).

It has been found that regulations that increase development times have a stronger effect on construction activity than regulations that increase development costs, even when the costs of the delays are smaller than the initial increase in development costs, when for instance through fees (Mayer & Sommerville, 2000). The key to why increased development times have such a strong effect, is the uncertainty for the developer created by the delays as opposed to more predictable increasements of development costs, which could discourage developers from developing in areas where regulations increase development times (Mayer & Sommerville, 2000). This is further emphasized by Schill (2005), who argues that uncertainty can be much more damaging to a project than any cost-increasing regulation. Unsurprisingly, it has been found that increased times to obtain a permit is significantly related to reduced housing development and increased housing prices (Glaeser & Gyourko, 2002; Schill, 2005).

2.2.3. Development Costs

To further investigate the potential effects of nitrogen regulations on the housing supply in the Netherlands, papers that have studied the effect of regulations that increase development costs on housing development have been analysed.

Firstly, according to Brueckner (2009), in a standard urban model, regulations that increase the cost of development result in developers being willing to pay less for the land, leading to a decrease in land value. As the regulations in his model solely affect residential function, non-residential development could be relatively more profitable developed, leading to a decrease in housing supply in the area affected by the regulation. However, for the case of nitrogen regulations, not only the development of houses is regulated, but also the development of any other function that can emit nitrogen in either the construction or the usage phase (EIB, 2019). Thus, development of an alternative function is not expected to be more desirable in this case. Nevertheless, this insight contributes to understanding how cost-increasing regulations influence housing supply and development. The following studies will elaborate further on this using practical examples.

Regarding the regulations imposed to protect ecosystems and vulnerable species (environmental regulations), the first regulation that is discussed are the wetland bylaws in Massachusetts, US. Wetland bylaws are reported to increase construction costs, decrease the share of developable land, cause delays and increase uncertainty due to increased complexity in the permitting process and commission reviews. Regarding construction costs, Sims and Schuetz (2009) state that this causes decreased returns of development for developers, reducing development on parcels affected by the wetland bylaws. Because of this available comparison between communities that have the stricter regulations versus the communities that do not, the case studied in Sims and Schuetz' paper is similar to the nitrogen case. First, when checking for an effect of the bylaws on housing development per jurisdiction, no significant effect was found on issued building permits, new housing units, or the amount of land used per new housing units, which they used as a measurement for density. However, second, they studied whether the bylaws caused shifts in location of development either to nearby jurisdictions without bylaws or to locations farther from the wetlands but within the same jurisdiction. For both analyses, they found significant relationships with new housing units. Meaning that the adoption of wetlands bylaws in a jurisdiction alters the spatial distribution of housing development, as seen by significantly increasing housing development in nearby jurisdictions and increasing the average distance of new housing units to wetlands in that jurisdiction.

A case similar to the nitrogen and N2000 site case, are the regulations imposed to protect a critical habitat (CH) in the US. The sites designated through this act are established to protect endangered plant and animal species. Within the areas designated as CHs, potential construction first requires a review of the plan and may even require modification, resulting in increased development costs and delays. Zabel and Paterson (2006) researched the effects of the designation of CHs in the state of California, due to a relatively large number of recent CHs in the state at that time, in combination with a high development pressure on the areas. To determine the effect on housing development, they used the number of housing permits granted in a municipality. When comparing municipalities that contained a CH with municipalities that did not, at first, the authors found no significant difference. However, when pairing the municipalities with a CH to the nearest municipality without, they did find a significant difference in issued building permits, similar to the results of Sims and Schuetz (2009). Additionally, using an econometric model, they found that the designation of a CH resulted in a 23.5% decrease in issued building permits on the short term and a 37.0% decrease on the long term. Interestingly, they found that the size of the area of the municipality that is covered by CHs barely affects the impact on issuance of building permits, concluding that the designation of a CH is an indication that all development in that municipality will be more expensive, and the municipal government becomes more risk averse and more cautious with issuing building permits.

Aside from the direct additional costs associated with development in CHs, i.e. plan modifications and delays, according to Kiel (2005), if the Endangered Species Act, under which the CHs are designated, decreases the amount of developable land, then the value of the remaining developable land should increase, which increases the cost of supplying housing. This argument is supported by a study by Quigley and Swoboda (2007) on the effect of CHs on housing development. They concluded that after a designation of a CH, there are relatively no major effects on the areas designated as CHs, in terms of rent and land rent, but mostly on the areas surrounding the CHs. This land had been available for development and still would be after the designation. However, within the general equilibrium framework used in the analysis, the reduction of developable land leads to a decrease in land value within the CH and an increase in land value outside these areas. Resulting in more land that can be profitably developed and higher densities in development in areas without the regulation. Note that this model approaches the CHs as an urban growth boundary and is not based on data from CH designations, rather, data is based on assumptions from averages in the US and not a specific region or city. So, they aim to understand what would happen after a designation of a CH near any city in the US, not what has happened. Quigley and Swoboda's findings are supported by the previously mentioned study by Brueckner (2009), who aside from measuring the effects of cost-increasing regulations, also studied the effects of urban growth boundaries. He concluded that the implementation of an urban growth boundary, and therefore the decrease in developable land, causes an increase in land values and house prices in the remaining developable land. These results are similar to the findings of Rouwendal (2023) and ABN AMRO (2020), who found increases in housing development in the areas that were not affected by the nitrogen regulations but close to areas that were.

In summary, increased development costs caused by a(n) (environmental) regulation generally results in a decrease in land value in the area affected by the regulation and an increase in land value in the surrounding unaffected areas, resulting in altered construction levels. Moreover, multiple studies found no significant effect on building permits or new construction on the affected area alone but do find a significant relative decrease in these variables when comparing to neighbouring areas without the regulation.

2.2.4. Elasticity of Housing Supply

The literature regarding environmental regulations is heavily focussed on the US, while there are differences in housing development mechanisms in the US compared to the Netherlands, which could determine how regulations affect changes in housing supply. Most notably is the difference in price-supply elasticity, for which the Netherlands and the US are on opposite ends of the spectrum (figure 3) (Cavalleri, Cournède, & Özsöğüt, 2019). The cause of the low elasticity of housing supply in the Netherlands has been contributed to the strict regulatory environment (Vermeulen & Rouwendal, 2007).

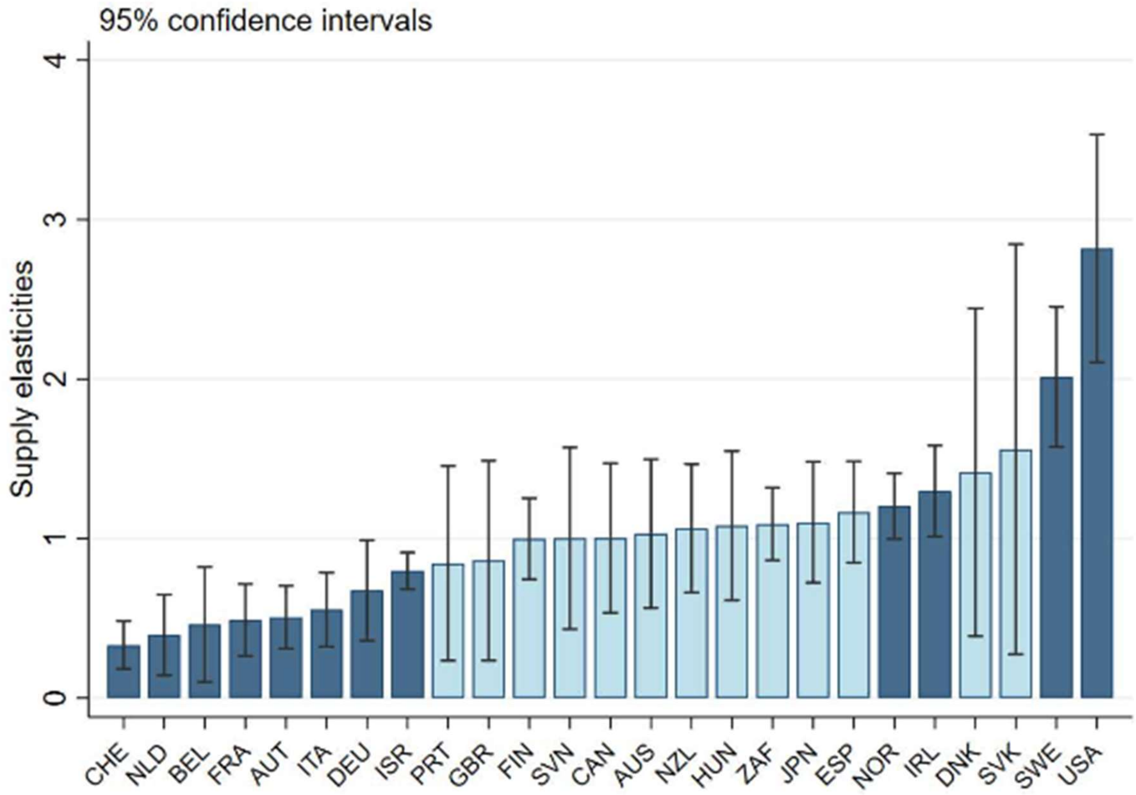


Figure 3: Supply elasticities for each country in the OECD in 2019. Source: Cavalleri, M. C., Cournède, B., & Özsöğüt, E. (2019). How responsive are housing markets in the OECD? National level estimates.

The elasticity of housing supply measures the degree to which changes in housing development react to changes in housing prices and costs (Gyourko & Molloy, 2015). As the Netherlands has a lower elasticity compared to the US, an increase in construction costs resulting from certain regulations may affect housing supply to a lesser extent in the Netherlands than in the US. Additionally, since construction activity is inherently less volatile in the Netherlands due to its lower elasticity, the impact of a single regulation on construction activity might be lower in the Netherlands compared to the US.

2.2.5. Hypotheses

Based on the literature review, the following hypotheses have been established: hypothesis 1 (H1) states that the nitrogen regulations have caused a decrease in housing development after the revocation of PAS, observable in both building permits and constructed new housing units, in municipalities that were subject to nitrogen regulations, so close to the N2000 sites, compared to municipalities that did not, so farther from these sites. The second hypothesis (H2) states that there is a group at middle range distance where housing development has increased due to shifts caused by nitrogen regulations, however, the exact distances are still unknown and need to be uncovered. The hypotheses for the effects after PAS are illustrated in figure 4. During PAS however, no effect of the nitrogen regulations on housing development is hypothesized (H3), as the regulations have been changed over time and the strictness of the regulations changed as a result (section 2.1.3.). This is supported by a claim from Ploegmakers, Rouwendal, and Van der Krabben (2022), stating that the likelihood of project delays after the establishment of zoning plans was minimal before 2019. Hypothesis 4 addresses the analyses on the potential spillover effects to neighbouring municipalities and in which it is hypothesized that if neighbouring municipalities are closer to the N2000 sites, thus more regulated (H1), an increase in housing development would be observed. Lastly, regarding the potential moderating effect of change in agricultural nitrogen emissions, hypothesis 5 states that a decrease in agricultural nitrogen emissions is significantly correlated with an increase in housing development, and vice versa.

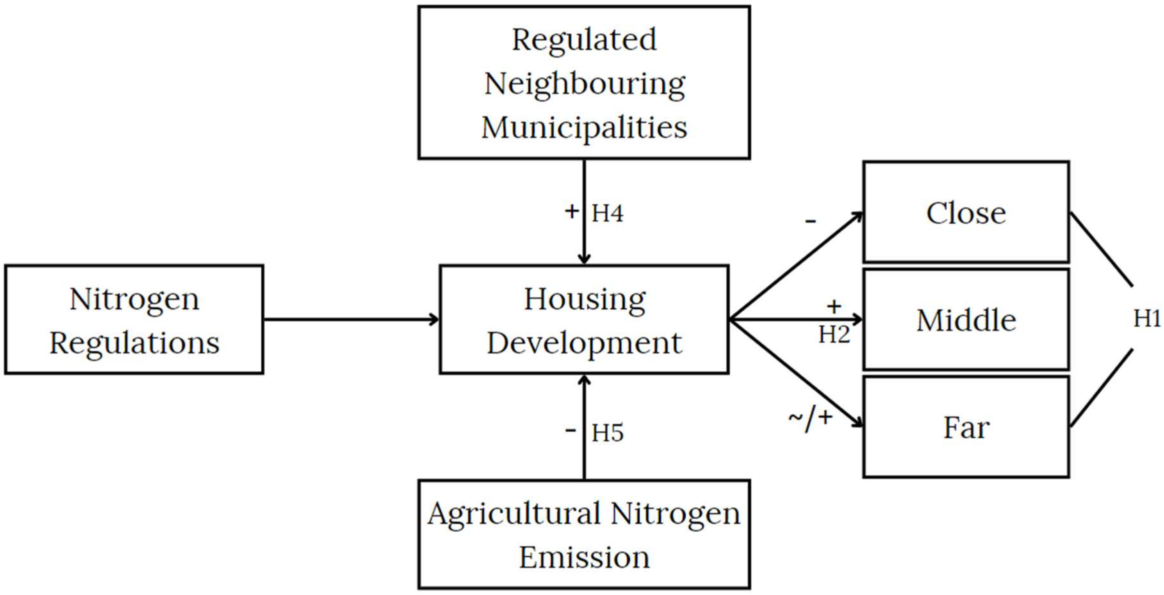


Figure 4: Visualisation of the hypotheses. + indicates a hypothesized increase, - a hypothesized decrease.

3. Methods

3.1. Data

3.1.1. Distance and Cover

Similar to other studies examining the effect of nitrogen regulation on housing development in the Netherlands, this study utilised the distance to, and coverage of, N2000 sites as an independent variable (ABN AMRO, 2020; Rouwendal, 2023). Since nitrogen deposition originating from construction projects to N2000 sites decreases with distance from the N2000 site, and the decision of issuance of building permits relies on potential increases in nitrogen deposition that would be caused by the construction projects, the proximity to these sites was expected to reflect the impact of the regulations on construction (EIB, 2023).

Aside from using the average distance to the closest N2000 site, this paper has analysed effects on municipalities with different N2000 site coverages. According to the EIB (2023), housing development is only affected within 2500 meters distance of the N2000 sites, so one of the coverage variables consists of the area of coverage of a buffer zone of 2500 meters in municipalities around the N2000 sites. However, while Rouwendal (2023) found a significant increase in building permits for municipalities with 0-40% coverage within the 2500 buffer zone, he found no significant effect on municipalities with a higher coverage than 40%. The analyses in this paper attempted to further explore this result by creating additional categories for the buffer zone coverage as well as creating a buffer zone for 1250 meters and analysing the effect of different coverages for that buffer zone, as the boundary for whether the area is affected by nitrogen regulations is highly dependent on the project size of the housing development (as nitrogen depositions for the ecological environmental assessment are calculated for the entire project and not per individual house). Thus, this boundary would be lower for smaller housing development projects (EIB, 2023). The addition of this smaller buffer zone would potentially reveal effects on housing development that the buffer zone of 2500 meters could not.

The program QGIS was used for calculating the distances and coverages. The municipality layer was collected from the CBS (n.d.-a.) and reflects the municipal boundaries in 2023. However, from 2015 to 2023, some municipalities merged with other municipalities, resulting in a reduction in total municipalities from 393 in 2015 to 342 in 2023 (CBS, n.d.-b). To maintain the consistent panel structure with the same units over the entire 9 years, the variables from the municipalities that merged through the years, were summed prior to the year of fusion. Thus, they were treated as if they had been one municipality throughout the entire observed time. Appendix I lists the municipal changes per year. The N2000 site layer was collected from the EEA (2022). As the analyses only focussed on the nitrogen sensitive N2000 sites, the non-sensitive N2000 sites had been deleted from the layer. Appendix II gives the complete list of nitrogen sensitive N2000 sites that were used in the analysis.

To be able to calculate the distance to the edge of the N2000 sites, a layer representing the vertices for the N2000 sites was created. As the outlines of the N2000 polygons are very detailed, vertices in this case provide a detailed outline of the sites. Based on the municipality layer, regular points were placed for every 100 meters, resulting in over 3.5 million points within municipal borders and for which the distance to the edge of the closest N2000 site was calculated. Figure 5 shows the resulting layer for calculated distances for the south of Zuid-Limburg.

However, as some points were positioned within a N2000 site, and thus the distance to the edge did not need to be calculated, rather the value was 0 for these points, the N2000 sites layer needed to be joined with the points layer to be able to form an equation where if the value was inside a N2000 site, the value for distance was 0, otherwise the value for the calculated distance remained. With this adjusted variable for distance, the points were then grouped by municipality and the descriptive statistics were determined.

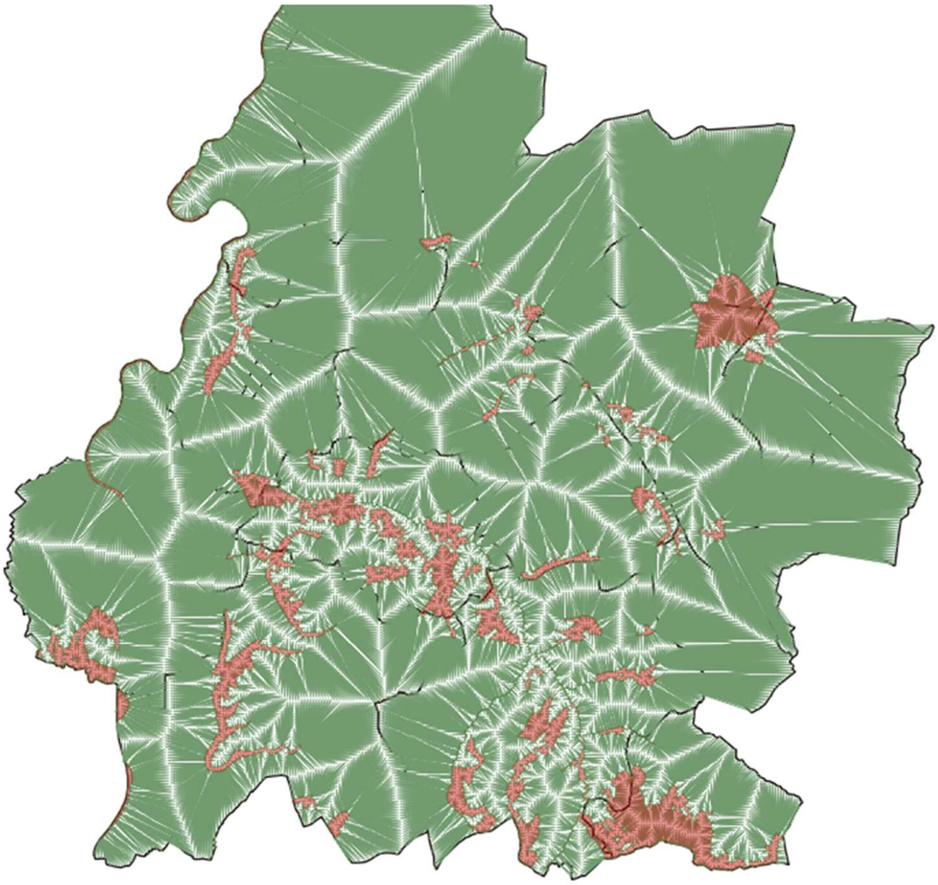


Figure 5: screenshot from the QGIS program, showing the lines from the regular points to the closest vertice of the N2000 sites for the Southern part of Zuid-Limburg.

The calculated average distances for each municipality were categorized into the categories: 0-1250, 1250-2500, 2500-5000, 5000-8000, and 8000+. These categories are more similar to the categories from the study from ABN AMRO (2020) than to Rouwendal's (2023) method of having 2 categories (0-2500, 2500+) based on the conclusion from the EIB (2023) that housing development is only affected within 2500 meters of N2000 sites. By adding additional categories, the analyses are not reliant on the conclusion from the EIB (2023) and could perhaps show a more nuanced and complex relationship between nitrogen regulations and housing development.

To obtain the data on coverage per municipality, buffer zones of 1250 and 2500 meters were created in QGIS (figure 6). After intersecting each buffer zone with the municipality layer, the intersection area can be calculated per municipality. The intersection areas for each municipality were categorized in the categories: 0%, 0-33%, 33-66%, 66-100% for the 1250-meter buffer zone and 0%, 0-25%, 25-50%, 50-75%, and 75-100% for the 2500-meter buffer zone. Note that the buffer zones also contain actual cover of the N2000 sites, so it is the cover from either 0 to 1250 meters from the N2000 site or 0 to 2500 meters.

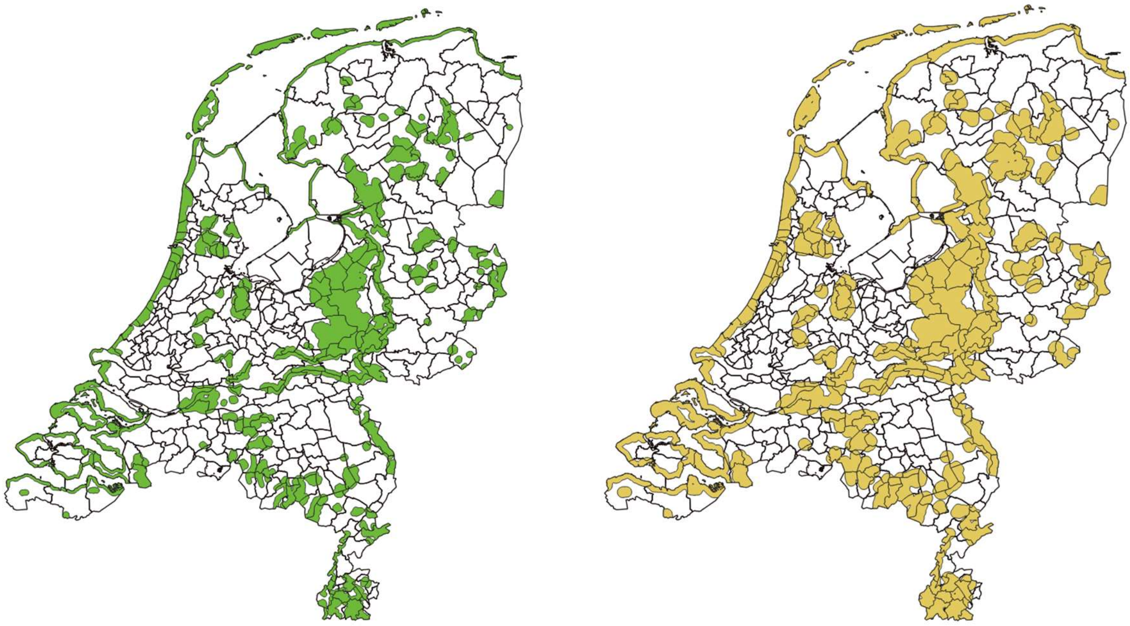


Figure 6: screenshot from the QGIS program, showing the buffer zones of 1250 meters (left) and 2500 meters (right) for the N2000 sites

Table 2: descriptive statistics for the categorical variables.

Variable	Categories	Count per category
Municipality	342	9
Year	9	342
Distance to N2000	0-1250 m	576
	1250-2500 m	630
	2500-5000 m	684
	5000-8000 m	603
	8000+ m	585
Percentage 1250 cover	0%	810
	0-25%	891
	25-50%	693
	50-100%	684
Percentage 2500 cover	0%	693
	0-33%	765
	33-66%	693
	66-100%	927

Lastly, to be able to analyse potential shifts in housing developments to adjacent municipalities, a variable containing the mean distance to the nearest N2000 sites or coverage of the two buffer zones of the adjacent municipalities was created by using the 'Join attributes by location' function in QGIS. As the municipality of Ameland does not have any adjacent municipalities, it was not included in the analyses.

3.1.2. Other Variables

To analyse the effect on housing development, the dependent variables in the analysis were building permits and new housing units. Building permits and new housing units, commonly used in similar studies to represent housing development (section 2.2.3.), were expected to accurately represent potential changes in housing development in response to the nitrogen regulations, and according to H1, were expected to be lower in municipalities closer to the N2000 sites.

The analyses included control variables to account for both observed and unobserved potential confounding factors to ensure that the results accurately reflected the effects of the nitrogen regulations. To control for unobserved heterogeneity and inherent differences in building permits or new housing units, the analyses incorporated random effects in the form of random intercepts for the municipalities. The observed time and municipality-varying confounding factors that were added to the analyses are housing stock, population size, mean standardised income, and urbanisation level. This follows the results from Ploegmakers et al. (2022) that population size significantly impacts the number of building permits issued and new housing construction per municipality, with mean income additionally having a significant effect on new housing construction.

Additionally, analyses were done to examine the effects of changes in agricultural nitrogen emissions and the potential relationship between distance or coverage and housing development. As throughout the years, several policies aimed at reducing nitrogen emissions originating from the largest nitrogen emitter in the Netherlands, the agricultural sector, have been implemented, as explained in section 2.1.3., additional analyses have been conducted that included a variable containing the change in total agricultural nitrogen emission per municipality. The variable is calculated by multiplying the nitrogen emission per hectare agricultural land by the number of hectares agricultural land in the municipality. Table 3 shows the sources and descriptive statistics for each variable.

Lastly, as it is hypothesized that the effects of the nitrogen regulations differed throughout the years (H3), with no expected significant effect on housing development from 2015 to 2018 (during PAS), but a significant effect from 2019 to 2022 (after PAS), time was added as a fixed effect, interacting with the distance or coverage categories. By including time as both an independent variable and an interaction term, the analyses allow for controlling for year specific trends that effect housing development in all distance or coverage categories, as well as its potential to modify the influence of distance or cover on the housing development, and thus reflect the effects of nitrogen policies.

Table 3: descriptive statistics and sources for the continuous variables.

Variable	Source	Count	Mean	SD	Median	Min. Value	Max. Value
Building permits	CBS Statline (n.d.-a)	2736	178.19	399.0	85	0	7494
New housing units	BAG (n.d.)	2716	191.5	401.67	100	0	7574
Housing stock	CBS Statline (n.d.-b)	2736	22904.56	36268.41	14311.5	527	474855
Population size	CBS Statline (n.d.-b)	2736	50587.9	73983.78	31852	919	918117
Income (€ x 1.000)	CBS Statline (n.d.-b)	2730	32.42	4.82	31.8	23.2	74.5

Change in nitrogen	CBS Statline (n.d.-b)	2394	-19603.79	111663.27	-3658.58	-1105762.41	869458.03

3.2. Analysis

After compiling the variables in one data set, a panel data analysis was used to investigate the effects of nitrogen regulations on building permits and new housing units over a period of 8 years (2015 to 2022). The analyses were conducted using a linear mixed-effects regression (lmer) model similar to the method used by Sims and Schuetz (2009) and performed using the program R and the package 'lmer'. To ensure robustness of the results and to be able to inspect whether the results change if the assumptions change, the analyses were performed using different model specifications. The assumptions of the lmer are: (1) residual normality, (2) homogeneity of the variance, and (3) linearity. To meet assumptions, the residual outliers were removed from each model, resulting in between 20 and 50 observations that were removed per analysis.

The first model serves as the base model from which the other models were extended. In the base model, the effect on the dependent variable is tested only against the independent variable, distance or coverage, with the addition of time as a fixed effect and random intercepts for the municipalities to control for inherent differences in building permits or new housing units between the municipalities. As for distances beyond 8 km from a N2000 site, effects on housing development from the nitrogen regulations can be concluded to be non-existent, even for the largest projects, based on existing literature (EIB, 2023). Therefore, the category that contains the municipalities with an average distance greater than 8 km had been set as the reference category and is not included in the equation, which is why the summation of the categories shows 4 categories, even though there are actually 5 categories. Equation 1 shows the base model. Note that the equations shown are an example using the dependent variable building permits and the independent categorical variable distance. However, the equation is the same for the other dependent and independent variables.

Equation 1:

$$BP_{it} = \beta_0 + \sum_{k=1}^{4} \beta_{1k} DistCategories_{ik} + \sum_{j=1}^{7} \beta_{2j} Year_{tj} + \sum_{n=1}^{28} \gamma_n \left(DistCategories_{ik} * Year_{tj}\right) + \gamma_i + \epsilon_{it}$$

Where BP is the dependent variable and contains the logarithm of the number of building permits for municipality i at time t. The categorical independent variable distance to the N2000 sites is represented by a series of dummy variables for each distance category except the reference category. Time is represented by a series of dummy variables for each year except the reference year, which is the first year, 2015. β represents the coefficients for these variables compared to the reference category. The interaction terms for each distance and year category is represented by the coefficient γ for each distance category *k* and year category *j* and allows for comparisons of the effect of distance on building permits across different years. ϵ is the error term for municipality i at time t.

Equation 2:

$$BP_{it} = \beta_0 + \sum_{k=1}^{4} \beta_{1k} DistCategories_{ik} + \sum_{j=1}^{7} \beta_{2j} Year_{tj} + \sum_{n=1}^{28} \gamma_n \left(DistCategories_{ik} * Year_{tj}\right) + \alpha X_{it} + \gamma_i + \epsilon_{it}$$

The second model, shown in equation 2, extends the base model by introducing time and municipality-varying control variables to the equation, represented by vector X. The other variables remain as defined in equation 1.

Equation 3:

$$BP_{it} = \beta_0 + \beta_1 Dist_i + \sum_{j=1}^{7} \beta_{2j} Year_{tj} + \sum_{n=1}^{7} \gamma_n \left(Dist_i * Year_{tj}\right) + \beta_4 DistN_i + \alpha X_{it} + \gamma_i + \epsilon_{it}$$

To be able to capture the influence of the neighbouring municipalities' regulation stringency on housing development in the municipalities, a model entailing the mean distance to the nearest N2000 site of the neighbouring municipalities, similar to Sims and Schuetz's (2009) methodology. This analysis aims to capture potential displacement or spillover effects to municipalities with less stringent nitrogen regulations. As the focus of this model is the overall effect of the distance or cover of the neighbouring municipalities instead of the distance or cover of the municipalities themselves, in this model, a continuous variable for distance or cover was used as opposed to a categorical variable, shown in equation 3 by the Dist variable for municipality i. DistN encompasses the average distance of the neighbouring municipalities to the N2000 sites. Additionally, this model incorporates fixed effects for time, Year variable, and other control variables, represented by vector X.

Equation 4:

$$BP_{it} = \beta_0 + \sum_{k=1}^{4} \beta_{1k} DistCategories_{ik} + \sum_{j=1}^{3} \beta_{2j} Year_{tj} + \sum_{n=1}^{12} \gamma_n \left(DistCategories_{ik} * Year_{tj}\right) + \beta_4 ChangeinNit_i + \sum_{p=1}^{4} \beta_{5p} (DistCategories_{ik} * ChangeinNit_i) + \alpha X_{it} + \gamma_i + \epsilon_{it}$$

The final model adds a variable containing the change in nitrogen emissions originating from the agricultural sector for municipality i at time t. Additionally, this model focuses on the period of time after PAS was abolished (2019-2022).

4. Results

4.1. Distance

Table 4: Distance to N2000 effect on log building permits and log new housing.

Variable		Building Permits (log)	New Housing (log)
Distance 0-1250		-0.22 (0.19)	0.13 (0.14)
Distance 1250-2500		-0.08 (0.19)	0.08 (0.14)
Distance 2500-5000		-0.07 (0.18)	0.23 (0.14) .
Distance 5000-8000		-0.13 (0.19)	0.23 (0.14) .
2016		0.04 (0.14)	0.28 (0.11) *
2017		0.35 (0.14) *	0.45 (0.11) ***
2018		0.4 (0.14) **	0.48 (0.11) ***
2019		0.32 (0.15) *	0.42 (0.12) ***
2020		0.32 (0.15) *	0.6 (0.12) ***
2021		0.55 (0.15) ***	0.63 (0.12) ***
2022		0.22 (0.16)	0.52 (0.13) ***
2016	**0-1250**	-0.19 (0.2)	-0.4 (0.16) *
	1250-2500	0.01 (0.19)	-0.22 (0.16)
	2500-5000	-0.03 (0.19)	-0.27 (0.15) .
	5000-8000	-0.15 (0.2)	-0.2 (0.16)
2017	**0-1250**	-0.16 (0.2)	-0.36 (0.16) *
	1250-2500	-0.02 (0.19)	-0.15 (0.16)
	2500-5000	0.02 (0.19)	-0.28 (0.15) .
	5000-8000	-0.03 (0.19)	-0.28 (0.16) .
2018	**0-1250**	-0.18 (0.2)	-0.44 (0.16) **
	1250-2500	-0.07 (0.19)	-0.03 (0.16)
	2500-5000	-0.15 (0.19)	-0.28 (0.15) .
	5000-8000	0.14 (0.2)	-0.33 (0.16) *
2019	**0-1250**	-0.44 (0.2) *	-0.31 (0.16) .
	1250-2500	-0.17 (0.19)	-0.03 (0.16)
	2500-5000	-0.16 (0.19)	-0.18 (0.15)
	5000-8000	-0.16 (0.2)	-0.1 (0.16)
2020	**0-1250**	-0.56 (0.2) **	-0.64 (0.16) ***
	1250-2500	-0.05 (0.2)	-0.21 (0.16)
	2500-5000	-0.26 (0.19)	-0.32 (0.15) *
	5000-8000	-0.15 (0.2)	-0.29 (0.16) .
2021	**0-1250**	-0.43 (0.2) *	-0.82 (0.16) ***
	1250-2500	-0.36 (0.19) .	-0.25 (0.16)
	2500-5000	-0.31 (0.19) .	-0.54 (0.15) ***
	5000-8000	-0.16 (0.2)	-0.35 (0.16) *
2022	**0-1250**	-0.44 (0.2) *	-0.54 (0.16) ***
	1250-2500	-0.18 (0.19)	-0.28 (0.16) .
	2500-5000	0.06 (0.19)	-0.37 (0.15) *
	5000-8000	-0.19 (0.2)	-0.2 (0.16)
Income		-0.1 (0.05) *	0.05 (0.03)
Sqrt population size		0.4 (0.11) ***	0.32 (0.08) ***
Log housing stock		0.45 (0.11) ***	0.51 (0.08) ***

Marginal R-squared	0.41	0.53
Conditional R-squared	0.69	0.71

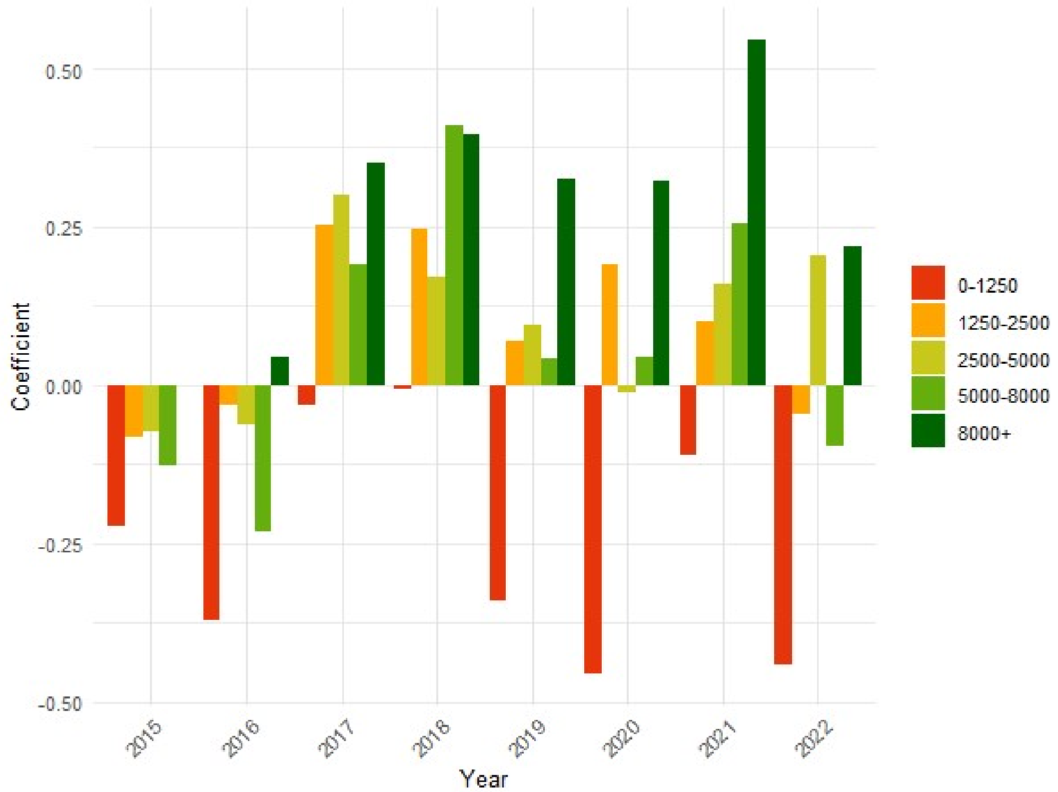
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1. Parentheses show standard errors.

Figure 7 shows the coefficients for the different distance categories compared to the reference category (8000+) in the reference year (2015), the intercept, throughout the years, while controlling for unobserved and observed confounding factors. Table 4 provides the regression results which consist of coefficients relative to the intercept. For the interaction terms, the coefficients are also relative to the coefficients of the reference group in the same year and the same category in the reference year, which, after calculating, results in the coefficients visualised in the figures. The regression results for the base models are listed in Appendix III.

Figure 7 shows a pattern emerging of increasing differences in building permits among the distance categories. Specifically, the number of building permits appears to increase with distance, with some exceptions, as time progresses. The regression results reveal significant, negative coefficients for the 0-1250 category from 2019 to 2022, indicating significantly fewer building permits in that category in those years compared to the reference category. Additionally, the reference group had significantly more building permits than in the reference year in all years except 2016 and 2022. The other categories had negative coefficients in most years, however insignificant, yet, almost significant in 2021. This could be due to a substantial increase in building permits in 2021 for the 8000+ category, which resulted in the other categories being significantly lower even though the coefficients do not seem to be considerably lower than in the other years, indicating a general increase in building permits in that year.

Similar to building permits, construction of new housing shows a trend of increasing units with distance. Regression results for new housing reveal significantly fewer new housing units in the 0-1250 category compared to the 8000+ category in every year except for 2019. For 2019, figure 7 shows that construction of new housing in that year for the 8000+ category was relatively low compared to other categories that year. Contrary to the regression results for building permits, the results for new housing also show significance for other groups: from 2019 to 2022 significant relative decreases are found for the 2500-5000 category and in 2018 the 5000-8000 category shows a significant relative decrease as well. Notable is that the coefficients for these categories in the reference year (2015) show almost significant increases compared to the 8000+ category, observable in the figure by higher coefficients in every category compared to the reference category which is 0 in the reference year as it is the intercept, thus the pattern that emerges in the later years of the analysis significantly deviates from the pattern in 2015. However, it is in line with expectations in the context of nitrogen regulations.

In summary, the analyses reveal an emerging pattern of increasing coefficients with greater distance from N2000 sites, particularly after 2019. Regression results indicate significantly fewer building permits and new housing units in the 0-1250 category compared to farther categories, aligning with hypotheses 1 and 3.



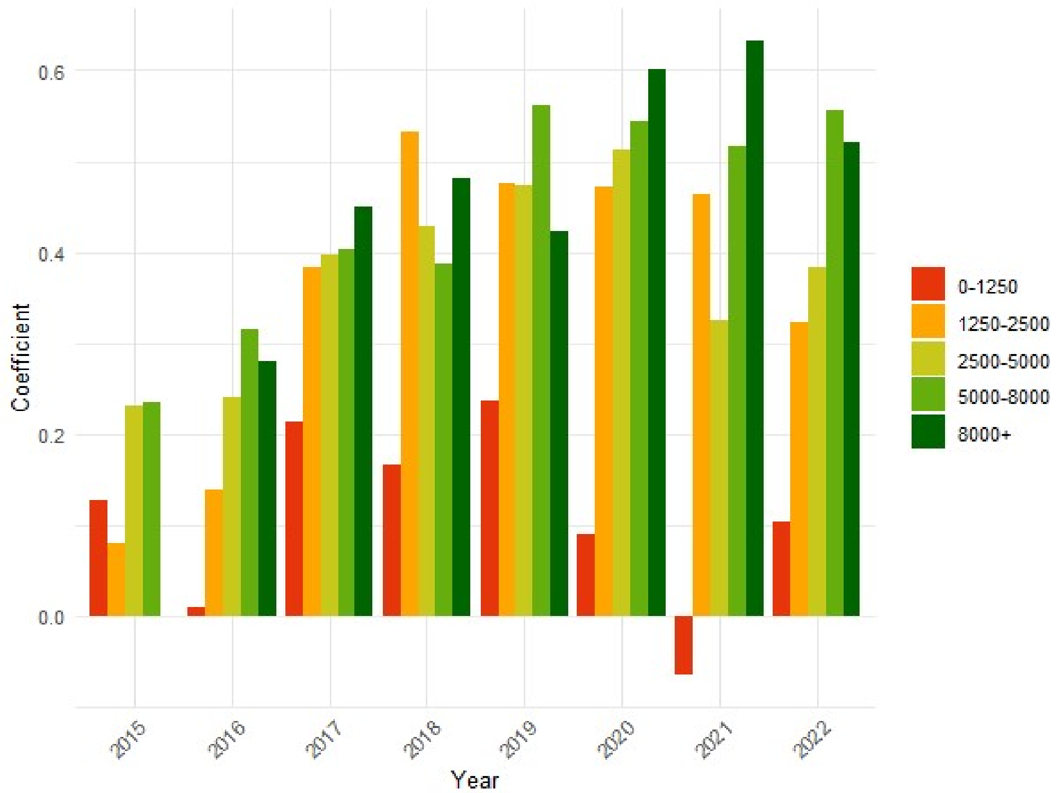


Figure 7: The effect of distance to N2000 sites on log building permits (upper) and log new housing (lower). Shows the regression coefficients for each distance category for each year compared to the reference category (8000+) in the reference year (2015).

4.2. 1250 Cover

Table 5: Percentage cover of a 1250 m buffer zone around N2000 sites effect on log building permits and log new housing.

Variable		Building Permits (log)	New Housing (log)
0-25% cover		-0.25 (0.16)	-0.18 (0.12)
25-50% cover		-0.08 (0.17)	0.01 (0.13)
50-100% cover		-0.21 (0.17)	-0.06 (0.13)
2016		-0.03 (0.12)	0.07 (0.1)
2017		0.26 (0.12) *	0.27 (0.1) **
2018		0.4 (0.12) **	0.24 (0.1) *
2019		0.18 (0.13)	0.22 (0.1) *
2020		0.11 (0.13)	0.39 (0.1) ***
2021		0.39 (0.14) **	0.35 (0.11) ***
2022		-0.03 (0.15)	0.28 (0.11) *
2016	**0-25%**	0.01 (0.16)	0.08 (0.13)
	25-50%	0.14 (0.18)	0.0 (0.14)
	50-100%	-0.11 (0.18)	-0.23 (0.14)
2017	**0-25%**	0.19 (0.16)	-0.01 (0.13)
	25-50%	0.1 (0.18)	-0.03 (0.14)
	50-100%	-0.07 (0.18)	-0.15 (0.14)
2018	**0-25%**	-0.12 (0.16)	0.11 (0.13)
	25-50%	0.04 (0.18)	0.08 (0.14)
	50-100%	-0.15 (0.18)	-0.19 (0.14)
2019	**0-25%**	0.04 (0.16)	0.22 (0.13) .
	25-50%	0.05 (0.18)	0.11 (0.14)
	50-100%	-0.22 (0.18)	-0.11 (0.14)
2020	**0-25%**	0.15 (0.16)	-0.01 (0.13)
	25-50%	0.13 (0.18)	-0.03 (0.14)
	50-100%	-0.24 (0.18)	-0.36 (0.14) *
2021	**0-25%**	-0.03 (0.17)	0.02 (0.13)
	25-50%	-0.14 (0.18)	-0.12 (0.14)
	50-100%	-0.19 (0.18)	-0.46 (0.14) **
2022	**0-25%**	0.35 (0.17) *	0.18 (0.13)
	25-50%	0.19 (0.18)	-0.12 (0.14)
	50-100%	-0.06 (0.18)	-0.3 (0.14) *
Income		-0.11 (0.05) *	0.04 (0.03)
Sqrt population size		0.4 (0.11) ***	0.32 (0.07) ***
Log housing stock		0.46 (0.11) ***	0.52 (0.08) ***
Marginal R-squared		0.41	0.53
Conditional R-squared		0.69	0.70

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Figure 8 shows an increasing difference in building permits between the category containing the largest coverage of the 1250 buffer zone and the category containing no coverage throughout the years. Moreover, the coefficients show a decrease in building permits in 2019 and 2020 and an increase in 2021, in line with the literature on nitrogen regulations. However, regression results (table 5) do not show significant differences. Additionally, the 25-50% category appears to contain an inherently large number of building permits, even having a higher coefficient that the other categories in 2016 and 2020, however, also insignificant, potentially due to the fact that this pattern was already present in the reference year. The regression results only show a significant difference compared to the reference category in 2022 for the 0-25% category, which gives a significant increase in building permits, while building permits in this category were inherently low, as seen in the previous years (figure 8). Lastly, significant increases in building permits were found in 2017, 2018 and 2021, but no significant difference among the groups, indicating an evenly spread increase.

Similar to building permits, the 50-100% category has the lowest coefficient for new housing in every year except for the reference year (figure 8). However, for new housing the coefficients for this category are significant for 2020 to 2022. Thus, despite the construction of new housing generally increasing in those years, indicated by the significant relative increases in every year except 2016, the category with the highest coverage of the 1250 N2000 buffer zone could not match the increase seen in the other categories. As with building permits, the 25-50% category shows an increase in new housing compared to the 50-100% category in all years except 2022, yet this increase is insignificant, as well as the other middle range category, 0-25%, which has positive coefficients for every year except for 2017 and 2020, even being almost significant in 2019.

All in all, the analyses reveal lower numbers of building permits and new housing units in almost every year. However, significance is only found in the analysis for new housing. Additionally, contrary to the analyses for distance, these analyses showed the hypothesized increase in housing development in the middle group compared to the farthest group (H2), however, mostly insignificant aside from 2022, when the regulations were less strict compared to the years prior.

Figure 8: The effect of coverage of a 1250 buffer zone around N2000 sites on log building permits (upper) and log new housing (lower). Shows the regression coefficients for each distance category for each year compared to the reference category (8000+) in the reference year (2015).

4.3. 2500 Cover

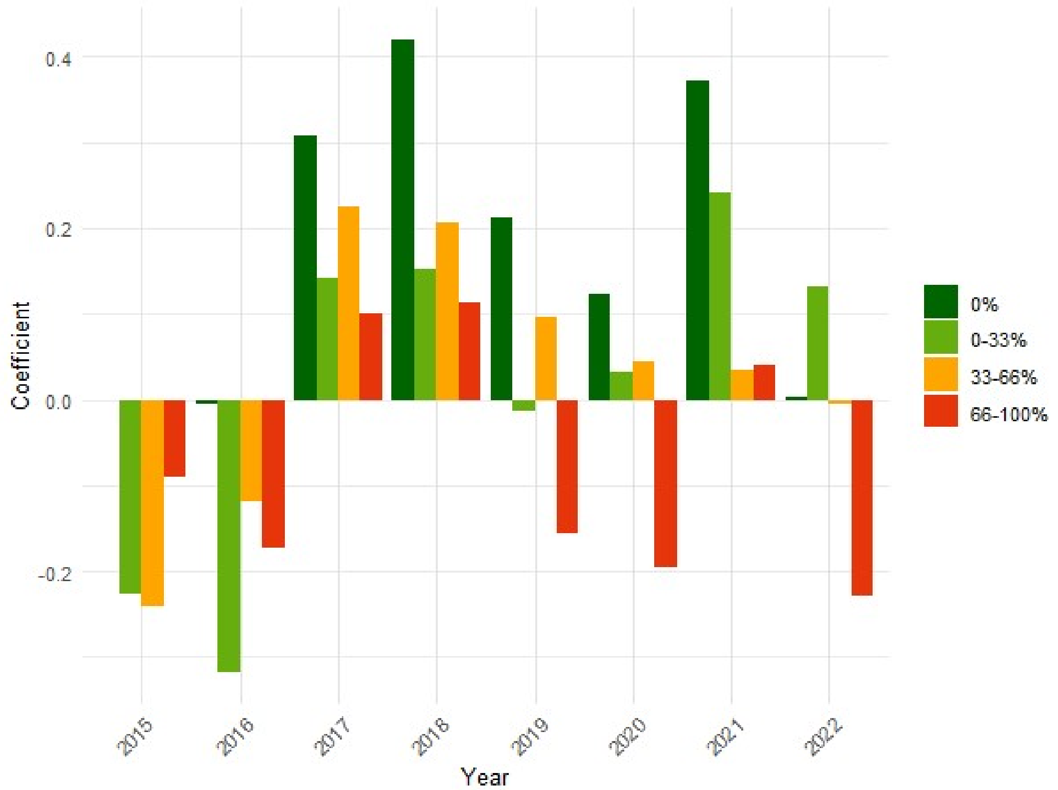
Table 6: Percentage cover of a 2500 m buffer zone around N2000 sites effect on log building permits and log new housing.

Variable		Building Permits (log)	New Housing (log)
0-33% cover		-0.23 (0.18)	-0.11 (0.13)
33-66% cover		-0.24 (0.18)	-0.09 (0.13)
66-100% cover		-0.09 (0.17)	-0.04 (0.12)
2016		-0.01 (0.13)	0.11 (0.1)
2017		0.31 (0.13) *	0.33 (0.11) **
2018		0.42 (0.13) **	0.24 (0.11) *
2019		0.21 (0.14)	0.25 (0.11) *
2020		0.12 (0.14)	0.44 (0.11) ***
2021		0.37 (0.15) *	0.42 (0.12) ***
2022		0.0 (0.16)	0.31 (0.12) *
2016	**0-33%**	-0.09 (0.18)	0.07 (0.14)
	33-66%	0.13 (0.18)	-0.13 (0.15)
	66-100%	-0.08 (0.17)	-0.15 (0.14)
2017	**0-33%**	0.06 (0.18)	-0.11 (0.14)
	33-66%	0.16 (0.18)	-0.13 (0.15)
	66-100%	-0.12 (0.17)	-0.13 (0.14)
2018	**0-33%**	-0.04 (0.18)	0.06 (0.14)
	33-66%	0.03 (0.18)	0.13 (0.15)
	66-100%	-0.22 (0.17)	-0.06 (0.14)
2019	**0-33%**	0.0 (0.18)	0.08 (0.14)
	33-66%	0.13 (0.18)	0.16 (0.15)
	66-100%	-0.28 (0.17)	-0.05 (0.14)
2020	**0-33%**	0.14 (0.18)	-0.11 (0.14)
	33-66%	0.16 (0.18)	-0.06 (0.15)
	66-100%	-0.23 (0.17)	-0.29 (0.14) *
2021	**0-33%**	0.1 (0.18)	-0.09 (0.14)
	33-66%	-0.1 (0.18)	-0.1 (0.15)
	66-100%	-0.24 (0.17)	-0.45 (0.14) **
2022	**0-33%**	0.36 (0.18) *	0.09 (0.14)
	33-66%	0.23 (0.18)	-0.02 (0.15)
	66-100%	-0.14 (0.17)	-0.26 (0.14) .
Income		-0.11 (0.05) *	0.04 (0.03)
Sqrt population size		0.38 (0.11) ***	0.3 (0.08) ***
Log housing stock		0.48 (0.11) ***	0.54 (0.08) ***
Marginal R-squared		0.40	0.52
Conditional R-squared		0.69	0.70

*Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1. Parentheses show standard errors.*

The results for the analysis for building permits and the 2500 buffer zone coverages are similar to that of the 1250 buffer zone coverages; no significant differences are found for the category containing municipalities with the highest coverage compared to the category containing municipalities without coverage. However, a significant, positive coefficient is found for 2022 for the 0-33% category.

From 2015 to 2019, new housing construction appears evenly distributed. However, in 2020, 2021, and 2022, the difference between the 0% category and the 66-100% category becomes most visible, particularly in 2021. Regression results confirm this, showing significant decreases for the 66-100% category during these years. Additionally, before 2019, the 33-66% category had the highest coefficient, indicating the highest amount of new housing. However, after 2019, the 0% category showed the highest coefficient. Contrary to the 1250 buffer zone analysis, the coefficient for the closest group (66-100%) in 2022 is insignificant in this analysis.



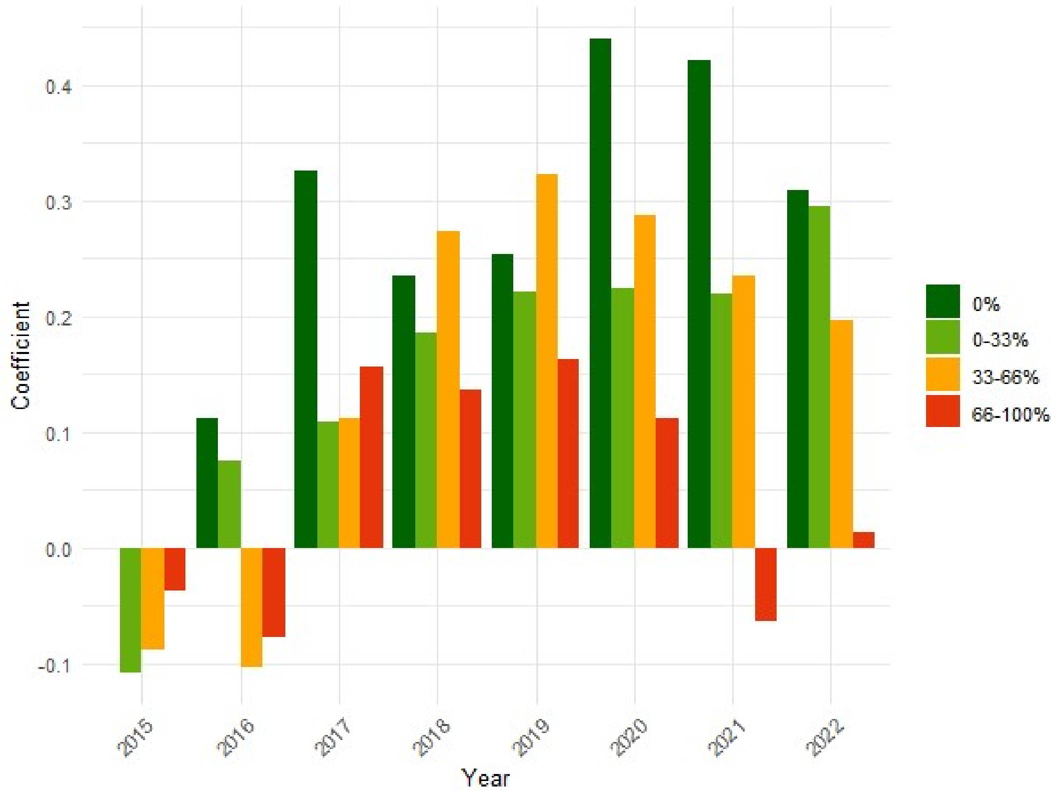


Figure 9: The effect of coverage of a 2500 buffer zone around N2000 sites on log building permits (upper) and log new housing (lower). Shows the regression coefficients for each distance category for each year compared to the reference category (8000+) in the reference year (2015).

4.4. Neighbour Model

Table 7: regression coefficients for neighbouring municipalities' distance and cover effect on log building permits and log new housing.

	Building Permits (log)	New Housing (log)
Distance Neighbour	-3.46e-5 (3.09e-4)	1.00e-4 (2.11e-4)
1250 Cover Neighbour	-1.86e-3 (3.13e-3)	-2.58e-3 (2.11e-3)
2500 Cover Neighbour	-1.55e-3 (2.63e-3)	-2.28e-3 (1.79e-3)

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

The aim of the analyses which included a variable for average distance to N2000 sites or coverage of either buffer zones for the N2000 sites of neighbouring municipalities was to check for potential shifts in housing development to neighbouring municipalities due to the nitrogen regulations. Based on the hypothesis (H4), a negative coefficient for distance was expected, as a higher distance of the neighbouring municipalities was expected to reduce building permits and new housing units due to spatial shifts in housing development to municipalities further from N2000 sites, and a positive coefficient for both coverages, following the same argumentation. The regression results (table 7) show that the observed coefficients are not in line with the expectations. However, the coefficients are small with relatively large standard errors and insignificant in all of the analyses. The full regression output for these analyses is shown in Appendix IV.

4.5. Change in Nitrogen Emissions

The aim of these analyses was to evaluate whether decreases or increases in agricultural nitrogen emissions affected housing development, specifically in the municipalities for which effects of nitrogen regulations were hypothesized (closer to the N2000 sites). Based on the hypothesis (H5), it was expected to observe negative, significant, coefficients in the categories closest to the N2000 sites and insignificant in the categories further from the N2000 sites, the hypothesized unaffected municipalities. However, even though the closest categories (0-1250, 50-100%, 66-100%), all show negative coefficients except for building permits in the 2500 cover analysis, no significance for change in nitrogen was found in any analysis. The regression results for these analyses are shown in Appendix V.

5. Conclusion

All in all, it is concluded that, generally, housing development of municipalities near N2000 sites have been affected by nitrogen regulations, resulting in significant decreases in housing development in municipalities within 1250 meters of the N2000 sites, confirming hypothesis 1. Regarding cover of N2000, results for construction of new housing align with this hypothesis, showing significant decreases from 2020 to 2022 in the category containing the highest percentage of cover (both 1250- and 2500-meter buffer zones). However, this significant decrease was not found for building permits. This difference may be due to data variations; for instance, in the reference year (2015), the coefficient for building permits in the highest coverage category (66-100% and 50-100%) was much lower than for new housing. Consequently, while this category showed a relative decrease in building permits each year, it was not significantly different from the reference year's values, unlike new housing. Alternatively, another process might explain this difference, which will be discussed further in the discussion section.

Regarding policy changes over the years, decreases in housing development closest to the N2000 sites especially amplified after the revocation of PAS. Moreover, this group was not positively impacted by the construction exemption imposed in late 2021. However, it can be concluded that this exemption has allowed construction to occur somewhat closer to the N2000 sites, as evidenced by the significant increase in building permits in the 0-25% category as opposed to the significant increases in the 0% category in the years prior, and the positive, but insignificant, coefficient in the 2500-5000 category. The hypothesized increase in a middle-distance range category (H2) was not found, as the results indicate a spread-out distribution of housing development outside of the areas affected by nitrogen regulations.

Lastly, the analyses for neighbouring municipalities' distance or cover and change in nitrogen did not result in significant results, contrary to what was hypothesized (H4 and H5). Thus, it is concluded that decreases in agricultural nitrogen emissions did not stimulate housing development in the same year.

6. Discussion

Regarding distance, the results from this study differ from those in Rouwendal's (2023) study, where a distance of 2500 meters was used as the divider for whether nitrogen regulations would have an effect. Rouwendal did not find a significant difference in building permits between the municipalities within and outside of this range. In this study, the distances were categorised into multiple ranges, of which the closest was up to 1250 meters. Significant decreases in building permits were found within this 1250-meter range, while no significant differences were found for the 1250–2500-meter category. This suggests that using 2500 meters as a threshold might not accurately capture the effects of nitrogen regulations. The impact of nitrogen regulations appear to primarily occur within 1250 meters, explaining why significant results were found in this study, but not in Rouwendal's. Regarding cover, the conclusion drawn from the results is different from the one in Rouwendal's study, despite similarities in the results. This study concludes that due to the construction exemption in late 2021 housing development shifted closer to the N2000 sites, as opposed to Rouwendal's conclusion that housing development shifted farther from the N2000 sites over time as a reaction to the nitrogen regulations. This study's conclusion is supported by results from the year prior to the construction exemption which showed a significant increase in the farthest category, while during the construction exemption the category that contained some N2000 buffer zone coverage showed a significant increase. Moreover, to confirm a shift farther from the N2000 sites, a significant decrease in building permits should be observable, which was not the case in this study.

In the study published by ABN AMRO (2020), a decrease in development was highlighted at a 0-5 km distance and an increase in housing development at 5-10 km from N2000 sites from 2019 to 2020. While ABN AMRO did not perform a statistical analysis, it is uncertain whether these differences were significant. Nevertheless, their results can be compared to this study's results. It is important to note that ABN AMRO studied houses under construction, whereas this study used data for houses where construction was completed, which could explain some differences in results. However, looking at the results for 2020, these seem similar to a certain extent, with significant decreases at 0-5 km distance, with the exception of 1250-2500 meters. ABN AMRO's observed increase in the 5-10 km range on the other hand is not observable in the results from this study. However, for this range, results are more difficult to compare as the categories chosen in this study differ from those chosen in their study, since the reference group here is 8+ km, and for ABN AMRO it was 10+ km. For 8+ km however, a significant increase was found in 2020.

When comparing the results to the international literature discussed in the literature review, which primarily contained studies from the US, the results are generally similar and thus align with the hypotheses formed from these studies, except for the hypothesized increase in the middle-distance group (H2). As for why the hypothesized increase in housing development in municipalities not directly affected by the nitrogen regulations was not found in this study, this could be due to the overall stricter regulatory environment in the Netherlands, as this hypothesis was partly based on literature from the US (i.e. Kiel, 2005; Quigley and Swoboda, 2007). This could prevent an increase in housing development in areas for which an increase in demand was hypothesized due to a decrease in housing development in nearby areas (right outside the by nitrogen regulations affected areas), either leading to an overall increase in housing development in all unaffected areas, and thus per area relatively small, or no increase at all. This could also explain why the analyses for distance and cover of the neighbouring municipalities did not result in significant results. Alternatively, this methodology used to analyse this shift in housing development might not be effectively applicable to the case of nitrogen regulations, as the methodology was inspired by a study from Sims and Schuetz (2009) who studied the effect of wetland bylaws, in which the number of years that the bylaw was in place was the independent variable. In that case, the adaptation of bylaws appeared to be a relatively random distribution, thus perhaps making it more effective in observing potential displacement effect caused by the bylaws. However, in this study, the distance or coverage does correlate with the distance or coverage of the observed municipalities, in other words, municipalities that have a short average distance to N2000 sites, have neighbours who also have a short average distance to N2000 sites, thus being more of a gradient as opposed to a random distribution. Therefore, this could potentially explain why in this study these analyses showed unexpected and insignificant results. To further analyse and effectively capture shifts in housing development due to nitrogen regulations, future studies could perform analyses per region separately.

The results for the potential moderating effect of changes in agricultural nitrogen emissions per municipality differed from expectations, as no significant effect was found. A potential explanation for this unexpected result is that perhaps there is a lag between changes in nitrogen levels and the issuance of building permits. Decreases in nitrogen emissions may not immediately lead to the issuance of building permits utilizing that decrease in nitrogen, potentially occurring years later and resulting in insignificant correlations. Secondly, the practice of leasing nitrogen space to nitrogen emitting projects, in which the same decrease in nitrogen emissions can temporarily be used for multiple projects, may also contribute to decreases in nitrogen emissions not correlating with increases in housing development (BIJ12, 2020). Alternatively, the utilizations of decreases in nitrogen emissions in other locations may simply not have had a significant impact on housing development, perhaps favourably being used for other practices, such as industrial or agricultural expansions. Additionally, due to the observed spatial shift in housing development farther from N2000 sites, it might not always be necessary to use these emissions reductions, as developing farther from N2000 sites might be a simpler and cheaper solution.

It is notable that the results for building permits and new housing show slight differences, despite their correlation and the expectation of similar outcomes (Ploegmakers et al., 2022; Somerville, 2001). This difference may be attributed to the fact that the first year of the analysis served as the reference year, and the number of building permits and new housing units per category differed in this year, which can lead to varying results as the results for the other years are compared to the reference year, without necessarily meaning that the variables are uncorrelated. Additionally, the differences in results could be due to values for new housing lagging behind issued building permits due to construction times, which could range from within the same year to several years (Ploegmakers et al., 2022). This lag is observable in the results after the revocation of PAS, for which building permits showed an immediate decrease in building permits in the closest distance category, but a decrease in new housing was only found after 2020.

To conclude, aside from altering the spatial distribution of housing development in the Netherlands, it does not appear that housing development as a whole has been negatively impacted by the nitrogen regulations, as development increased in most of the investigated areas. Thus, it seems that nitrogen regulations have not been a major contributor to the housing crisis in the Netherlands. However, given the numerous changes in nitrogen regulations in the previous years and the appointment of a new cabinet in the Netherlands, it is expected that nitrogen regulations will continue to evolve. Therefore, ongoing research is necessary to study the effects of these regulations on housing development.

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Appendix

Appendix I

Lists the municipality changes per year (CBS, n.d.-b).

Year changed	Previous municipality	New municipality
2016	De Friese Meren	De Fryske Marren
2016	Groesbeek	Berg en Dal
2016	Bussum	Gooise Meren
	Muiden	
	Naarden	
2016	Edam-Volendam	Edam-Volendam
	Zeevang	
2017	Schijndel	Meierijstad
	Sint-Oedenrode	
	Veghel	
2018	Bellingwedde	Westerwolde
	Vlagtwedde	
2018	Hoogezand-Sappermeer	Midden-Groningen
	Slochteren	
	Menterwolde	
2018	Het Bildt	Waadhoeke
	Franekeradeel	
	Menameradiel	
	Littensaradiel	
2018	Leeuwarden	Leeuwarden
	Leeuwarderadeel	
	Littenseradiel	
2018	Súdwest-Fryslân	Súdwest-Fryslân
	Littenseradiel	
2018	Rijnwaarden	Zevenaar
	Zevenaar	
2019	Bedum	Het Hogeland
	Eemsmond	
	De Marne	
	Winsum	
2019	Ten Boer	Groningen
	Groningen	
	Haren	
2019	Grootegast	Westerkwartier
	Leek	
	Marum	
	Zuidhorn	
2019	Dongeradeel	Noardeast-Fryslân
	Kollumerland en Nieuwkruisland	
	Ferwerderadiel	
2019	Geldermalsen	West Betuwe
	Neerijnen	

	Lingewaal	
2019	Haarlemmerliede en Spaarnwoude	Haarlemmermeer
	Haarlemmermeer	
2019	Leerdam	Vijfheerenlanden
	Vianen	
	Zederik	
2019	Noordwijk	Noordwijk
	Noordwijkerhout	
2019	Oud-Beijerland	Hoeksche Waard
	Binnenmaas	
	Korendijk	
	Cromstrijen	
	Strijen	
2019	Giessenlanden	Molenlanden
	Molenwaard	
2019	Aalburg	Altena
	Werkendam	
	Woudrichem	
2019	Onderbanken	Beekdaelen
	Nuth	
	Schinnen	
2021	Appingedam	Eemsdelta
	Delfzijl	
	Loppersum	
2022	Beemster	Purmerend
	Purmerend	
2022	Heerhugowaard	Dijk en Waard
	Langedijk	
2022	Landerd	Maashorst
	Uden	
2022	Boxmeer	Land van Cuijk
	Cuijk	
	Grave	
	Mill en Sint Hubert	
	Sint Anthonis	
2023	Brielle	Voorne aan Zee
	Hellevoetsluis	
	Westvoorne	
2023	Amsterdam	Amsterdam
	Weesp	

Appendix II

Shows the list of Natura 2000 sites that are vulnerable to nitrogen depositions (LNV, 2022). These are the sites that were included in this research:

Groningen
Lieftinghsbroek

Friesland
Alde Feanen
Bakkeveense duinen
Duinen Ameland
Duinen Schiermonnikoog
Duinen Terschelling
Duinen Vlieland
Groote Wielen
Oudegaasterbrekken, Fluessen en omgeving
Rottige Meenthe & Brandemeer
Sneekermeergebied
Van Oordt's Mersken
Wijnjeterper Schar
Drenthe
Bargerveen
Drents-Friese Wold & Leggelderveld
Drentsche Aa-gebied
Drouwenerzand
Dwingelderveld
Elperstroomgebied
Fochteloërveen
Holtingerveld
Mantingerbos
Mantingerzand
Norgerholt
Overijssel
Aamsveen
Achter de Voort, Agelerbroek &
Voltherbroek
Bergvennen & Brecklenkampse Veld
Boetelerveld
Borkeld
Buurserzand & Haaksbergerveen
De Wieden
Dinkelland
Engbertsdijksvenen
Landgoederen Oldenzaal
Lemselermaten
Lonnekermeer
Olde Maten & Veerslootslanden
Sallandse Heuvelrug
Springendal & Dal van de Mosbeek
Uiterwaarden Zwarte Water en Vecht
Vecht- en Beneden-Reggegebied
Weerribben
Wierdense Veld
Witte Veen
Gelderland
Bekendelle
De Bruuk
Korenburgerveen
Landgoederen Brummen
Lingegebied & Diefdijk Zuid
Loevestein, Pompveld & Kornsche
Boezem
Rijntakken
Stelkampsveld
Veluwe
Willinks Weust
Wooldse Veen
Utrecht
Binnenveld
Botshol
Kolland & Overlangbroek
Uiterwaarden Lek
Zouweboezem
Noord-Holland
Duinen Den Helder - Callantsoog
Duinen en Lage Land Texel
Eilandspolder
Ilperveld, Varkensland,
Oostzanerveld & Twiske
Kennemerland-Zuid
Naardermeer
Noordhollands Duinreservaat
Oostelijke Vechtplassen
Polder Westzaan
Schoorlse Duinen
Wormer- en Jisperveld &
Kalverpolder
Zwanenwater & Pettemerduinen
Zuid-Holland
Broekvelden, Vettenbroek & Polder
Stein
Coepelduynen
Duinen Goeree & Kwade Hoek
Meijendel & Berkheide
Nieuwkoopse Plassen & De Haeck
Solleveld & Kapittelduinen
Voornes Duin
Westduinpark & Wapendal
Zeeland
Canisvliet
Groote Gat
Kop van Schouwen
Manteling van Walcheren
Vogelkreek
Yerseke en Kapelse Moer
Zwin & Kievittepolder
Noord-Brabant
Biesbosch

Brabantse Wal
Deurnsche Peel & Mariapeel
Groote Peel
Kampina & Oisterwijkse Vennen
Kempenland-West
Langstraat
Leenderbos, Groote Heide & De Plateaux
Loonse en Drunense Duinen & Leemkuilen
Oeffelter Meent
Regte Heide & Riels Laag
Strabrechtse Heide & Beuven
Ulvenhoutse Bos
Vlijmens Ven, Moerputten & Bossche Broek
Limburg
Bemelerberg & Schiepersberg
Boschhuizerbergen
Brunssummerheide
Bunder- en Elslooërbos
Geleenbeekdal
Geuldal
Grensmaas
Kunderberg
Leudal
Maasduinen
Meinweg
Noorbeemden & Hoogbos
Roerdal
Sarsven en De Banen
Savelsbos
Sint Jansberg
Sint Pietersberg & Jekerdal
Swalmdal
Weerter- en Budelerbergen & Ringselven
Zeldersche Driessen
Ministerie van I&W
Grevelingen
IJsselmeer
Krammer-Volkerak
Maas bij Eijsden
Noordzeekustzone
Oosterschelde
Voordelta
Waddenzee
Westerschelde & Saeftinghe
Zwarte Meer
Ministerie van Defensie
Witterveld

Appendix III

Base model full output tables:

Table 8: Distance to N2000 effect on log building permits and log new housing base without control variables.

Variable		Building Permits (log)	New Housing (log)
Distance 0-1250		-2.79 (1.33) *	-1.91 (1.29)
Distance 1250-2500		-2.47 (1.3) .	-1.41 (1.26)
Distance 2500-5000		-0.68 (1.28)	-0.03 (1.24)
Distance 5000-8000		1.34 (1.32)	2.11 (1.28) .
2016		0.29 (0.59)	1.02 (0.52) *
2017		2.2 (0.59) ***	2.23 (0.52) ***
2018		1.84 (0.59) **	2.52 (0.52) ***
2019		1.03 (0.59) .	2.68 (0.52) ***
2020		1.68 (0.6) **	3.89 (0.52) ***
2021		1.72 (0.6) **	3.31 (0.52) ***
2022		0.44 (0.59)	3.21 (0.52) ***
2016	**0-1250**	-1.42 (0.84) .	-0.69 (0.74)
	1250-2500	0.1 (0.82)	-0.55 (0.72)
	2500-5000	-0.21 (0.81)	-0.33 (0.71)
	5000-8000	-1.75 (0.83) *	-0.23 (0.73)
2017	**0-1250**	-1.59 (0.84) .	-1.78 (0.73) *
	1250-2500	-0.48 (0.82)	-0.75 (0.72)
	2500-5000	-1.1 (0.81)	-0.52 (0.71)
	5000-8000	-1.54 (0.83) .	-0.71 (0.73)

2018	**0-1250**	-1.31 (0.84)	-1.71 (0.74) *
	1250-2500	-0.01 (0.82)	-0.59 (0.72)
	2500-5000	-0.89 (0.81)	-0.72 (0.71)
	5000-8000	0.09 (0.83)	-0.97 (0.73)
2019	**0-1250**	-1.76 (0.84) *	-1.49 (0.74) *
	1250-2500	-0.24 (0.82)	-0.44 (0.72)
	2500-5000	-0.72 (0.81)	-0.52 (0.71)
	5000-8000	-0.62 (0.83)	-0.36 (0.73)
2020	**0-1250**	-2.55 (0.85) **	-2.93 (0.74) ***
	1250-2500	-0.81 (0.82)	-1.87 (0.72) **
	2500-5000	-1.63 (0.81) *	-1.83 (0.71) **
	5000-8000	-0.97 (0.83)	-1.25 (0.73) .
2021	**0-1250**	-1.42 (0.85) .	-3.07 (0.74) ***
	1250-2500	-0.96 (0.83)	-1.18 (0.72)
	2500-5000	-0.74 (0.81)	-2.21 (0.71) **
	5000-8000	-0.63 (0.85)	-0.19 (0.73)
2022	**0-1250**	-1.54 (0.85) .	-2.62 (0.75) ***
	1250-2500	-0.21 (0.82)	-1.55 (0.72) *
	2500-5000	-0.01 (0.81)	-1.21 (0.71) .
	5000-8000	-0.93 (0.84)	0.35 (0.73)
Marginal R-squared		0.06	0.07
Conditional R-squared		0.81	0.85

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 9: Percentage cover of a 1250 m buffer zone around N2000 sites effect on log building permits and log new housing without control variables.

Variable		Building Permits (log)	New Housing (log)
0-25% cover		1.22 (1.11)	1.51 (1.08)
25-50% cover		-0.39 (1.18)	0.33 (1.15)
50-100% cover		-1.87 (1.18)	-1.33 (1.15)
2016		-0.11 (0.51)	0.57 (0.44)
2017		0.61 (0.51)	1.57 (0.44) ***
2018		1.5 (0.51) **	1.65 (0.44) ***
2019		0.15 (0.51)	1.82 (0.44) ***
2020		0.35 (0.51)	2.47 (0.44) ***
2021		0.8 (0.51)	2.37 (0.44) ***
2022		-0.74 (0.51)	2.22 (0.44) ***
2016	**0-25%**	-0.31 (0.7)	0.38 (0.61)
	25-50%	0.69 (0.74)	0.34 (0.65)
	50-100%	-0.9 (0.75)	-0.46 (0.65)
2017	**0-25%**	1.24 (0.7) .	0.41 (0.61)
	25-50%	1.18 (0.74)	0.02 (0.65)
	50-100%	-0.01 (0.75)	-0.95 (0.65)
2018	**0-25%**	-0.16 (0.7)	0.64 (0.61)
	25-50%	0.57 (0.74)	0.36 (0.65)
	50-100%	-0.73 (0.74)	-0.87 (0.65)
2019	**0-25%**	0.8 (0.7)	1.34 (0.61) *
	25-50%	0.51 (0.74)	0.47 (0.65)
	50-100%	-0.53 (0.74)	-0.62 (0.65)
2020	**0-25%**	0.91 (0.7)	0.31 (0.62)

	25-50%	0.52 (0.74)	-0.19 (0.65)
	50-100%	-1.11 (0.75)	-1.25 (0.65) .
2021	**0-25%**	0.5 (0.71)	0.4 (0.61)
	25-50%	0.58 (0.75)	-0.68 (0.65)
	50-100%	-0.3 (0.75)	-1.83 (0.65) **
2022	**0-25%**	1.43 (0.7) *	1.4 (0.61) *
	25-50%	1.04 (0.74)	-0.4 (0.65)
	50-100%	0.12 (0.76)	-1.61 (0.66) *
Marginal R-squared		0.04	0.54
Conditional R-squared		0.81	0.85

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 10: Percentage cover of a 2500 m buffer zone around N2000 sites effect on log building permits and log new housing without control variables.

Variable		**Building Permits (log)**	**New Housing (log)**
0-33% cover		2.22 (1.19) .	2.65 (1.15) *
33-66% cover		-0.57 (1.22)	0.31 (1.18)
66-100% cover		-1.2 (1.14)	-0.84 (1.1)
2016		-0.04 (0.55)	0.74 (0.48)
2017		0.86 (0.55)	1.72 (0.48) ***
2018		1.4 (0.55) *	1.59 (0.48) ***
2019		0.2 (0.55)	1.88 (0.48) ***
2020		0.47 (0.55)	2.7 (0.48) ***
2021		0.78 (0.56)	2.65 (0.48) ***
2022		-0.5 (0.55)	2.19 (0.48) ***
2016	**0-33%**	-0.58 (0.75)	0.2 (0.66)
	33-66%	0.63 (0.77)	-0.33 (0.67)
	66-100%	-0.67 (0.72)	-0.29 (0.63)
2017	**0-33%**	0.68 (0.75)	0.0 (0.66)
	33-66%	1.19 (0.77)	0.09 (0.67)
	66-100%	-0.21 (0.72)	-0.85 (0.63)
2018	**0-33%**	0.4 (0.75)	0.54 (0.66)
	33-66%	0.53 (0.77)	0.64 (0.67)
	66-100%	-0.66 (0.72)	-0.48 (0.63)
2019	**0-33%**	0.63 (0.75)	0.64 (0.66)
	33-66%	1.09 (0.77)	0.84 (0.67)
	66-100%	-0.74 (0.72)	-0.36 (0.63)
2020	**0-33%**	0.84 (0.75)	0.11 (0.66)
	33-66%	0.67 (0.77)	-0.44 (0.68)
	66-100%	-1.18 (0.72)	-1.21 (0.63) .
2021	**0-33%**	1.28 (0.76) .	0.01 (0.66)
	33-66%	0.73 (0.77)	-0.57 (0.68)
	66-100%	-0.85 (0.73)	-1.95 (0.63) **
2022	**0-33%**	1.31 (0.76) .	1.39 (0.66) *
	33-66%	1.21 (0.77)	0.25 (0.68)
	66-100%	-0.43 (0.72)	-1.48 (0.64) *
Marginal R-squared		0.06	0.07
Conditional R-squared		0.81	0.85

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Appendix IV

Neighbour analyses full output tables:

Table 11: Distance to N2000 and average distance of neighbouring municipalities effect on log building permits and log new housing base without control variables.

Variable	Building Permits (log)	New Housing (log)
Distance	1.43e-4 (2.38e-4)	-1.17e-4 (1.68e-4)
Distance Neighbour	-3.46e-5 (3.09e-4)	1.00e-4 (2.11e-4)
2016	-0.05 (0.1)	-0.04 (0.08)
2017	0.27 (0.1) **	0.15 (0.08) .
2018	0.24 (0.1) *	0.16 (0.08) *
2019	0.06 (0.11)	0.21 (0.09) *
2020	-0.02 (0.11)	0.14 (0.09)
2021	0.12 (0.12)	0.01 (0.09)
2022	4.68e-4 (0.13)	0.09 (0.1)
Distance:2016	4.53e-5 (1.56e-4)	1.96e-4 (1.26e-4)
Distance:2017	1.04e-4 (1.55e-4)	1.76e-4 (1.27e-4)
Distance:2018	2.05e-4 (1.57e-4)	1.98e-4 (1.26e-4)
Distance:2019	1.95e-4 (1.57e-4)	2.02e-4 (1.26e-4)
Distance:2020	3.18e-4 (1.57e-4) *	3.88e-4 (1.26e-4) **
Distance:2021	3.73e-4 (1.57e-4) *	4.95e-4 (1.28e-4) ***
Distance:2022	1.87e-4 (1.57e-4)	3.62e-4 (1.28e-4) **
Income	-0.1 (0.05) *	0.03 (0.03
Sqrt population size	0.37 (0.11) ***	0.31 (0.08) ***
Log housing stock	0.48 (0.11) ***	0.53 (0.08) ***
Marginal R-squared	0.40	0.52
Conditional R-squared	0.69	0.70

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 12: Percentage cover of a 1250 m buffer zone around N2000 sites and average cover of neighbouring municipalities effect on log building permits and log new housing base without control variables.

Variable	Building Permits (log)	New Housing (log)
1250 Cover	-1.04e-3 (2.61e-3)	8.517e-04 1.865e-03
1250 Cover Neighbour	-1.86e-3 (3.13e-3)	-2.583e-03 2.106e-03
2016	-0.01 (0.08)	0.13 (0.07) .
2017	0.38 (0.09) ***	0.27 (0.07) ***
2018	0.39 (0.09) ***	0.31 (0.07) ***
2019	0.21 (0.1) *	0.35 (0.08) ***
2020	0.26 (0.1) **	0.45 (0.08) ***
2021	0.4 (0.11) ***	0.43 (0.08) ***
2022	0.2 (0.12) .	0.4 (0.09) ***
Cover:2016	-6.46e-4 (2.10e-3)	-2.91e-3 (1.71e-3) .
Cover:2017	-2.01e-3 (2.09e-3)	-1.47e-3 (1.71e-3)
Cover:2018	-1.92e-3 (2.10e-3)	-2.19e-3 (1.71e-3)
Cover:2019	-1.96e-3 (2.10e-3)	-2.18e-3 (1.70e-3)
Cover:2020	-4.91e-3 (2.10e-3) *	-5.03e-3 (1.71e-3) **
Cover:2021	-3.75e-3 (2.10e-3) .	-6.77e-3 (1.70e-3) ***
Cover:2022	-3.89e-3 (2.14e-3) .	-5.66e-3 (1.74e-3) **

Income	-0.11 (0.05) *	0.03 (0.03)
Sqrt population size	0.4 (0.11) ***	0.33 (0.08) ***
Log housing stock	0.44 (0.12) ***	0.5 (0.08) ***
Marginal R-squared	0.40	0.52
Conditional R-squared	0.69	0.70

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 13: Percentage cover of a 2500 m buffer zone around N2000 sites and average cover of neighbouring municipalities effect on log building permits and log new housing base without control variables..

Variable	Building Permits (log)	New Housing (log)
2500 Cover	-6.67e-4 (2.14e-3)	5.37e-4 (1.54e-3)
2500 Cover Neighbour	-1.55e-3 (2.63e-3)	-2.28e-3 (1.79e-3)
2016	-0.01 (0.09)	0.15 (0.08) .
2017	0.37 (0.09) ***	0.28 (0.08) ***
2018	0.41 (0.1) ***	0.3 (0.08) ***
2019	0.24 (0.1) *	0.34 (0.08) ***
2020	0.25 (0.11) *	0.45 (0.08) ***
2021	0.47 (0.11) ***	0.44 (0.09) ***
2022	0.21 (0.13) .	0.41 (0.1) ***
Cover:2016	-2.06e-4 (1.70e-3)	-2.25e-3 (1.38e-3)
Cover:2017	-1.21e-3 (1.69e-3)	-1.14e-3 (1.38e-3)
Cover:2018	-1.65e-3 (1.70e-3)	-1.19e-3 (1.38e-3)
Cover:2019	-1.90e-3 (1.70e-3)	-1.06e-3 (1.37e-3)
Cover:2020	-2.78e-3 (1.70e-3)	-3.28e-3 (1.38e-3) *
Cover:2021	-3.72e-3 (1.70e-3) *	-4.69e-3 (1.38e-3) ***
Cover:2022	-2.68e-3 (1.71e-3)	-3.62e-3 (1.39e-3) **
Income	-0.11 (0.05) *	0.03 (0.03)
Sqrt population size	0.38 (0.11) ***	0.32 (0.08) ***
Log housing stock	0.47 (0.11) ***	0.51 (0.08) ***
Marginal R-squared	0.40	0.52
Conditional R-squared	0.69	0.70

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Appendix V

Change in nitrogen full output tables:

Table 14: Distance to N2000 and change in nitrogen effect on log building permits and log new housing.

Variable		Building Permits (log)	New Housing (log)
Distance 0-1250		-0.66 (0.2) **	-0.22 (0.14)
Distance 1250-2500		-0.23 (0.2)	0.0 (0.14)
Distance 2500-5000		-0.22 (0.19)	0.01 (0.13)
Distance 5000-8000		-0.25 (0.2)	0.04 (0.14)
2020		-0.05 (0.14)	0.14 (0.11)
2021		0.25 (0.14) .	0.15 (0.11)
2022		-0.11 (0.14)	0.1 (0.11)
2020	**0-1250**	0.0 (0.19)	-0.3 (0.15) .
	1250-2500	0.09 (0.19)	-0.13 (0.15)
	2500-5000	-0.06 (0.19)	-0.11 (0.15)

	5000-8000	0.02 (0.2)	-0.1 (0.15)
2021	**0-1250**	0.05 (0.19)	-0.45 (0.15) **
	1250-2500	-0.22 (0.19)	-0.18 (0.15)
	2500-5000	-0.22 (0.19)	-0.3 (0.15) *
	5000-8000	-0.14 (0.19)	-0.16 (0.15)
2022	**0-1250**	0.12 (0.2)	-0.32 (0.15) *
	1250-2500	0.06 (0.19)	-0.21 (0.15)
	2500-5000	0.23 (0.19)	-0.2 (0.15)
	5000-8000	0.0 (0.19)	-0.04 (0.15)
Income		-0.12 (0.05) *	0.06 (0.03) .
Sqrt population size		0.42 (0.12) ***	0.25 (0.08) **
Log housing stock		0.46 (0.13) ***	0.61 (0.08) ***
Change in nitrogen		-9.08e-4 (9.91e-4)	-2.49e-4 (7.72e-4)
Change in nitrogen	**0-1250**	4.99e-4 (7.85e-4)	-1.07e-4 (6.10e-4)
	1250-2500	7.22e-6 (6.17e-4)	3.79e-4 (4.79e-4)
	2500-5000	-1.64e-4 (6.95e-4)	1.39e-4 (5.34e-4)
	5000-8000	-1.17e-4 (4.59e-4)	-2.92e-4 (3.57e-4)
Marginal R-squared		0.42	0.57
Conditional R-squared		0.72	0.74

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 15: Percentage cover of a 1250 m buffer zone around N2000 sites and change in nitrogen effect on log building permits and log new housing.

Variable		**Building Permits (log)**	**New Housing (log)**
0-25% cover		-0.25 (0.17)	-0.02 (0.12)
25-50% cover		-0.01 (0.18)	0.09 (0.12)
50-100% cover		-0.44 (0.18) *	-0.21 (0.12) .
2020		-0.07 (0.12)	0.15 (0.09) .
2021		0.19 (0.12)	0.11 (0.09)
2022		-0.21 (0.12) .	0.08 (0.09)
2020	**0-25%**	0.13 (0.16)	-0.2 (0.13)
	25-50%	0.05 (0.17)	-0.12 (0.13)
	50-100%	-0.02 (0.17)	-0.23 (0.13) .
2021	**0-25%**	-0.08 (0.16)	-0.18 (0.12)
	25-50%	-0.15 (0.17)	-0.21 (0.13)
	50-100%	0.1 (0.17)	-0.29 (0.13) *
2022	**0-25%**	0.37 (0.16) *	-0.06 (0.12)
	25-50%	0.19 (0.17)	-0.27 (0.13) *
	50-100%	0.25 (0.17)	-0.28 (0.14) *
Income		-0.13 (0.05) *	0.06 (0.03)
Sqrt population size		0.42 (0.13) ***	0.26 (0.08) **
Log housing stock		0.47 (0.13) ***	0.62 (0.08) ***
Change in nitrogen		-7.24e-5 (4.71e-4)	-3.60e-5 (3.63e-4)
Change in nitrogen	**0-25%**	-3.17e-4 (5.91e-4)	-1.77e-4 (4.54e-4)
	25-50%	4.56e-4 (6.87e-4)	4.52e-5 (5.27e-4)
	50-100%	-4.08e-4 (9.47e-4)	-8.91e-4 (7.28e-4)
Marginal R-squared		0.41	0.56
Conditional R-squared		0.72	0.74

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*

Table 16: Percentage cover of a 2500 m buffer zone around N2000 sites and change in nitrogen effect on log building permits and log new housing.

Variable		Building Permits (log)	New Housing (log)
0-33% cover		-0.25 (0.19)	-0.12 (0.13)
33-66% cover		-0.13 (0.19)	0.03 (0.13)
66-100% cover		-0.35 (0.17) *	-0.13 (0.12)
2020		-0.09 (0.13)	0.16 (0.1)
2021		0.17 (0.13)	0.13 (0.1)
2022		-0.21 (0.13)	0.05 (0.1)
2020	**0-33%**	0.13 (0.18)	-0.12 (0.14)
	33-66%	0.04 (0.18)	-0.2 (0.14)
	66-100%	0.03 (0.17)	-0.19 (0.13)
2021	**0-33%**	0.1 (0.17)	-0.15 (0.13)
	33-66%	-0.27 (0.18)	-0.21 (0.14)
	66-100%	0.06 (0.17)	-0.34 (0.13) **
2022	**0-33%**	0.42 (0.18) *	0.06 (0.14)
	33-66%	0.14 (0.18)	-0.19 (0.14)
	66-100%	0.23 (0.17)	-0.25 (0.13) .
Income		-0.13 (0.05) **	0.05 (0.03)
Sqrt population size		0.4 (0.13) **	0.24 (0.08) **
Log housing stock		0.48 (0.13) ***	0.64 (0.08) ***
Change in nitrogen		-1.62e-4 (4.77e-4)	-5.16e-5 (3.67e-4)
Change in nitrogen	**0-33%**	1.38e-4 (6.21e-4)	-3.68e-4 (4.76e-4)
	33-66%	-1.72e-4 (6.68e-4)	2.07e-4 (5.14e-4)
	66-100%	4.06e-4 (7.88e-4)	-3.90e-4 (6.07e-4)
Marginal R-squared		0.40	0.56
Conditional R-squared		0.72	0.74

*Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Parentheses show standard errors.*