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Working from home, changing housing preferences and price dynamics in the Dutch real estate market

A difference-in-differences hedonic regression analysis into the effects of the 2020 working from home surge on home office price premia

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Abstract

The Covid-19 pandemic and therefrom ensuing lockdowns enforced by the government caused widespread changes in work- and commuting behaviour among the Dutch workforce. As social distancing measures were implemented by companies to reduce infections, working from home took an enormous flight. As early research has pointed out, workers are very content with this form of hybrid-working, signalling the start of new work patterns for those workers that have the potential to work from home. Consequently, the question arises to what extent the additional time spent at home by workers is leading to changing housing needs and preferences. This thesis investigates whether the rise of working from home, initially incepted by the Covid-19 pandemic, has caused a price premium for home offices, for lease and sale transactions respectively. By using extensive transactiondata from the Dutch Association of Realtors (NVM), we estimate a hedonic price regression using fixed effects, to see what impact this surge for working from home has had on residential real estate in The Netherlands. While the results do not show ubiquitous results for the presence of a home office, the models do point to a price premium for home offices in lease transactions. If the habit of working - at least partially - from home manifests itselfs permanently among Dutch workers, this initial short-run shift in demand for housing with a home office could lead to larger price premia for additional, potential home offices in the long run. Such a shift has implications for policymakers and real estate professionals alike in formulating building strategies and assignments.

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Acronyms

CBD	Central Business District
NVM	Nederlandse Coöperatieve Vereniging van Makelaars en Taxateurs
CBS	Centraal Bureau voor de Statistiek
BAG	Basisregistratie Adressen en Gebouwen
hbo	hoger beroepsonderwijs
wo	wetenschappelijk onderwijs

1 Introduction

The Covid-19 pandemic has forced companies and households alike to reconsider the living- and work spaces they use. A well-known phenomenon spurred by the pandemic is the rise of working from home, where workers can balance their workdays between the office and their homes. While the effects of this new work mode on the occupancy rate and demand for office space has been discussed from the start of the pandemic (Hoesli and Malle (2021), Ling, Wang, and Zhou (2020)) there is limited research yet that investigates the effects of working from home on the transaction rents and prices of homes in light of changing demands for specific housing characteristics such as the presence of a home office. Such insights, however, could add to a better understanding of how preferences for housing have changed due to the societal impact of the pandemic.

As of now, the current stock of housing in the Netherlands exist for roughly 22 percent out of small houses (< 75 m2), 58 percent of middle-large houses (75 till 150 m2) en 20 percent of large houses (150 m2 or more). The percentage of middle-large houses is, however, growing at a slower rate than that of small or large houses. While the average floor area of houses in the Netherlands has increased slightly since 2012, the average floor area of apartments is decreasing.

Table 2: Dutch housing stock - Floor area

	Average floor area:		
	Total	Houses	Apartments
	(1)	(2)	(3)
2012	119	138	84
2022	120	142	80

Source CBS, 2022

The Netherlands has a relatively high number of rooms per person [1], divided by the number of people in the household) compared to the European average of 1.6 rooms per person Eurostat (2022). With 2.1 people per household, the Dutch therefore live relatively large compared to the European average of 2.3 persons per households.

Table 3: Dutch housing stock - Number of rooms

	Average no. of rooms per person:		
	Total	Houses	Apartments
	(1)	(2)	(3)
2018	1.9	1.9	2.0
2019	1.9	1.9	1.9
2020	1.9	1.9	2.0

Source Eurostat, 2022

Since the Dutch government imposed a lockdown in march 2020, the number of people that have at least sporadically worked from home in that year increased by 100.000, which is substantial. The largest increase since the pandemics is the number of people that have almost completely switched from working

[1] counted as the number of rooms in a house excluding bathrooms and kitchens

Table 4: Dutch workforce - number of workers

			Subcategories working from home		
	Total	Never works from home	Total	< 4 days	> 4 days
	(1)	(2)	(3)	(4)	(5)
2019	8.953.000	5.453.000	3.500.000	2.220.000	1.280.000
2020	8.951.000	5.279.000	3.674.000	2.068.000	1.606.000

Source CBS, 2021

at their offices, to working from home. More than 300.000 people in 2020 have switched to working from home compared to 2019. From further research from the CBS, it has become apparent that a high percentage of companies foresee a future in which working from home is structurally incorporated in the work week. These intentions differ heavily between sectors due to the nature of the sectoral work. s In IT, business and financial services and real estate, more than 50 percent of companies expect to incorporate working from home permanently. On the other hand, more than 80 percent of companies within the leisure, transporation and construction sectors indicate that this is not an option due to the nature of the work most of their employees perform.

Identifying whether - and for which - types of housing the demand for a home office has increased could therefore have important implications for the development or redevelopment of the future housing stock. To our knowledge, the impact of increased working from home habits on specific housing characteristics has not been researched so far.

The research question therefore reads:

> *"To what extent has the rise of working from home during the Covid-19 pandemic affected demand and consequently transaction prices of houses with- and without a home office in the Netherlands?"*

The assumption is that working from home possibilities for employees have resulted in different housing demands concerning the number of rooms, in lieu of the need for a home office. It is assumed that people will need more space, in the form of a home office, as they need to be able to work in a quiet environment, undisturbed by other people in the house. In this research, it cannot be determined for certain whether a house has a home office for transaction data. In the data chapter, we elaborate further on the identification of a home office in the data.

1.1 *Relevance of the research*

The Netherlands currently faces a great housing crisis, with soaring prices for real estate and increasing shortages in supply. New construction is already adopting to changing household composition, mobility changes and, admittedly, the need for increased quantity; as the average floor area of rental apartments is decreasing in new developments (Kadaster (2022)). The surge of working from home since the Covid-19 pandemic has furthermore changed commuting and working habits for people, creating the need to rethink and shape future infrastructure, offices and homes. The identification of changed housing demands in light of remote-working has, as of yet, not been pursued yet in the economic literature. As such, this

thesis works towards a better understanding of the effects of remote-working on the Dutch housing markets. Such an enhanced understanding of the complex field of residential real estate post-lockdown can aid policymakers, developers and further real estate professionals in creating demand-minded policies which benefit from the added perspective of remote-working insights.

Furthermore, this paper adds to the real estate literature on Covid-19, by investigating demand changes and price dynamics for the working from home phenomenon. While previous papers have primarily focused on the immediate locational effects of Covid-19 on migration, and subsequent price dynamics within a spatial setting, there has been little focus on changed preferences of housing characteristics and potential price changes. Finally, this paper suggests the time placebo fixed effects regression from Buitelaar et al. (2021) as a method to investigate changed preferences and price premia for housing characteristics, as opposed to spatial dynamics and developments .

1.2 *Outline*

The paper proceeds as follows; first, we give an overview of the literature concerning working from home, specifically its surge during the pandemic. Mainly, we are interested in predictions on the short or long run nature of the working from home phenomenon and its manifestation within the Netherlands. From our findings in the literature, we then formulate some hypotheses which we will test in our results section. Next, we describe the used methods and specification. We consider the data used, and the assumptions we make in creating the variables that proxy our phenomena of interest. We also give an overview of the descriptive statistics. The results of the hedonic difference-in-differences regressions are given, and we also perform some robustness checks. We conclude with a summary, a discussion of the robustness of our results and implications for further research.

[1] e.g. the convergence of house prices between the suburbs and city centers

2 Literature review

Since the Covid-19 pandemic, quite a few papers have been published on the overall effects of the pandemic on the housing market in cities Ramani and Bloom (2021); Gupta, Mittal, Peeters, and Van Nieuwerburgh (2021), ranging from demand for office space, migration between urban centers and suburbs, to research into rents. Much less has been written on the price effects dynamics on housing characteristics due to Covid-19.

First, the focus is on the literature covering the development of working from home, focusing on the drivers of remote working before and since the pandemic. We furthermore discuss the literature on the socio-economic groups that tend to work from home. Next, we discuss the impact of Covid-19 on housing preferences, with a particular focus on working from home as the cause of changed housing needs. We look at both housing characteristics and locational preferences. Lastly, we discuss the economic theory on the difference between short-run shocks and fundamental shocks, and their different impacts on long-run demand change and equilibria for house prices.

2.1 *Working from home*

Working from home has seen a surge since the Covid-pandemic, and has prompted workers to stay home while working for companies which had a physical location that would have required commuting beforehand. There is a burgeoning literature on remote working and working from home, mostly focussing on the phenomenon in the United States, looking at the main drivers of working from home and its effect on spatial mobility patterns, local economics and migration. Before the inception of the pandemic, working from home already saw a surge due to technological prowess which allowed digital communication to replace vis-a-vis working and collaborating. According to the "City Paradox", so called by Althoff, Eckert, Ganapati, and Walsh (2020), highly-educated workers who do not need to live close to CBD or highly productive places anymore due to their remote working opportunities, often live at the most central places. In fact, white-collar workers tend to live more central, while blue-collar workers commute into productive places, has been observed before the start of the pandemic as well. However, Buitelaar et al. (2021) argue that assumptions about the search for bigger, less urban dwellings are often ill-founded in relation to the pandemic and working from home, as they detect a convergence of urban and suburban dwellings before the inception of the Covid-19 pandemic. As such, the authors reject the idea that the pandemic was the sole driver behind trends such as a movement towards more peripheral areas. They do, however, specifically mention that when working from home will be structurally implemented for most companies with working from home potential, then more buyers will look for larger dwellings at larger distances from their office.

Ton et al. (2022) investigate the effects of Covid-19 on tele-working in the Netherlands, and how the short-run adjustments and experiences of different groups might predict more long-run shifts in mobility. They mainly research train-commuters, as they argue that this group is most likely to have changed commuting patterns radically due to the lockdown preventions. Ton et al. (2022) find that people that have jobs with high working from home potential are most positive about the shift to hybrid-working,

and expect to continue at least partially with remote-working in the foreseeable future. De Haas, Faber, and Hamersma (2020) similarly find that a majority of people experience working from home as a positive change, and are likely to adjust their working- and commuting patterns more permanently. The Ministerie van Infrastructuur en Waterstaat (2021) also found in a large-scale survey among more than 1.200 Dutch companies that they expect working from home to stay, mainly due to positive effects on productivity and significant commuting time-reductions. The literature on the Dutch workforce hence all seem to confirm that the Covid-19 pandemic has spurred a change in working- and commuting habits that is likely to last even after health- and mobility restrictions have been completely lifted.

2.1.1 *Who works from home?*

Yasenov (2020) investigated which groups within the US population are most likely to be able to work from home. He found that high-earning and well-educated workers are most likely to have opportunities to work from home. The effects are strongest for highly educated workers in contrast to lower educated workers. However, most indicators of socio-economic class and status display similar patterns in which higher social economic status gives more opportunity for remote working. Van Der Drift, Wismans, and Olde Kalter (2022) also find that in the Netherlands, workers with high income reduced their travel to work significantly more than lower income workers. Ton et al. (2022) find in their respondent data that remote working is most frequent with workers with a higher education. Bick, Blandin, and Mertens (2020) also find in their nation-wide study in the US that education level was strongly related to the probability that a worker was working from home in May 2020. Workers with a high education had almost 7 times as much chance to be working from home compared to workers with a low education. They also find that before the Covid-19 pandemic, similar patterns in terms of who was working from home were present. Teleworking was more ubiquitous for high-earning workers, which correlated with all other socio-economic determinants for working from home such as ethnicity, the type of work and education. Overall, income and education, which are, indeed, already highly correlated seem to have a strong relationship with working from home potential for individuals.

2.2 *Covid-19 and housing*

Davis, Ghent, and Gregory (2021) investigate the elasticity of substitution between working at home and in the office, and find that working from home will likely increase after the pandemic, thereby affecting wages and demand for office space. They do not, however, further investigate how working from home affects demand for workers' own homes. Delventhal, Kwon, and Parkhomenko (2022) similarly predict that working from home is likely to endure, but also focus on the allocation of offices, productivity and residential living within the wider city structures rather than the demands and preferences of employees for their own housing. Bloom (2020) performed a large scale survey under US workers. The results of this study showed that working from home was likely to stay, and that hence, companies and households would consider relocation to less central, cheaper areas in the suburbs. As such, there has been little focus yet on the changed demand due to the Covid-19 working from home surge on residential housing characteristics.

2.2.1 *Locational preferences that changed*

Ouazad (2020) focuses on the shock of Covid-19 on house prices compared to other types of short-run and fundamental shocks. He mainly focuses on locational preferences, rather than the preferences for the house itself. He finds that short-run shocks such as pandemics have temporary effects on urban areas. However, he finds that more fundamental shifts in education levels, industial composition of the town or migration do have lasting impact.

Brueckner, Kahn, and Lin (2021) find that the annual changes in house prices and rents are lower in the counties with high productivity, meaning that places with high-paying jobs with the potential to work from home became less desirable. They use a monocentric city model, which, while being very appropriate for North America, is not very easily applicable to the city structures in the Netherlands.

Similarly, Gupta et al. (2021) also look at difference between urban and suburban locations in the United States. They estimate the bid-rent curves, before and during the pandemic, and find that the curves are flattening, meaning that the price premia for city centers are diminishing relative to more suburban locations. Furthermore, they find that working from home effects on prices are stronger for rents than sales, relating this to the ability of renters to respond more swiftly to such shocks. They do, however, find such significant changes for sale transactions at the postcode level that they foresee long-term effects of working from home too.

Delventhal et al. (2022) and Davis et al. (2021) developed spatial-economic models in which the effects of increased working from home possibilities are related to CBD - suburban dynamics for commuting and residing. Overall, the literature on spatial (re)distribution of workers due to the effects of Covid-19 commonly finds that central districts and places with high productivity have become less dense, while there is a visible shift towards the suburbs and more peripheral areas. As aforementioned, however, as most papers focus on North-American cases, such effects will be more difficult to find in The Netherlands due to the high density and connectivity between Dutch cities.

2.2.2 *The effect of working from home due to covid on the housing preferences*

Tomal and Helbich (2022) look at both changes in preferences for location and housing characteristics. By using the case study of Cracow, they find that Covid-19 caused greater rental dips in the city center and around the university than in more remote suburbs. Their findings again hint at the flattening prices in more productive areas, although they do not explicitly look at working from home as an explanatory factor. Stanton and Tiwari (2021) investigate the expenditure of remote working households and non remote workings households. Their findings are in line with other literature which indicates that remote workers spend more money on housing, mostly due to the fact that they buy and rent larger dwellings with more rooms. Hence, the literature seems to confirm that remote working might influence housing preferences in terms of dwelling size and characteristics

2.3 *Short-run versus mid-run effects*

The hypotheses in this thesis concerning the speed at which the pandemic, and consequently, working from home, would impact lease and sale transactions are founded in economic theory concerning real

estate prices adjustments, in particular adjustments to exogenous shocks. These hypotheses are described at the end of this chapter. A well-known model discussing both rents and sales prices of real estate is the four-quadrant model of DiPasquale and Wheaton (1992). They study the dynamics between two markets; the market for real estate space (occupiers) and the market for real estate assets. In this model, rents first adjust to changed demand in the occupier market, after which sale prices are determined by the return. Of course, the four-quadrant model considers the entire real estate market; while the hypotheses in this thesis expect diverging prices for different types of dwellings. However, the model does allow for a simple simulation in which we can model a positive exogenous shock as working from home for demand for houses with a home office, and see how this affects rents first, after which sales prices will follow. Ouazad (2020) find that while housing markets might react to shocks in the short-run, there is little evidence that exogenous shocks, such as pandemics however, have long-lasting effects. They argue that, since house prices capitalize the entire flow of future rents, they are resilient to short-run shocks. Yet while the event we study coincides with exactly the sort of short-run shock Ouazad (2020) and Francke and Korevaar (2021) describe as having little impact on sales prices in the long-run, the focus is more on the working from home shift incepted by the pandemic. Furthermore, as aforementioned studies have shown, the working from home shift is likely to cause a more fundamental shift in our mobility patterns and housing preferences. As such, we expect that while the immediate effects of the pandemic in terms of movements and house prices such as in the United States might not be permanent or the sole driver of such migration, working from home does have a structural impact on housing demand.

2.4 *Key-takeaways*

As the number of people working from home in the Netherlands increased substantially since the Covid-19 pandemic, more and more workers have now experienced the benefits of working from home on a more permanent basis. Ton et al. (2022) and De Haas et al. (2020) have indicated that working from home, for at least part of the week, is therefore likely to remain a more permanent working habit for workers with working from home potential. This working from home potential is often defined as having a professional service- or office job that requires higher education levels.

In the United States, the pandemic and working from home have instigated a migration of high-earning, well-educated households from productive areas such as CBD's to more peripheral locations, in larger dwellings. This development is thought to be caused by concurrent shocks and trends, such as the fear of contagion, but also a priori existing developments such as the gradual increase of remote workers.

Lastly, the dynamics between rent and sales price follow a pattern in which rents react first to a demand shock, after which the house prices change as to now incorporate the new entire flow of future rents. While pandemics themselves are classified as short-run shocks with little long-run impact on rents and sale prices, fundamental social, industrial and demographic shocks and developments can establish new equilibria. Assuming that working from home concerns a more permanent shift in demand, we therefore expect a shift in rents and, eventually, sales prices.

2.5 *Hypotheses*

Following the previous findings of the existing literature, we will test the following hypotheses:

Hypothesis 1 *The marginal price of a home office will have increased due to increased demand for a space to work from home following the growing hybrid-working habits.*

Due to the increase of working from home, housing preferences will have changed as to cater to the need to be able to concentrate on work within the home. Houses have gained an additional function; namely that of an office, and thus the preferred characteristics of houses will change accordingly. The marginal price households are willing to pay for an extra room will have increased due to the new-found use of the home office.

Hypothesis 2 *The price effect will have been the strongest for rental houses at first.*

Economic theory dictates that rents are indicative of the the current flow value of houses, while house prices capitalize current and future flow values. As such, we expect that the early shock of the lockdown and remote working will first be visible in a relative increase in rents for houses with a home office compared to houses without a home office.

Hypothesis 3 *The price effect will have become gradually stronger for sale transactions, as these indicate the long-run change in mobility due to remote working.*

As working from home becomes more of a long-run trend during the pandemic, the changed housing preferences in terms of floor area and home offices will have been capitalized in the sales prices of houses.

Hypothesis 4 *The price effect will have become gradually stronger outside of the G4, as people move further away from work, commute less and increase their remote-working days.*

Following the findings in the economic literature, it is observed that the further people have to commute, the more attractive working from home becomes. As such, we expect price effects to be the largest outside of the G4, as most offices are concentrated in the Randstad and most people outside of the G4 will probably have to commute for their work.

Hypothesis 5 *The price effect will have been stronger in neighborhoods with a well-educated demographic.*

Preliminary research has shown that people that are well-educated are most likely to work-from-home. This is mainly attributed to the fact that most jobs that have well-educated workers - such as professional service jobs - do not require, for example, physical machinery to be able to work, or direct sales to consumer. We do not have household level data concerning the transacted properties, and hence, this limits us in testing whether well-educated households have started paying a price premium for a home office. We do, however, have information at the district-level on education levels. By assuming that

[1] in retail or the food- and drinks sector e.g.

segregation based on education level (and other socio-economic indicators) remains unchanged, we thus expect well-educated households to pay a price premium for houses in the neighborhoods that they would like to live in. This would include both people moving from one well-educated neighborhood to another well-educated neighborhood. We therefore assume that in neighborhoods where many well-educated people live, demand for home offices will have been stronger and therefore price-effects greater.

Hypothesis 6 *Homes without a home office will be listed longer due to Covid and working from home than houses with a home office.*

As a similar proxy for changinge preferences - and hence - demands, the change in the number of days a property is listed is analysed. This is also an independent variable suggested by Gautier, Siegmann, and Van Vuuren (2009) as to measure demand changes ahead of prices, when prices display stickyness. As more people have the need for larger dwellings, increased demand will shorten the matching time for such properties and thus result in shorter listing times.

3 Methodology

3.1 *Event studies theory and model*

Most aforementioned studies use a hedonic price regression, extended with fixed effects, as their base model. Gautier et al. (2009) investigate whether house prices in neighborhoods with a high percentage of non-western immigrants were negatively affected by the murder on Theo van Gogh. The authors likewise use a fixed effects specification with fixed effects, using a dummmy for the variable of interest. They furthermore test for sticky prices, and serial correlation. Also, due to the unwillingness of sellers to immediately lower prices, they also test their assumptions looking for longer "time-on-the-market" for houses in neighborhoods with more non-western immigrants.

Tomal and Helbich (2022) use a hedonic price regression, yet extend it with a geographically and temporally weighted regression, developed by Huang, Wu, and Barry (2010). The model uses one focal point in time and place, and lets observations take on a relative weight from that focal point. Tomal and Helbich (2022) argue that variation is most likely to be the largest around a shock, and hence they allocate the most weight to transactions directly after the lockdown, and closest to the city center. This approach is perhaps more appropriate for single city case studies.

Claassens and Koomen (2017) use a fixed effects regressions, measuring these effects at the municipal level. They create a vector with additional spatial variables, such as distances to different amenities and include these in the dataset. The addition of extra spatial variables mostly had to do with the fact that Claassens and Koomen (2017) were interested in the effect of these spatial and environmental factors, while the variable of interest in this research is primarily that of the presence of a home office.

In this research, it is assumed that the fixed effects capture such spatial heterogeneity sufficiently, hence making the inclusion of locational variables such as distance to school in this dataset obsolete.

3.2 *Used model - difference-in-difference*

To capture the effect of the working from home surge since the Covid-19 pandemic and lockdowns, we make use of a time-dependent difference-in-differences model like Buitelaar et al. (2021) in their research on the Dutch housing market before and after Covid-19. Difference-in-difference models are very commonly used, and rely on the parallel trends assumption. This assumption dictates that the control- and treatment group would have followed the same trends in the absence of the treatment. Here, the control group are the transactions without a home office, and the treatment group are all the transactions with a home office. In the context of this research then, the price development of houses with- and without a home office would have followed similar trends, controlling for other characteristics of course. The model is defined as follows:

[1]The motive of his murder primarily had to do with his anti-islamic stance and support for atheistic and islam-critic politicians and other public figures.

$$y_{it} = \beta_0 + \beta_1 \text{Treatment}_i + \beta_2 \text{Post-Treatment Period}_t + \beta_3(\text{HomeOffice}_i \times \text{Post-Treatment Period}_t) + x'_{i\ell t}\,\beta + \epsilon_{i\ell t} \tag{1}$$

Where the estimator β_3 is calculated as the difference in effect for the houses with a home office and without one:

$$\begin{aligned}\hat{\beta}_3 = &[\overline{P}_{\text{HomeOffice=1,CovidYear=1}} - \overline{P}_{\text{HomeOffice=1,CovidYear=0}}] \\ &- [\overline{P}_{\text{HomeOffice=0,CovidYear=1}} - \overline{P}_{\text{HomeOffice=0,CovidYear=0}}]\end{aligned} \tag{2}$$

General concerns with difference-in-differences models are less pervasive for research on the housing market Baker, Larcker, and Wang (2022). As houses are immovable, concerns about mobility between treatment and control group are eliminated for my particular research. Furthermore, the Covid-19 pandemic and subsequent surge of working from home advices and obligations in the Netherlands could be considered an exogeneous and unanticipated event, neither affecting the treatment and control group, further limiting possible mobility or anticipation between the treatment- and control group.

There are concerns about concurrent developments such as high inflation, more accessible mortgage financing options and overall cyclical effects on transaction prices. In this paper, these developments are controlled for by including time fixed effects for each year.

3.3 *Empirical specification*

3.3.1 *Difference-in-differences model*

We specify our difference-in-differences model as follows; with a treatment group that consists of houses with at least one home office, and the post-treatment period as the period after the inception of the Covid-19 pandemic.

$$\begin{aligned}\ln P_{i\ell t} = &\gamma \text{HomeOffice}_i + \zeta \text{CovidYear}_t + \theta(\text{HomeOffice}_i \times \text{CovidYear\_}t) \\ &+ x'_{i\ell t}\,\beta + \eta_\ell + \mu_t + \epsilon_{i\ell t}\end{aligned} \tag{3}$$

where $P_{i,\ell,t}$ is the log of the price of transaction i located in submarket ℓ at time t. This can be either a sale transaction or rental transaction, and P is the log of the rent per square meter.

HomeOffice is a dummy variable that denotes whether the transacted property has no, one or more than two home office or home offices respectively, where γ, measures the effect of the working from home-surge for our treatment group of houses with at least one home office.

We also include a dummy which indicates whether the transaction took place either before Covid-19, in the first year (from 01-03-2020 until 01-03-2021) or in the most recent year (from 01-03-2021 till now) as to be able to see whether the price premia develop over time. While the first lockdown was officially

installed the 16th of march, the first of march is used for simplicity in further index calculations. This is especially of interest for the sale transactions as these adjust in reaction to changing rental prices, and might therefore not be visible yet in the first year. ζ thus captures the effect of either of these years and the effect of the lockdown and working from home measures, and allows us to look at pre- and post-treatment differences.

The vectors $\eta_\ell = (\eta_1, \ldots, \eta_L)$ and $\mu_t = (\mu_1, \ldots, \mu_T)'$ are location- and time fixed effects that capture spatial- and temporal variations in prices. Fixed effects are measured at the PC4 level. The fixed effects regression thereby removes the variation that exists between the PC4 levels, which allows us to investigate within-group variation for the variables of interest. This will therefore give a more unbiased estimator of the effect of the home office, rather than variation between PC4 areas on price. Controlling for spatial variation at the PC4 level will presumably lower the variation between the location dummies, as heterogeneity between PC4 areas will be lower than between municipalities.

We also include an interaction term of the variable of interest; HomeOffice, and the pre- and post treatment dummy. The effect of a potential home office during Covid-19 is measured with θ.

The vector x and the corresponding time-and space invariant parameter β include the impact of property characteristic control variables on prices. These include the construction year, property type, maintenance state, energylabel and the log of the floor area.

The error term ϵ is assumed to be normally distributed with mean zero and standard deviation σ_ϵ We furthermore use a two-way fixed effects model with clustered standard errors by submarket.[2]

3.3.2 *Difference-in-difference-in-differences model - outside the G4*

Next, the model for the investigation of the fourth hypothesis, concerning price premia for houses outside the G4 with a home office, is defined. Herefore, the difference-in-difference-in-differences model, described by Wooldridge (2007) and Olden and Møen (2020), is used in order to see the effects between an additional grouping distinction, namely that of transactions inside- and outside the G4. This model is fairly underdocumented, yet has been used in several economic papers over the years (Walker (2013),Gruber (1994)). The underlying parallel trendss assumption is in essence similar to that of the difference-in-differences model; namely that the difference between the outcomes of two groups in the treatment state, are the same as the difference between these groups in the control state. In the context of this research, this means that the difference between transactions inside- and outside the G4 with a home office, is the same as the difference beteween transactions inside- and outside the G4 without a home office.

The difference-in-difference-in-differences model is specified as follows:

[2]Using the felm package in R

$$
\begin{aligned}
y_{it} = {} & \beta_0 + \beta_1 \text{Treatment}_i + \beta_2 \text{Post-Treatment Period}_t + \beta_3 \text{Group}_i \\
& + \beta_4(\text{HomeOffice}_i \times \text{Post-Treatment Period}_t) \ + \beta_5(\text{HomeOffice}_i \times \text{Group}_i) \\
& + \beta_6(\text{Group}_i \times \text{Post-Treatment Period}_t) + \beta_7(\text{HomeOffice}_i \times \text{Group}_i \times \text{Post-Treatment Period}_t) \\
& + x'_{i\ell t}\,\beta + \epsilon_{i\ell t}
\end{aligned}
\tag{4}
$$

The estimator β_7 is therefore, simply, the difference between two difference-in-difference estimations. The calculation of this estimator is specified below, using the control- and treatment, pre-and post, and additional difference-in-difference-in-differences groups used in this research, for the difference in transactions inside- and outside the G4:

$$
\begin{aligned}
j\hat{\beta}_7 = {} & [\overline{P}_{\text{HomeOffice=1,OutsideG4=1,CovidYear=1}} - \overline{P}_{\text{HomeOffice=1,OutsideG4=1,CovidYear=1}}] \\
& - [\overline{P}_{\text{HomeOffice=0,OutsideG4=1,CovidYear=1}} - \overline{P}_{\text{HomeOffice=0,OutsideG4=1,CovidYear=0}}] \\
& - [\overline{P}_{\text{HomeOffice=1,OutsideG4=0,CovidYear=1}} - \overline{P}_{\text{HomeOffice=1,OutsideG4=0,CovidYear=0}}] \\
& - [\overline{P}_{\text{HomeOffice=0,OutsideG4=0,CovidYear=1}} - \overline{P}_{\text{HomeOffice=0,OutsideG4=0,CovidYear=0}}]
\end{aligned}
\tag{5}
$$

In this research context, the following specification is used for estimating the hedonic price regression:

$$
\begin{aligned}
\ln P_{i\ell t} = {} & \gamma \text{HomeOffice}_i + \zeta \text{CovidYear}_t + \lambda \text{OutsideG4}_i \\
& + \theta(\text{HomeOffice}_i \times \text{CovidYear}_t) + \rho(\text{CovidYear}_t \times \text{OutsideG4}_i) + \omega(\text{HomeOffice}_i \times \text{OutsideG4}_i) \\
& + \psi(\text{HomeOffice}_i \times \text{CovidYear}_t \times \text{OutsideG4}_i) + x'_{i\ell t}\,\beta + \mu_t + \epsilon_{i\ell t}
\end{aligned}
\tag{6}
$$

The sign λ considers the difference between transactions inside and outside of the G4, the four largest cities in The Netherlands, where OutsideG4 is a dummy that is 1 when the municipalitycode corresponding to the transaction was not one of the G4 municipalitycodes.

We also include an interaction term of the Covid dummy and the Outside of the G4 dummy, where the sign ρ captures the efect of a property outside of the G4 transacted during Covid-19. We furthermore include an interaction term of the HomeOffice dummy and the Outside of the G4 dummy, where the sign ω captures the effect of a house with at least one home office transacted outside of the G4. Finally, our interaction term of interest is that of the Covid-19, HomeOffice and Outside of the G4 dummies, where ψ captures the effect of a house with at least one home office, transacted during Covid-19 outside of the G4. The effect of ψ is explained above in formula (5).

3.3.3 *Difference-in-difference-in-differences model - Education*

The third model is largely based on the difference-in-differences model used by Gautier et al. (2009). They use data on the ethnic composition of neighborhoods to create control- and treatment group to see whether neighborhoods with a high percentage of people with a non-western ethnic background, specifically from North-African or Middle-Eastern countries, experienced price-drops after the Theo van Gogh murder. Likewise, we use data on the district level level to determine a treatment group; namely neighborhoods where a high percentage of people live that are likely to work from home. This model uses education levels, respectively, in line with the literature on remote-working demographics which finds a correlation between socio-economic status and working from home. Using these statistics, we will be able to make a distinction between neighborhoods where working from home will have been more or less pervasive since the Covid-19 pandemic.

As such, we estimate a model in which we use an additional control and treatment group based on income level, to see whether effects in neighborhoods with a high income level is stronger.

$$\begin{aligned}\ln P_{i\ell t} = {} & \gamma \text{HomeOffice}_{\,i} + \zeta \text{CovidYear}_{\,t} + \phi \text{Education}_{\,i} + \theta(\text{HomeOffice}_{\,i} \times \text{CovidYear}_{\,t}) \\ & + \xi(\text{HomeOffice}_{\,i} \times \text{Education}_{\,i}) + \kappa(\text{Education}_{\,i} \times \text{CovidYear}_{\,t}) \\ & + \pi(\text{HomeOffice}_{\,i} \times \text{CovidYear}_{\,t} \times \text{Education\_}i) + x'_{i\ell t}\,\beta + \mu_t + \epsilon_{i\ell t}\end{aligned} \tag{7}$$

Education is a dummy indicating whether more than 30,2 percent of the neighborhood has a hbo or wo degree, where ϕ measures the effect when the dummy is 1. ξ measures the effect when a transacted house has at least one home office and was transacted in a neighborhood with a high percentage of well-educated people. We also include an interaction term with sign κ which measures the effect when a transacted house was sold during Covid-19 in a neighborhood with a high percentage of well-educated people. We furthermore include an interaction variable of a high education level with home offices during Covid-19, to see what the price effect has been for houses with a home office in high-earning neighborhoods. This effect is denoted by the sign π.

3.3.4 *Days model*

Finally, we estimate a model in which we look at the effect of working from home during the pandemic on the listing time of properties with a home office:

$$\begin{aligned}\ln D_{i\ell t} = {} & \gamma \text{HomeOffice}_{\,i} + \zeta \text{CovidYear}_{\,t} + \theta(\text{HomeOffice}_{\,i} \times \text{CovidYear\_}t) \\ & + x'_{i\ell t}\,\beta + \eta_\ell + \mu_t + \epsilon_{i\ell t}\end{aligned} \tag{8}$$

where $\ln D_i$ is the log of the number of days that a property is listed.

4 Data and Descriptive Statistics

4.1 *Data*

4.1.1 *NVM transactions*

We will use transaction data from the NVM database on either rentals or sales. The NVM is the national association of realtors in The Netherlands. The database includes all transactions that are established via realtors that are members of the NVM. For the years 2010 until 31st of march 2022, the raw dataset includes 2.081.997 price observations, of which 299.473 rental transactions and 1.809.883 sale transactions. The NVM database includes actual transaction prices, as opposed to listing prices on platform such as Funda or Pararius, thereby offering a more accurate picture of the price effects of different types of houses. The dataset is enriched with each property's ID from the Dutch Basic Registration of Addresses and Buildings (BAG) from Kadaster, which contains all buildings in the Netherlands.

There are significantly fewer rental transactions in the database as opposed to sale transactions. This can be attributed to the fact that in 2021 there are almost 8 times as many owner-occupied houses (4.549.480) than private (liberalized) rental houses (1.106.2572) according to the CBS (2021). From these rental houses, an even smaller percentage falls outside of the liberalization rules. In 2018, of the 3.007.000 rental houses, 482.000 were liberalized voor de Leefomgeving (2019). Both the sale- and lease transactions are, however, of such a substantial size that there is little concern for biases.

4.1.2 *CBS neighborhood- and district data*

Furthermore, the dataset contains CBS information on the district codes, and relating demographic and social-economic data, needed to create the treatment and control group for the third model which investigates differences between types of neighborhoods. The CBS publishes yearly statistics per district on socio-economic demographics. As there is a lag in the publishing of this data, the most recent, complete dataset is that of 2019. District composition pertaining the overall education level, however, is not likely to change significantly across the entire country within the span of 1 to 3 years, however. As such, we assume that the education level of 2019 will still be a solid indicator of working from home potential at the district level.

4.1.3 *Assumptions*

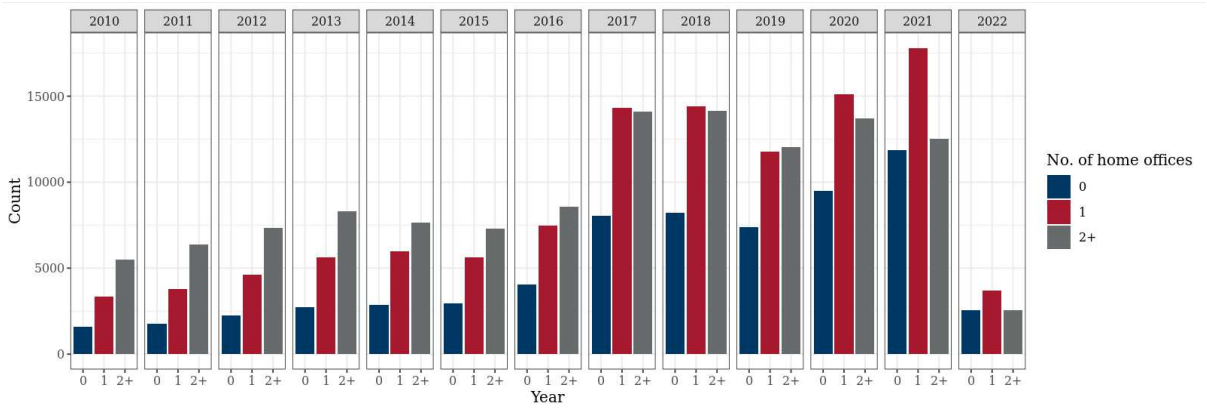
1. For lease transactions, there is a potential home office when there are at least two bedrooms. It is assumed that at least one bedroom is needed for sleeping, and that by default the additional bedroom will have the potential of being a home office. It is not taken into account that such additional rooms will not be used as a home office.

2. For sale transactions, there is a potential home office when there are at least three bedrooms. As is visible from figure 1, the number of transactions that concern houses with home offices is more

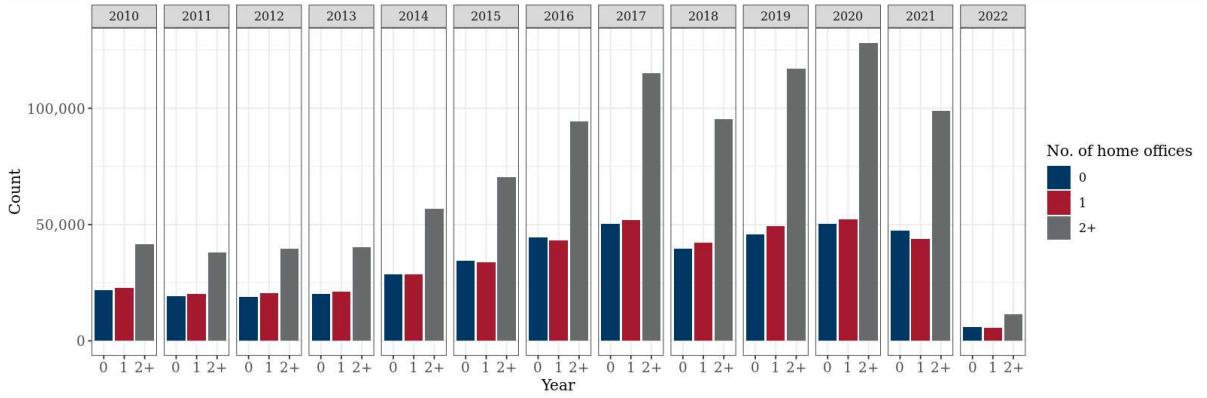
[2]Data on the *wijk* according to the CBS classification

Figure 1: Number of transactions

(a) Lease



(b) Sale



disparate for the sale transactions than for the lease transactions. This is additionally shown in the average number of rooms and floor area in table 5. It is therefore assumed that due to the fact that sale transactions often concern larger houses, at least three bedrooms are - on average - needed for sleeping, and that by default the additional fourth bedroom will have the potential of being a home office. It is not taken into account that such additional rooms will not be used as a home office.

3. It is assumed that the shock effect of working from home incepted at the start of the pandemic, when the first lockdown was initiated by the government.

4. It is assumed that the possibility that someone works from home can be proxied by the level of education; as is confirmed by the literature.

   (a) It is assumed that well-educated is defined by having a hbo or wo degree, following the definition of the CBS.

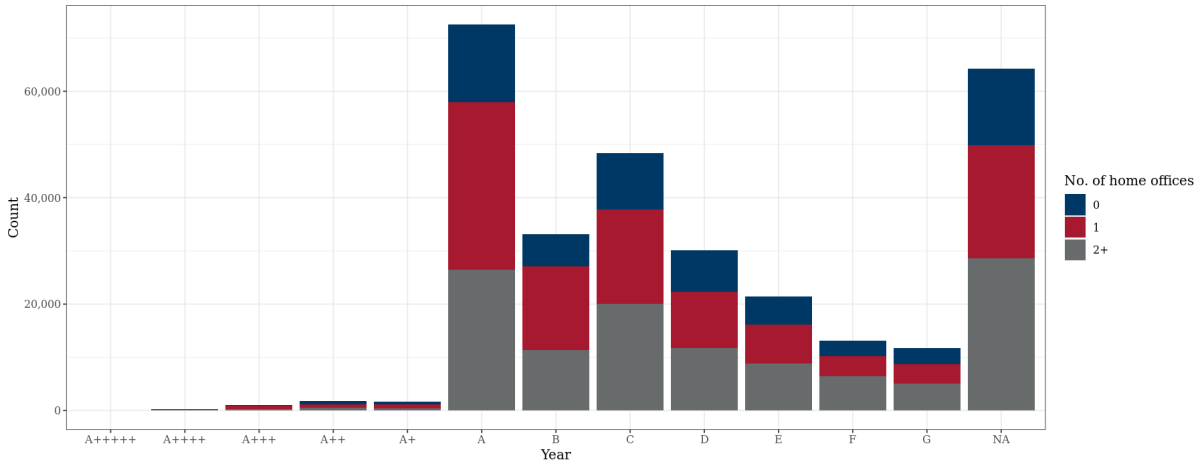
   (b) It is assumed that a neighborhood can be labelled as a "well-educated" neighborhood if it has a higher percentage of high-educated people than the national average of 30.3 percent.

5. The date at which a house enters the market is identified as the date that the NVM-broker uploads the listing in the NVM portal.

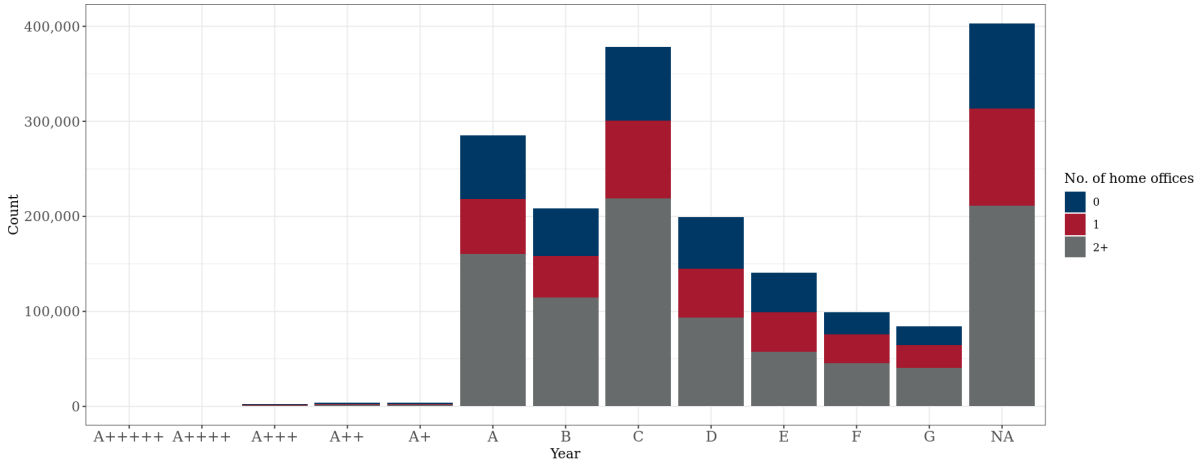
6. The transaction date is identified as the date that the deed was signed.

Figure 2: Number of transactions - Energylabel

(a) Lease



(b) Sale

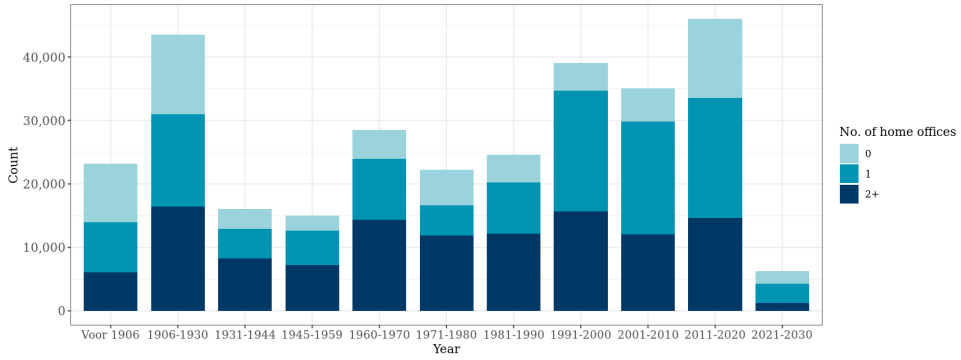


4.1.4 *Descriptive Statistics*

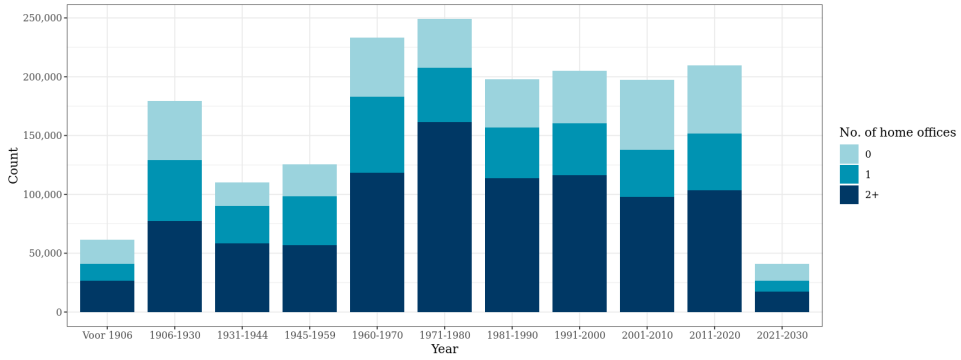
Tables 4 and 5 give an overview of the descriptive statistics of the dataset, seperated in both lease and sale transactions. A table with the cleaning measures for removing outliers can be found in the appendix. Some diffferences between the lease and sale transactions must be noted. Firstly, the listing time is almost twice as long for sale transactions than for lease transactions. This makes sense in the context of the monetary value of the transaction, as well as the flexibility that leasing has with respect to owning a house. Furthermore, the average number of rooms- and bedrooms is larger for sale transactions than for lease transactions. This is accounted for in the definition of the minimum number of rooms for a potential home office. Of the lease transactions, 30 percent of all transactions took place in the G4, while for the sale transactions, this was only 10 percent. Lastly, it is interesting to see that lease transactions more often took place in districts with a high percentage of well-educated people.

Figure 3: Number of transactions - Construction

(a) Lease



(b) Sale



The control variables for the construction period and energylabel are illustrated by figures 2 and 3, respectively. As a large number of transactions do not include an energylabel, quite some transactions are therefore left out of the regressions. For the lease transactions, a notable portion of all properties either falls in the construction period of 1906-1930, and the periods from 2000 onwards. For the sale transactions, the properties are more evenly spreads over all construction periods. Figure 4 shows the average floor area of properties with no, one or 2 or more potential home offices. The dotted vertical line denotes the moment when the Covid-19 pandemic started in the Netherlands. The development of this average is parallel for all 3 types of properties, for both lease and sale transactions.

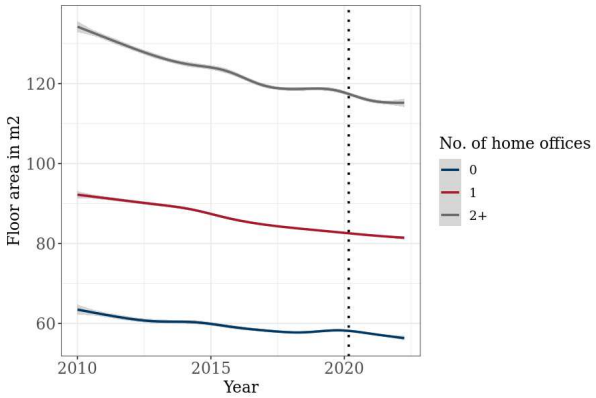
4.1.5 *Development of prices over time*

Figures 5 and 6 show a price and rent index over time. The index is calculated over monthly averages, and march 2020 is the starting point of the index (index = 100). The dotted vertical line denotes the point in time where the rent and sale price index is 100. For the lease transactions, there is a visible divergence between the properties with and without at least one home office from the point where the Covid-19 pandemic started. For the lease transactions, there seems to be more of a parallel development between properties with- and without at least one home office.

A major assumption for this paper is that the working from home surge was spurred by the Covid-19 pandemic, and was not a pre-existing trend. While this issue is discussed and analysed in the robustness tests in the results chapter, the figures with the index development of the lease- and sale transactions do not show any signs of an a priori trend in which properties with a potential home office diverged from

Figure 4: Number of transactions - Floor area

(a) Lease



(b) Sale

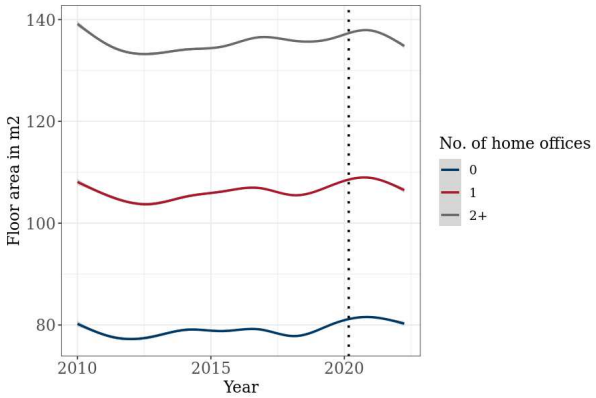


Table 5: Descriptive Statistics lease transactions

Variable	*Description*	N	Mean	St. Dev.	Min	Max
Rent	*Transacted rental price per month*	299,473	1,196	567	100.0	5,000
DaysOnMarket	*Number of days between the listing and signing of the deed*	299,473	64.4	84	2	1,000
FloorArea	*Square meters that are usable living spaces and where the ceiling is >1,50 meters*	299,473	93.5	36.6	25	250
NumberRooms	*Number of rooms excluding kitchens and bathrooms*	299,473	3.5	1.4	1	24
NumberBedrooms	*Number of rooms excluding kitchens, bathrooms and a living area*	221,584	2.3	1.1	0	20
OutsideG4	*A dummy, which has value 1 if the transacted house was located outside of the G4*	299,473	0.7	0.5	0	1
IsCovid	*A dummy, which takes value Covid year 1 if the transaction took place between 01-03-2020 and 01-03-2021, and value Covid year 2 if the transaction took place after 01-03-2021*	299,473	0.1	0.3	0	1
PctHoogOpgeleiden	*The percentage of people with at least an undergraduate HBO- or WO bachelor in the district*	283,925	0.4	0.2	0.0	1

Notes: The table presents descriptive statistics for the lease transactions. The dataset concerns the NVM transactions containing rental and sales transactions from 2010 untill 2022.

properties without a potential home office.

Table 6: Descriptive Statistics sale transactions

Variable	*Description*	N	Mean	St. Dev.	Min	Max
PurchasePrice	*Transacted sales price*	1,809,883	298,112	169,571	50,000	2,500,000
DaysOnMarket	*Number of days between the listing and signing of the deed*	1,809,883	122.7	167.5	2	1,000
FloorArea	*Square meters that are usable living spaces and where the ceiling is >1,50 meters*	1,809,883	115.5	38.0	25	250
NumberRooms	*Number of rooms excluding kitchens and bathrooms*	1,809,883	4.5	1.4	1	25
NumberBedrooms	*Number of rooms excluding kitchens, bathrooms and a living area*	1,379,491	3.1	1.2	0	16
OutsideG4	*A dummy, which has value 1 if the transacted house was located outside of the G4*	1,809,883	0.9	0.3	0	1
IsCovid	*A dummy, which takes value Covid year 1 if the transaction took place between 01-03-2020 and 01-03-2021, and value Covid year 2 if the transaction took place after 01-03-2021*	1,809,883	0.2	0.4	0	1
PctHoogOpgeleiden	*The percentage of people with at least an undergraduate HBO- or WO bachelor in the district*	1,663,720	0.3	0.1	0.0	1.0

Notes: The table presents descriptive statistics for the sale transactions. The dataset concerns the NVM transactions containing rental and sales transactions from 2010 untill 2022.

Figure 5: Index - Lease transactions

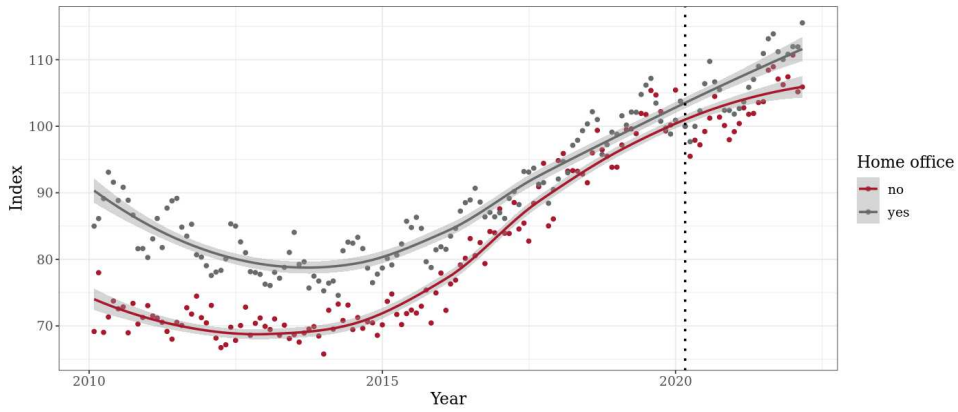
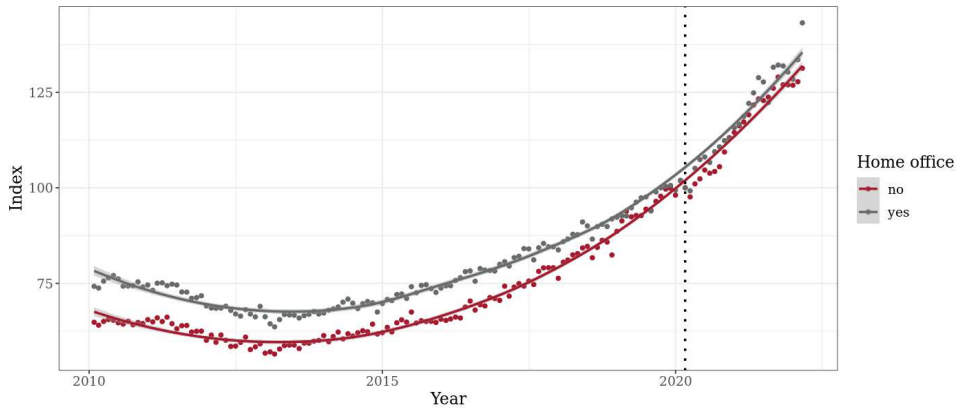


Figure 6: Index - Sale transactions



5 Results

5.1 *Lease and sale transactions*

The tables 6 and 7 show the results of the difference-in-differences, and difference-in-difference-in-differences models respectively. The description and analysis of the results will be structured around the hypotheses specified in the literature review.

Table 7: Fixed effects regression lease transactions

	Dependent variable:			
	Log of the rent			Log of listing time
	(1)	(2)	(3)	(4)
HomeOffice(1)	0.003 (0.005)	-0.031^{**} (0.012)	-0.020^{*} (0.012)	−0.029 (0.020)
HomeOffice(2+)	0.006 (0.005)	-0.079^{***} (0.027)	-0.048^{***} (0.018)	0.013 (0.022)
CovidYear1	-0.011^{**} (0.005)	-0.048^{***} (0.014)	0.027^{**} (0.013)	−0.0004 (0.027)
CovidYear2	0.010^{*} (0.006)	-0.027^{**} (0.011)	0.091^{***} (0.013)	-0.101^{***} (0.031)
OutsideG4		-0.320^{***} (0.024)		
HighEducation			0.266^{***} (0.019)	
HomeOffice(1)×CovidYear1	0.016^{***} (0.005)	0.005 (0.013)	0.016 (0.012)	−0.028 (0.029)
HomeOffice(2+)×CovidYear1	0.026^{***} (0.005)	0.042^{*} (0.023)	0.006 (0.014)	-0.127^{***} (0.029)
HomeOffice(1)×CovidYear2	0.017^{***} (0.005)	0.012 (0.009)	0.007 (0.012)	-0.045^{*} (0.026)
HomeOffice(2+)×CovidYear2	0.053^{***} (0.006)	0.039^{*} (0.022)	0.017 (0.013)	-0.170^{***} (0.026)
CovidYear1×OutsideG4		0.067^{***} (0.016)		
CovidYear2×OutsideG4		0.096^{***} (0.014)		
HomeOffice(1)×OutsideG4		−0.012 (0.016)		
HomeOffice(2+)×OutsideG4		−0.010 (0.032)		
HomeOffice(1)×CovidYear1×OutsideG4		0.018 (0.016)		
HomeOffice(2+)×CovidYear1×OutsideG4		−0.036 (0.027)		
HomeOffice(1)×CovidYear2 ×OutsideG4		0.016 (0.014)		
HomeOffice(2+)×CovidYear2 ×OutsideG4		0.004 (0.026)		
HomeOffice(1)×HighEducation			0.004 (0.015)	
HomeOffice(2+)×HighEducation			−0.001 (0.022)	
CovidYear1×HighEducation			-0.050^{***} (0.014)	
CovidYear2×HighEducation			-0.089^{***} (0.014)	
HomeOffice(1)×CovidYear1×HighEducation			−0.001 (0.015)	
HomeOffice(2+)×CovidYear1×HighEducation			0.025 (0.019)	
HomeOffice(1)×CovidYear2×HighEducation			0.012 (0.015)	
HomeOffice(2+)×CovidYear2×HighEducation			0.048^{**} (0.019)	
Construction period	Yes	Yes	Yes	Yes
Property type	Yes	Yes	Yes	Yes
Energylabel	Yes	Yes	Yes	Yes
Maintenance state	Yes	Yes	Yes	Yes
Fixed effect Year	Yes	Yes	Yes	Yes
Fixed effect PC4	Yes	No	No	Yes
Observations	125,478	125,478	125,478	125,478
Adjusted R^2	0.781	0.512	0.506	0.164
Residual Std. Error	0.175 (df=122409)	0.262 (df=125403)	0.263 (df=125403)	0.869 (df=122409)

Notes: The table presents the effects of the presence of a home office and Covid-19 on rental prices, using the dataset of the NVM transactions containing rental and sales transactions registered at the Dutch association of realtors from 2010 untill 2022. The model is run in a log-linear, with the exception of the floor area, for which we use the log. The other explanatory variables are mainly control variables for the type of property such as construction period and maintenance state. We also included a dummy indicating whether a transaction was made for a property in the G4 or outside of the G4. We furthermore included interaction variables to see whether there was a price premium for home offices outside of the G4. We include a dummy indicating whether a transaction was made in a district with a high percentage of well-educated people. We furthermore include an interaction variable to see whether there was a price premium for home offices in these districts with a high potential for remote workers. Fixed effects on the year and PC4 level are included, and standard errors are clustered at the PC4 level as well. Per variable, the coefficient and the standard error of the coefficient are displayed. Finally, the number of observations and the adjusted R-squared are demonstrated for all four models. The asterixes ***, ** and * denote statistical significance at the 1, 5 and 10 percent level, respectively. The standard errors p-value are denoted by parentheses.

Hypothesis 1 *The marginal price of a home office will have increased due to increased demand for a space to work from home following the growing hybrid-working habits.*

The signs for the interaction terms between Covid-19 and the presence of at least one home office are highly significant. For homes with one home office, the effect in the first and second year is roughly

Table 8: Fixed effects regression sale transactions

	Dependent variable:			
	Log of transaction price			Log of listing time
	(1)	(2)	(3)	(4)
HomeOffice(1)	0.0002 (0.002)	-0.114^{***} (0.013)	-0.023^{***} (0.005)	0.003 (0.006)
HomeOffice(2+)	0.002 (0.002)	-0.088^{***} (0.019)	-0.017^{***} (0.006)	-0.047^{***} (0.007)
CovidYear1	0.074^{***} (0.002)	0.073^{***} (0.007)	0.095^{***} (0.004)	-0.207^{***} (0.010)
CovidYear2	0.171^{***} (0.003)	0.164^{***} (0.008)	0.199^{***} (0.005)	-0.310^{***} (0.012)
OutsideG4		-0.344^{***} (0.023)		
HighEducation			0.311^{***} (0.013)	
HomeOffice(1)×CovidYear1	-0.013^{***} (0.002)	-0.011 (0.010)	-0.028^{***} (0.004)	-0.075^{***} (0.009)
HomeOffice(2+)×CovidYear1	-0.032^{***} (0.002)	-0.001 (0.010)	-0.045^{***} (0.004)	-0.059^{***} (0.009)
HomeOffice(1)×CovidYear2	0.0001 (0.003)	-0.007 (0.009)	-0.023^{***} (0.004)	-0.140^{***} (0.009)
HomeOffice(2+)×CovidYear2	-0.017^{***} (0.003)	0.001 (0.012)	-0.039^{***} (0.004)	-0.196^{***} (0.009)
CovidYear1×OutsideG4		0.025^{***} (0.008)		
CovidYear2×OutsideG4		0.036^{***} (0.009)		
HomeOffice(1)×OutsideG4		0.067^{***} (0.015)		
HomeOffice(2+)×OutsideG4		0.054^{**} (0.021)		
HomeOffice(1)×IsCovidYear1×OutsideG4		-0.016 (0.010)		
HomeOffice(2+)×IsCovidYear1×OutsideG4		-0.046^{***} (0.010)		
HomeOffice(1)×CovidYear2 ×OutsideG4		-0.010 (0.010)		
HomeOffice(2+)×CovidYear2 ×OutsideG4		-0.039^{***} (0.012)		
HomeOffice(1)×HighEducation			-0.050^{***} (0.010)	
HomeOffice(2+)×HighEducation			-0.031^{**} (0.013)	
IsCovidYear1×HighEducation			-0.021^{***} (0.006)	
CovidYear2×HighEducation			-0.041^{***} (0.007)	
HomeOffice(1)×IsCovidYear1×HighEducation			0.032^{***} (0.007)	
HomeOffice(2+)×IsCovidYear1×HighEducation			0.013^{*} (0.007)	
HomeOffice(1)×CovidYear2×HighEducation			0.048^{***} (0.008)	
HomeOffice(2+)×CovidYear2×HighEducation			0.038^{***} (0.007)	
Construction period	Yes	Yes	Yes	Yes
Property type	Yes	Yes	Yes	Yes
Energylabel	Yes	Yes	Yes	Yes
Maintenance state	Yes	Yes	Yes	Yes
Fixed effect Year	Yes	Yes	Yes	Yes
Fixed effect PC4	Yes	No	No	
Observations	963,583	963,583	963,583	963,583
Adjusted R^2	0.869	0.620	0.655	0.261
Residual Std. Error	0.168 (df = 959552)	0.287 (df = 963508)	0.274 (df = 963508)	0.959 (df = 959552)

The table presents the effects of the presence of a home office and Covid-19 on sales prices, using the dataset of the NVM transactions containing rental and sales transactions registered at the Dutch association of realtors from 2010 untill 2022. The model is run in a log-linear, with the exception of the floor area, for which we use the log. The other explanatory variables are mainly control variables for the type of property such as construction period and maintenance state. We also included a dummy indicating whether a transaction was made for a property in the G4 or outside of the G4. We furthermore included interaction variables to see whether there was a price premium for home offices outside of the G4. We include a dummy indicating whether a transaction was made in a district with a high percentage of well-educated people. We furthermore include an interaction variable to see whether there was a price premium for home offices in these districts with a high potential for remote workers. Fixed effects on the year and PC4 level are included, and standard errors are clustered at the PC4 level as well. Per variable, the coefficient and the standard error of the coefficient are displayed. Finally, the number of observations and the adjusted R-squared are demonstrated for all four models. The asterixes ***, ** and * denote statistical significance at the 1, 5 and 10 percent level, respectively. The standard errors p-value are denoted by parentheses.

2 percent. The effect for houses with 2 or more home offices is even larger with a positive price effect of 3 percent in the first year and 5 percent in the second year. This base model estimation hence indicates that there has indeed ben an effect of the surge of working from home during Covid-19 on the price premium of home offices.

The effects for the sale transactions are generally negative and highly signigicant, except when a house has one home office and is sold during the first year of Covid-19. This would mean that for sale transactions, the presence of a home office had a negatively pressing effect during Covid-19. The negatives effects lessen, however, in the second year of the Covid-19 pandemic, from 4 percent to two percent for houses with two home offices. The effects, therefore, do not confirm the initial hypothesis for both lease and sale transactions. In the development of the sales price discounts, however, it is visible

[2]The percentage impact our interaction terms and dummies is calculated as follows: price change

that the negative effects are lessening. From the base model regressions, it is therefore not apparent that working from home has caused a price premia for a home office for both lease and sale transactions.

Placing these results within the context of the four-quadrant model of DiPasquale and Wheaton (1992), the results hint that the changes still take place in the upper-right quadrant, where demand shocks affect rents. According to this model, these effects will gradually influence sales prices as well, when the renewed flow of future rents is capitalized.

Hypothesis 2 *The price effect will have been the strongest for rental houses at first.*

As mentioned in the previous paragraph, rental transactions showed strong signs over all years for the interaction term between Covid-19 and the presence of a home office, while sale transactions showed either non-significant or negative effects for home offices during Covid-19. These results are in line with theory regarding the progression of demand shock effects on rents and sale prices subsequently. The increasing magnitude of the positive effects of a home office over time, furthermore hints at the solidification of working from home habits for workers, and the effect on their housing preferences.

Hypothesis 3 *The price effect will have become gradually stronger for sale transactions, as these indicate the long-run change in mobility due to remote working.*

In the dataset from 2010 till april 2022, there are no strong signs that a price premium effect for home offices took effect for sale transactions, as the estimates in fact show a price discount. Rental transactions have showed the largest price premia for home offices, whereas sale transactions either did not show any premia or lesser effects on pricing. While the effects for sale transactions do not have the expected positive sign, there are slight signs of a decreasing negative effect over time. As such, we cannot confirm our a priori expectation that the price increase for home offices would have followed suit to the rental transactions. Yet due to the somewhat shorter window of time over which the demand shock effect on sales prices is measured, we cannot reject the hypothesis completely either, as the capitalization of the adjusted rents in the sales prices might not have set in yet.

Hypothesis 4 *The price effect will have become gradually stronger outside of the G4, as people move further away from work, commute less and increase their remote-working days.*

The signs for the interaction terms between the dummy for Outside of the G4, the presence of a home office and a transaction during Covid-19 are not ubiquitously positive and significant for both the rental and sale transactions. For the rental transactions, the location outside of the G4 does not have any significant effects at all, while for the sale transactions, there are significant negative effects for houses with 2 or more home offices. Larger houses with more potential home offices even display a price discount if they are located outside of the G4. As such, the data does not show strong signs for price premia for home offices outside of the G4, contrary to my initial hypothesis. While the average rent and sale price for houses in the G4 is indeed higher than outside of the G4, the estimates do not, however, show a convergence either by having smaller signs over time.

Hypothesis 5 *The price effect will have been stronger in neighborhoods with a highly-educated demographic.*

The difference-in-difference-in-differences model distinguishing between districts with a high average education level and less well-educated districts showed that for rental transactions, there was no distinguishable price premium for properties with a home office in districts where more potential remote workers live during Covid-19. The specification incorporating a socio-economic proxy for remote-working renters or buyers hence does not give a significant uniform positive relationship between rent and properties with at least one potential home office.

For the sale transactions, there is a strong positive price effect for houses with a home office in districts where more potential remote workers, i.e. well educated workers, live during Covid-19. The effects are even stronger in the second year, with a price premium of 5 percent for houses with one home office, and 4 percent for houses with 2 or more home offices. The estimates again show the same patterns as in the previous specifications, in which there is a progressively positive trend over the years during Covid-19.

Hypothesis 6 *Homes without a home office will be listed longer due to Covid and working from home than houses with a home office.*

In column (4), the model using the log of days on the market is specified to investigate the effect of the presence of a home office on listing time during Covid-19. The results show that for the lease transactions, properties with 2 or more home offices are listed 14 percent less days in the first Covid-19 year, and 19 percent less days in the second Covid-19 year. For sale transactions, the interaction term is negative and highly significant for all possible combinations of Covid-19 years and the number of potential home offices. The negative effect on listing time is strongest for houses with 2 or more potential home offices. It is somewhat unanticipated that the listing time effect is this strong for the sale transactions, as the effects of a home office on price were not clear for the previous specifications. An explanation of this could be in the stickyness of prices, as mentioned by Gautier et al. (2009). A caveat in this reasoning, however, is that the stickyness they observe is upward, meaning that prices do not fall as quickly as demand falls, while these results hint at stickyness in the other direction. The relation between the insignificant price premium and shorter listing times for sale transactions is therefore a difficult phenomenon to explain in the context of these results.

5.2 *Robustness*

Now, the robustness of the results is tested by estimating 4 additional specifications. Column (1) shows the specification ran with a more precise time fixed effect; at the quarter level instead of year level. For the second specification (column (2)) the home office definition is extended as any house that has 4 of more rooms for lease transactions, and to 5 or more rooms for sale transactions. This will test the concern that setting the limit for a home office too low will not sufficiently capture the demand for a home office. In column (3), only the subset of apartments is used. Finally, a robustness check is emplemented that is partially based on the difference-in-differences model of Buitelaar et al. (2021) in their paper on Dutch housing trends during Covid-19. Namely, the key identifying assumption for difference-in-differences estimations is that the treatment- and control groups would have had parallel price developments during

the studied timeframe, if the treatment or event, in this case increased working from home, would not have happened Baker et al. (2022). Herein, they use a parallel-trends assumption to check whether the spatial convergence of house prices pre-existed Covid-19. They scale back the dataset to before Covid-19, to thereby check whether the coefficient for the spatial convergence was already significant and positive then. This specification takes a similar approach, using the transactions until the first of march 2020, and setting a dummy at the first if march of 2018 to mimic the Covid-19 period from 2018 till 2020.

Table 9: Robustness checks lease transactions

	Dependent variable:			
	Log of the rent			
	Quarter fixed effects	Adjusted home office	Apartments subset	Placebo Covid-19 effect
	(1)	(2)	(3)	(4)
HomeOffice(1)	0.002 (0.004)		0.021^{***} (0.005)	-0.015 (0.011)
HomeOffice(2+)	0.005 (0.005)		0.050^{***} (0.006)	0.010 (0.011)
RobustHomeOffice		0.00003 (0.004)		
CovidYear1	-0.016^{***} (0.006)	-0.001 (0.004)	-0.016^{***} (0.005)	
CovidYear2	-0.018^{**} (0.007)	0.021^{***} (0.005)	0.012^{**} (0.006)	
RobustCovidYear1				0.047^{***} (0.014)
RobustCovidYear2				0.055^{***} (0.014)
HomeOffice(1)×CovidYear1	0.016^{***} (0.005)		0.013^{***} (0.005)	
HomeOffice(2+)×CovidYear1	0.027^{***} (0.005)		0.013^{**} (0.006)	
HomeOffice(1)×CovidYear2	0.017^{***} (0.005)		0.012^{**} (0.005)	
HomeOffice(2+)×CovidYear2	0.053^{***} (0.006)		0.026^{***} (0.007)	
RobustHomeOffice×CovidYear1		0.016^{***} (0.005)		
RobustHomeOffice×CovidYear2		0.042^{***} (0.005)		
HomeOffice(1)×RobustCovidYear1				0.015 (0.013)
HomeOffice(2+)×RobustCovidYear1				-0.011 (0.013)
HomeOffice(1)×RobustCovidYear2				0.016 (0.013)
HomeOffice(2+)×RobustCovidYear2				-0.003 (0.012)
Construction period	Yes	Yes	Yes	Yes
Property type	Yes	Yes	Yes	Yes
Energylabel	Yes	Yes	Yes	Yes
Maintenance state	Yes	Yes	Yes	Yes
LogFloorArea	Yes	Yes	Yes	Yes
Fixed effect Quarter	Yes	No	No	No
Fixed effect Year	No	Yes	Yes	Yes
Fixed effect PC4	Yes	Yes	Yes	Yes
Observations	125,478	125,478	78,680	56,416
Adjusted R^2	0.782	0.781	0.779	0.797
Residual Std. Error	0.175 (df = 122373)	0.175 (df = 122412)	0.165 (df = 76655)	0.181 (df = 53542)

The table shows the results of the robustness tests for the lease transactions. As in our results, we use the log of the rent as the dependent variable in the fixed effects regressions. The "robust" Covid years denote the placebo Covid years, with robust Covid year 1 covering the time between 01-03-2018 and 01-03-2019, and Covid year 2 spanning the period between 01-03-2019 and 01-03-2020. We measure the effect of one home office, and at least 2 home offices. In the second column, we measure the effect of a home office when there are at least 2 home offices, so 3 or more rooms. We still include control variables for the type of property such as construction period, the log of the floor area and maintenance state. The asterixes ***, ** and * denote statistical significance at the 1, 5 and 10 percent level, respectively. The standard errors p-value are denoted by parentheses.

In column (1), when using time fixed effects at the quarter level for the lease transactions, the coefficients for the interaction terms stay exactly the same as in the results. The signs for the different years of the Covid-19 dummy have changed negatively size and are significant at the 0.1 percent level. Similarly, the signs for the interaction terms for the sales transactions have barely changed in sign and significance-level. It can therefore be concluded that the base model is robust against more precise time-specific shocks.

For the rental transactions in column (2), the signs for 2 or more home offices are slightly larger for the two Covid-19 years than in the base model results.. For the sale transactions, the signs of the interaction terms of 2 or more home offices and sold during Covid-19 are again highly significant and negative. Thereby, the robustness test again indicates that for sale transactions, the potential extra

Table 10: Robustness checks sale transactions

	Dependent variable:			
	Log of the transaction price			
	Quarter fixed effects	Adjusted home office	Apartments subset	Placebo Covid-19 effect
	(1)	(2)	(3)	(4)
HomeOffice(1)	0.0001 (0.002)		0.012^{***} (0.004)	0.033^{***} (0.003)
HomeOffice(2+)	0.002 (0.002)		0.001 (0.005)	0.036^{***} (0.003)
RobustHomeOffice		0.002^{**} (0.001)		
CovidYear1	0.038^{***} (0.003)	0.067^{***} (0.001)	0.049^{***} (0.003)	
CovidYear2	0.060^{***} (0.003)	0.171^{***} (0.002)	0.151^{***} (0.005)	
RobustCovidYear1				0.082^{***} (0.004)
RobustCovidYear2				0.147^{***} (0.004)
HomeOffice(1)×CovidYear1	-0.012^{***} (0.002)		-0.012^{***} (0.003)	
HomeOffice(2+)×CovidYear1	-0.030^{***} (0.002)		-0.013^{***} (0.004)	
HomeOffice(1)×CovidYear2	0.0003 (0.003)		-0.015^{***} (0.004)	
HomeOffice(2+)×CovidYear2	-0.016^{***} (0.003)		-0.015^{***} (0.004)	
RobustHomeOffice2×CovidYear1		-0.024^{***} (0.001)		
RobustHomeOffice2×CovidYear2		-0.016^{***} (0.002)		
HomeOffice(1)×RobustCovidYear1				-0.033^{***} (0.004)
HomeOffice(2+)×RobustCovidYear1				-0.041^{***} (0.004)
HomeOffice(1)×RobustCovidYear2				-0.052^{***} (0.004)
HomeOffice(2+)×RobustCovidYear2				-0.072^{***} (0.004)
Construction period	Yes	Yes	Yes	Yes
Property type	Yes	Yes	Yes	Yes
Energylabel	Yes	Yes	Yes	Yes
Maintenance state	Yes	Yes	Yes	Yes
LogFloorArea	Yes	Yes	Yes	Yes
Fixed effect Quarter	Yes	No	No	No
Fixed effect Year	No	Yes	Yes	Yes
Fixed effect PC4	Yes	Yes	Yes	Yes
Observations	963,583	963,583	148,699	612,903
Adjusted R^2	0.872	0.869	0.899	0.855
Residual Std. Error	0.167 (df = 959516)	0.168 (df = 959555)	0.145 (df = 146320)	0.171 (df = 608909)

The table shows the results of the robustness tests for the sale transactions. As in our results, we use the log of the rent as the dependent variable in the fixed effects regressions. The "robust" Covid years denote the placebo Covid years, with robust Covid year 1 covering the time between 01-03-2018 and 01-03-2019, and Covid year 2 spanning the period between 01-03-2019 and 01-03-2020. We measure the effect of one home office, and at least 2 home offices. In the second column, we measure the effect of a home office when there are at least 2 home offices, so 4 or more rooms. We still include control variables for the type of property such as construction period, the log of the floor area and maintenance state. The asterixes ***, ** and * denote statistical significance at the 1, 5 and 10 percent level, respectively. The standard errors p-value are denoted by parentheses.

rooms for a home office did not cause a price premium in the first two Covid-19 years, yet rather a price discount. DiPasquale and Wheaton (1992) their theory does not explain sales prices falling after a positive demand shock. As the estimates of the base model for the sale transactions were somewhat larger and negative, this begs the question whether the effects of the home office could indeed be better measured by extending the perimeter of a potential home office in our estimations for sale transactions.

The third column (3) shows the results of the base model difference-in-differences regression, run for transactions of apartments only. As in the first column of the robustness tests, the coefficients for the interaction terms stay exactly the same as in the results. For the sale transactions, the signs are all negative and highly significant, and imply a negative effect of approximately 1 to 2 percent of houses with one or more home offices sold during Covid-19. As with the previous robustness test, which extended the minimum amount of rooms to distinguish a house as having a potential home office, the most notable change is that of the interaction term between properties with 1 home office sold during the second Covid-19 year. This term has now become highly signficant and negative too, and implies a price discount of 2 percent.

The interaction terms of the placebo Covid period (from 2018 till 2020) in column (4) are all insignificant and have unubiquitous signs. This confirms our hypothesis that the working from home

surge, noticed after the imposition of the lockdown, has impelled a price premium for home offices with rental transactions. As opposed to Buitelaar et al. (2021), who find a similar coefficient before Covid-19, we do not find price premia for home officies in rental transactions in the period leading up to Covid-19.

For the sale transactions, all interaction terms for a sale with a home office during the placebo years are all highly significant and negative. It must also be noted that, in fact, the discount became even larger in the second placebo Covid-19 year. These effects for the placebo Covid-19 period dummmy with the sale transactions are, therefore, not indicative of a price premium trend before Covid-19, and therefore does not negate our hypothesis that the working from home surge during Covid-19 is the driver of price premia.

6 Conclusion

6.1 *Summary*

This paper has investigated the effect of increased working from home habits in The Netherlands on the rental and sales prices of properties with a home office. Building on the idea within real estate economics that more fundamental shifts in terms of work and mobility patterns can cause new equilibria, this paper differs from most pandemic focused papers, in the sense that it investigates a more permanent demand shift caused by the pandemic, rather than the more short-run, public health related shock of the pandemic itself. The results of the hedonic price model so far only show ubiquitous price premia for the rental transactions. This mainly informs us about the phase this demand shift is possibly in, currently capitalizing the exogenous positive demand shock in the rents. According to the four-quadrant model of DiPasquale and Wheaton (1992), sales prices adjust post- adjustment of rental prices. As we are now entering the third year of the pandemic in 2022, the effects on the sales market may start to become more apparent in the future.

6.2 *Discussion*

6.2.1 *Identification of a home office*

The dataset used in this paper is somewhat limited in the sense that it does not contain exact data on whether or not a room in the transacted house is used as a home office by the buyer or renter. Hence, households might buy a house with 3 bedrooms, yet not use one for working from home. Being able to see at the household level whether a transacted property is bought with either the potential for a home office or the predetermined function of a home office would make the regression more accurate, and would allow for a more precise estimate of the price premium of a potential home office. This would remain a difficult function to measure, however, as people might want to pay a premium for an additional room, as to first use this as a home office, and consequently transform it to a babyroom. Yet still, being able to gauge the demand of a households for a home office, prior to their rental or sale transaction would greatly help the accuracy of the regressions.

6.2.2 *Remote working*

As aforementioned, more specific household or dwelling data on the presence of a home office would benefit the precision of the price premium estimate. Yet in fact, data on the household level would also help to get an insight in whether the buyer or renter is in fact a remote worker. This paper uses education levels as a proxy for remote working, yet the only available data was at the neighborhoodlevel. Microdata could therefore also be useful in determining at the household level whether people are remote workers, and would hence have changed preferences for their dwellings.

6.2.3 *High income high earning bias towards large houses*

This paper has used a high education level within a district as a proxy for remote workers in the third estimation. As already discussed in the results, districts with a high education level showed the largest price premium for home offices. It must be noted, however, that using such aggregrate averages in these types of neighborhoods might mix the price-premium of the demand for a home office with demand for larger dwellings in general, as the pool of homes that are bought by well-educated households will be tend to have more expensive, larger dwellings in it due to strong correlations with income, and hence more likely to contain a home office in the first place.

6.2.4 *Larger houses in the countryside*

Furthermore, prior research has found that increased working from home habits are more prevalent outside of large cities, as commuting times were longer and the reduced costs of traveltime were greater. As the houses outside of the G4 or the Randstad in general tend to be larger in the first place, the conscious choice between no home office or a home office would have been difficult to discern in this research.

6.2.5 *Other developments in the Dutch real estate market*

As is fairly well-known in the Netherlands, the Dutch real estate market has seen strong price increases for almost a decade now. Demand is growing, and construction cannot keep pace in the most coveted areas in the Netherlands such as large cities or the Randstad. The "waterbed effect", eluding to the gradual spreading out of high real estate prices from the city of Amsterdam to surrounding places, has caused prices to increase as far as the most Eastern province of Overijssel. Buitelaar et al. (2021) also investigate the concurrence of Covid-19 with a priori established developments such as the gradual wrinkle effect of the price increases from the Randstad to more peripheral areas. They stress the importance of considering these different concurrent drivers of house prices outside of the Randstad, as to not overestimate the effect on the pandemic for the increasing prices. While the literature does confirm that a large proportion of the Dutch workforce has begun to incorporate hybrid-working in their workpatterns, it is important to realize that scarcity is still a large driver of Dutch real estate prices. While this paper has attempted to control for such developments by using the time fixed effects in the regressions, using more detailed data on the transacted dwellings and the buyers or renters could aid in isolating the effect of working from home from these coinciding real estate developments.

6.2.6 *Working from home a fundamental shift*

Throughout this paper it is assumed that working from home comprises a more fundamental shift in the demand for residential dwellings in The Netherlands, as opposed to, for example, the exodus researched by Gupta et al. (2021) and Ouazad (2020) from US cities due to fear of contagion at the start of the pandemic. Dutch research among workers has found that a significant portion of workers with the potential to work-from-home are planning to continue with more hours of remote working than they did before the start of the pandemic. If, however, working from home will eventually become less

prevalent, the predictions concerning the price effects of home office demands for owner-occupied houses would have to be adjusted downwards.

6.3 *Implications for further research*

The implications for economic policymakers are not clear yet, but show the first confirmations of a more permanent shift towards demand for additonal rooms for remote working. In the current Dutch real estate market, with soaring prices, lagging construction, and a current tendency to build smaller rather than larger dwellings, such a shift might open up discussions about redistribution of space among different functions (e.g. work, leisure, consumption and living). As stressed before, however, a follow-up research to test whether sale transactions will show a similar trend is necessary to formulate concrete policies on the demand shift of working from home. As aforementioned in the discussion, the proper identification of a home office and remote workers in transaction data remains an issue for the estimation of a price premium. Using micro level data could help in isolating the demand for home office from the demand for an additional bedroom, playroom et cetera, and hence give a clearer picture of the effects of working from home on housing preferences. Furthermore, as the results only showed price premia fore rental properties, later research could perhaps benefit from a larger window of time, where the four quadrant model has shifted to a new phase in which sale prices are affected by the rents.

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7 Appendix

Figure 7: Difference in income - Sale transactions

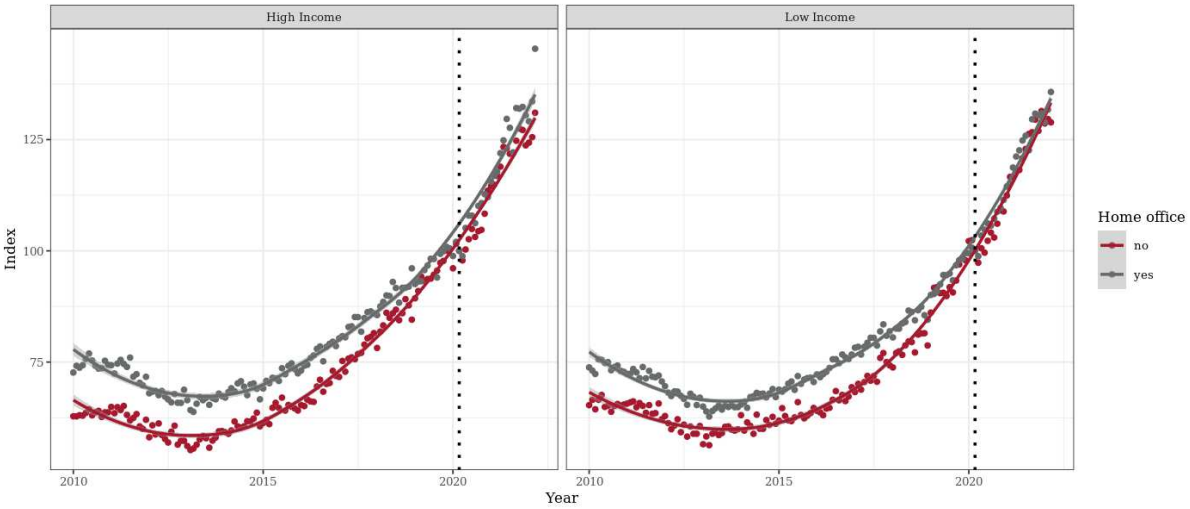

Figure 8: Difference in income - Lease transactions

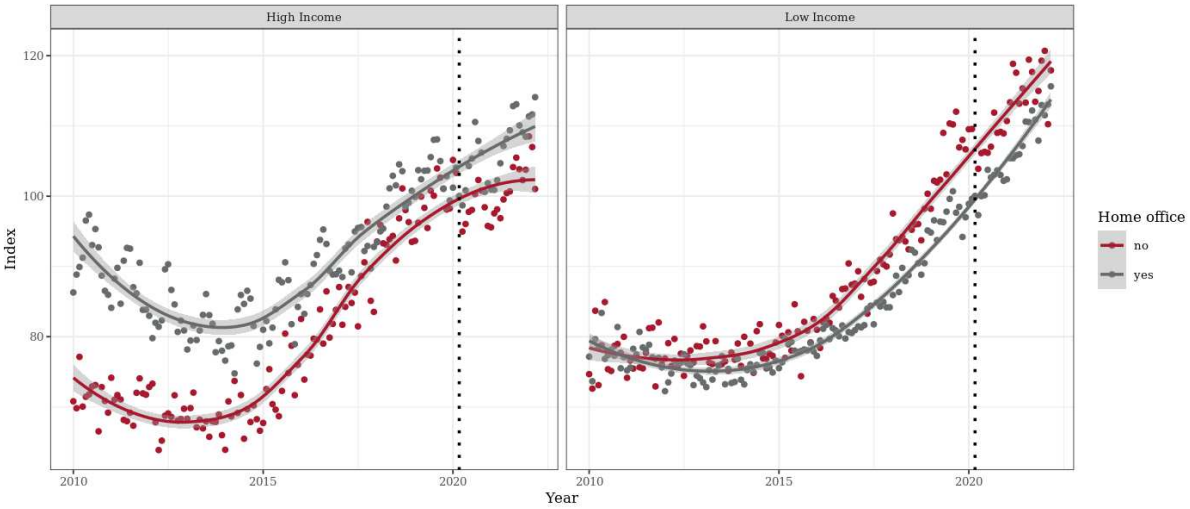

Table 11: Conditions for cleaning the NVM dataset

	Variables	Lease	Sale
1	Transactionprice	<100 euro	<25.000 euro
2	Transactionprice	>5000 euro	>2.500.000 euro
3	Postcode	missing	missing
4	Number of rooms	<1	<1
5	Number of rooms	>25	>25
6	Transactiondate	missing	missing
7	Transactiondate	<2010-01-01	<2010-01-01
8	Transactiondate	>2022-03-31	>2022-03-31
9	Usable Floor Area	<25	<25
10	Usable Floor Area	>250	>250
11	Land Area	>10.000	>10.000
12	Construction Year	<1300	<1300
13	Days On The Market	missing	missing
14	Property Type	missing	missing
15	Property Type	missing	missing

Figure 9: Difference in education - Lease transactions

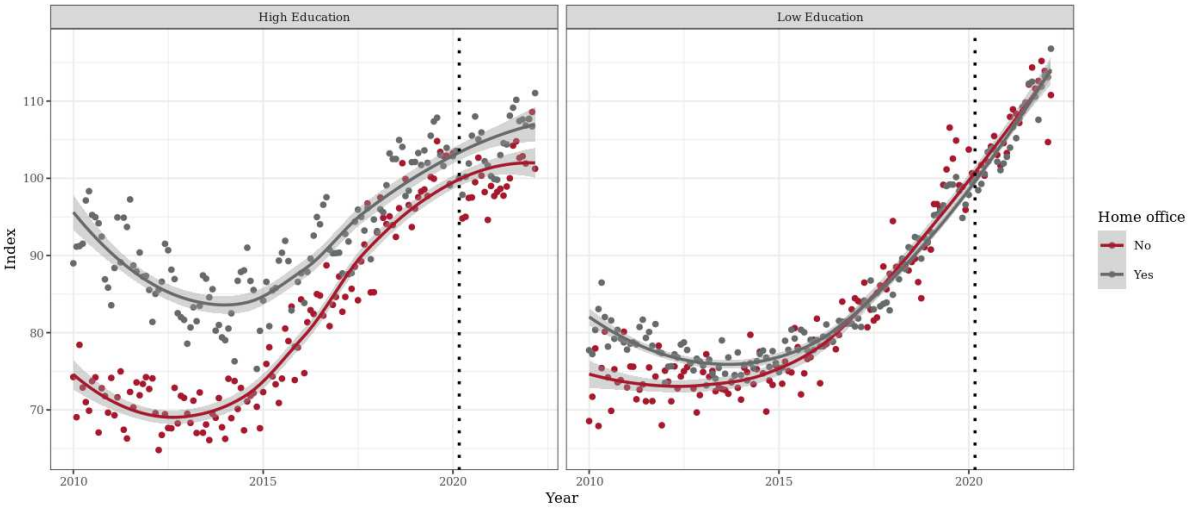

Figure 10: Difference in education - Sale transactions