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DISCUSSION PAPER SERIES

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ABSTRACT

Working from Home and Commuting: Heterogeneity over Time, Space, and Occupations

Teleworking may increase the willingness to accept a longer commute. This paper presents new evidence of the effect of teleworking on the length of commutes. We use novel panel data from the Netherlands, for the years 2008-2018, and find stronger effects compared to studies that use older data. Between 2008 and 2018 however, the effect was remarkably stable: workers that started teleworking increased their commutes by 12 percent on average. We analyse heterogeneity in the effect of teleworking on commuting across different levels of urbanization and across occupations. This study stresses the effects of teleworking on the geographical scale of labour markets, and provides important inputs for policymakers that aim to promote teleworking.

JEL Classification: R11, R41, O18

Keywords: telecommuting, commuting time, information technology, fixed effects

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1. Introduction

Advances in information and communication technology allow an increasingly large number of workers to work from home on or more days per week. This has caught the attention of policy-makers that aim to reduce CO2 emissions, in order to fulfil the reductions agreed upon in the Paris Agreement.[1] However, when people work from home one day in the week, they may be willing to travel to work for longer distances on the other days. This casts doubts on the net effect of working from home. Policies that promote teleworking may actually have adverse effects on commuting distance. At the same time, longer commuting distances imply an increase in the size of labour markets, and increasing levels of job-accessibility in remote areas. As a consequence, the externalities associated with large labour markets, such as better matching and higher productivity, may spread over larger areas.

Despite the substantial interest in policy circles for the possible effects of teleworking, only a handful of studies explore whether it leads to longer commutes. Most of these studies note that the proper data to identify the direction of causality between teleworking and commuting is lacking. Two recent studies that use (synthetic) panel data are exemptions to this, and show that those who start teleworking tend to accept longer commutes. De Vos et al. (2018) use data from 2002 until 2014 and show that workers tend to accept a 5 percent longer commute after adopting teleworking. Gubins et al. (2019) show that between 1996 and 2010, teleworkers increased their commutes 5-9 times more than non-teleworkers.

Despite such first findings, there are still important gaps in the literature on teleworking and commuting. First, there is a general lack of studies using longitudinal data, apart from the two studies cited above (De Vos et al. 2018, Gubins et al. 2019). The estimates from panel data studies should approach the causal effect of teleworking on commuting because they are based on changes in teleworking and commuting, and because time-invariant characteristics are controlled for by fixed effects (Angrist and Pischke, 2008). Additional evidence based on different panel data sources adds to the robustness of the findings of the few studies that used panel data. Second, it is still unclear whether the effects of teleworking on commuting are growing as telework technologies progress and working from home becomes a closer substitute to working at the job location (Pajevic and Shearmur, 2017). Third, there has been little

[1] See for instance the proposed measures for the Dutch Climate Agreement (https://www.klimaatakkoord.nl/documenten/publicaties/2018/07/10/hoofdlijnen-compleet).

attention for spatial heterogeneity in the effects of teleworking on commuting. One may for instance expect that the effects of teleworking are smaller in urban areas, with high-quality infrastructure and thick labour markets, compared to rural areas (Rhee, 2008). Finally, there is a lack of clear and specific estimates for different job-types, that can be used as inputs for teleworking policies. This is important in order to make realistic estimates of the effects that teleworking policies will have on CO2 emissions, and labour market dynamics.

In this paper we aim to fill these gaps by using the Longitudinal Internet Studies for the Social Sciences (LISS) data from the Netherlands, that covers the years 2008 until 2018. We use this data set to estimate the effect of teleworking on commuting, and we compare our findings with the handful of previous studies. Furthermore, we broaden the scope by analysing whether the effects differ over time, space, and different occupations. We present an overview of effect sizes that can be used by policymakers to make projections about the environmental, economic and social effects of schemes that promote teleworking.

We find that on average, workers that start teleworking increase their commute by 12 percent. This estimate is higher than previous estimates with Dutch data from 2002 until 2014. When we split our study period 2008-2018 in early and later years, we find that the magnitude of the effect of teleworking on commuting has remained remarkably stable. Regarding spatial heterogeneity, we find strong and significant effects across all levels of urbanization, and the effects are strongest in moderately urban areas. Our results further show that not all occupations show the same relationship between teleworking and commuting, and the effects are especially sizeable for jobs that require academic skills and for lower-order administrative jobs.

The rest of this paper is structured as follows. In Section 2 we discuss earlier literature on teleworking and commuting, and we position our work in this literature. In Section 3 we introduce the methods used in the estimations, and we discuss the data. Section 4 presents the results, and Section 5 concludes.

2. Literature review

2.1 Previous studies

Empirical research on the relationship between home-based teleworking and commuting started with Nilles (1991), who used data from the California Pilot Telecommuting Project that was done with State employees. One of the main findings of this study was that telework was associated with relocations to places farther from the workplace. Around this time, several other teleworking studies were conducted based on data from such experiments (e.g. Hamer et al. 1991, Henderson and Mokhtarian 1996, Koenig et al. 1996, see Andreev et al. 2010 for an overview), although few have analysed the effects on commuting distance. In a review paper by De Graaff (2004) it is noted that up until then, studies of teleworking and commuting did not rule out a positive relationship.

With the increased accessibility of large-scale surveys, research on teleworking and commuting moved beyond analysing the results from one-off experiments. Examples include Jiang (2008), Zhu (2012,2013), Kim et al. (2012), and Melo and De Abreu e Silva (2017). These studies pay explicit attention to the problem of estimating a causal relationship between teleworking and commuting. Next to omitted variables, these problems relate to reverse causality (long commutes leading to teleworking) and sorting (people who dislike commuting or who prefer rural living may telework more). These studies do not however resolve these empirical problems. For instance: Zhu (2012) uses 'internet use at home' as an instrument for teleworking, but does not consider that individual abilities may be correlated with the use of ICT (Gubins et al. 2019); Kim et al. (2012) concur that "causality cannot be established with these data" (p. 1163); and Melo and de Abreu Silva (2017) note that "data-related limitations did not allow us to address issues of selection and/or simultaneity bias" (p. 1).

Two more recent studies shed new light on the relation between teleworking and commuting. Using Dutch panel data, De Vos et al. (2018) find that workers that start teleworking increase their commute by 5%. Their model employs individual fixed effects, so the estimates are based on time variation, and this method should deal with biases due to sorting. Gubins et al. (2019) have a slightly different angle, and estimate the effect of the penetration of teleworking across 'professions' on average commuting times within these professions. They use survey data from 1996 and 2010, and employ propensity score matching to construct credible counterfactuals, essentially creating a synthetic panel. While they do not find differences in average commuting times between treated (teleworking) and untreated (non-teleworking) professions, their results show that teleworkers increased their commutes 5-9 times more than non-teleworkers (12.07 vs 1.32 or 2.3 km).

2.2 Contributions to the literature

We contribute to the literature in four ways. First, we reproduce the results of De Vos et al. (2018) using more recent data from a different panel survey. Over the last decades a literature on teleworking and commuting has emerged, in which it has been common to re-estimate earlier results with different data (see the literature reviews of De Graaff 2004 and Andreev et al. 2010). Given the increasingly stressed importance of reproduction of research findings, this study continues this tradition.

Second, we assess whether the effects of teleworking on commuting have grown stronger or weaker over the years. We aim to answer the question whether the increases in *workplace mobility* in recent years, due to inter alia advancements in technology and increasing flexibility and temporality of contracts (Pajevic and Shearmur 2017), have made working from home a better substitute for working at the job location, and teleworkers more footloose. As changes in the relationship between teleworking and commuting may equally be influenced by for instance housing market dynamics, this is mainly an exploratory exercise.

Third, we analyse geographic variation in the effect of teleworking on commuting by estimating the effect separately across different levels of urbanization. A modelling exercise by Rhee (2008) suggests that whether or not people telecommute, and to what extent this impacts commute lengths is dependent on the residential location (distance to CBD), together with the degree to which employment is centralized, the substitutability of home-work and on-site work, and congestion levels. In a setting such as the Netherlands, with a polycentric structure of proximate cities, telework may not only serve as a means to sustain a long commute to the nearby city for suburban or rural residents, but it may equally allow inhabitants of one city to sustain a longer commute to another city (Muhammad et al. 2008).

Finally, we pay attention to the differences in teleworking penetration across professions, by estimating the effects of teleworking on commuting separately for different (groups of) occupations. A number of studies has paid attention to heterogeneity in teleworking across occupations. For instance Vilhelmson and Thulin (2016) show that in Sweden teleworking is still concentrated in higher occupations in the advanced services sector. Studies such as Melo and De Abreu e Silva (2017) and Kim et al. (2015) focus on particular sets of occupations, such as non-agricultural or white-collar workers. Gubins et al. (2019) use variation in teleworking between professions to estimate the effects of teleworking on commuting distance. Our study is the first to include specific estimates for different occupations, that can be used as inputs for telework policies.

3. Empirical strategy

3.1 Methodology

We will start our analysis by reproducing the results from De Vos et al (2018), with our data set that contains more recent data. The main regression model is as follows:

$$Commuting\ time_{it} = \alpha Telework_{it} + \beta X_{it} + \eta_i + \theta_t + \epsilon_{it} \tag{1}$$

where X_{it} is a vector of control variables, η_i are individual fixed effects, θ_t are time fixed effects, and ϵ denotes the error term. The individual fixed effects control for all time-invariant characteristics of persons. The control variables include personal characteristics and education, occupation, and industry dummy variables.

In their sensitivity analysis, De Vos et al. (2018) estimate two different models. First, they estimate a lagged dependent variable (LDV) model. According to Angrist and Pischke (2008) the results of fixed effects models on the one hand, and LDV models on the other, provide boundaries of the effect of interest, depending on the type of selection bias at force. This model includes the 2-year lag of commuting time, and is as follows:

$$Commuting\ time_{it} = \alpha Telework_{it} + \beta X_{it} + \gamma Commuting\ time_{i,t-2} + \epsilon_{it} \tag{2}$$

Second they estimate a long-differences model using only the first and last year of the data, as it may take time for the effects of teleworking to take full effect. We follow De Vos et al. (2018) in these two robustness checks.

Next we examine the heterogeneity of the effect of teleworking on commuting. To this end we estimate fixed effects models that include an interaction between teleworking and time periods, (groups of) occupations and 5 levels of urbanization (*stedelijkheid* in Dutch) of the municipality of residence. The data source that we use has a measure of *professions* that is comparable to the ISCO-08 standard of occupations, but not the same. Table 4 in Appendix A shows the correspondence between the LISS measure of professions and the ISCO-08 standard. The LISS measure does not include a separate category for military workers, it does not distinguish between clerical, and sales workers, but it does distinguish between higher- and intermediate management. The measure of urbanization we use is the only spatial indication present in the data, and it corresponds to a standard measure used by Netherlands Statistics, based on the density of addresses in the municipality. It distinguishes ‘Very strongly urban areas’ (2500 addresses/km^2 or more), ‘Strongly urban areas’ (1500-2500/km^2), ‘Moderately urban areas’ (1000-1500 addresses/km^2), ‘Slightly urban areas’ (500-1000/km^2) and ‘Non-urban areas’. Figure 5 in Appendix A shows a map of levels of urbanization across Dutch municipalities.

3.2 Data description

The data used in this study comes from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS). This panel has been running since 2008, and we use the 11 available waves up until 2018. The results of this study should be interpreted keeping in mind the specifics of the context in which the data was gathered. First, the Netherlands is a country characterized by a polycentric urban structure, where it is relatively common to live in one city and work in another city. In the Netherlands teleworking is thus not necessarily most attractive for residents of suburban or rural areas. Second, teleworking is a widespread phenomenon due to a high penetration of fast internet among other things (Muhammad et al. 2008), and in this sense the results of this study may be used to forecast the effects of teleworking in countries that still have lower levels of connectivity and teleworking. Finally, house price dynamics have been extreme between 2008 and 2018. They have plummeted between 2008 and 2012, and risen fast beyond 2012, especially in urban areas. High urban house prices may have pushed workers to use telework as a substitute for living in urban areas close to the workplace.

LISS is a panel survey that is filled out online, but respondents are selected based on a representative sample from the population registers, and households that could not otherwise participate were offered a pc and internet connection (Scherpenzeel and Das, 2010). The panel consists of 6000-7500 respondents every year. Our estimation sample consists of employed respondents between 18 and 65 years old, with non-missing values for education, occupation, industry, and hours worked. This leads to a sample of 22,577 observations.

The survey specifically asks respondents if they have a ‘working at home day’, and whether this occurs less than one, one, or more times a week. Our definition of teleworkers is based on this question, and we consider every respondent with a ‘working at home day’ as a teleworker. Our definition of teleworkers is comparable to an often used definition given by Mokhtarian et al. (2005), in that we consider employees that replace the commute by working at home. It differs in the sense that we do not include teleworkers who work from other locations than home, and that it is ambiguous about the usage of ICT. Figure 1 shows the share of teleworkers for every year in our sample. A stark increasing pattern is visible between 2008 and 2016, which shows that teleworking is still on the rise.

Figure 2 shows that the spatial variation of growth in teleworking, across levels of urbanization, is limited. That said, growth rates have been especially high in ‘Very strongly urban’ and ‘Moderately urban areas’. Whether teleworking is feasible seems much more dependent on the type of occupation. Figure 3 shows a clear distinction between occupations where teleworking grew, and other occupations. Teleworking grew in ‘Higher academic’, ‘higher supervisory’, ‘Intermediate academic’, ‘Intermediate supervisory and commercial’, and ‘Other mental work’. It decreased or remained stable in manual, unskilled, and agrarian work.

Due to data limitations the only feasible measure of commuting in the data is one-way commuting time. The survey asks to state how many minutes it usually takes to travel between home and the workplace. Figure 4 shows that the distribution of this variable differs between non-teleworkers and teleworkers, with more teleworkers having longer commutes. The lack of information on commuting distance should not be problematic, and the use of commuting time can be justified by the (reasonable) assumption that commuting speed is optimally chosen (Van Ommeren and Fosgerau 2009, De Vos et al. 2018).

Table 1 shows the summary statistics. On average, 16.7 percent of the sample consists of teleworkers, and most of these telework less than a day per week on average. The average commuting time is 27.72 minutes. We also show summary statistics of control variables. We include control variables that are customary in this literature, on age, sex, having children or a partner, work duration, education, occupation type and industry. We lack reliable data on income and firm size, but we are confident that our use of individual fixed effects and industry controls will limit biases due to these omitted variables.

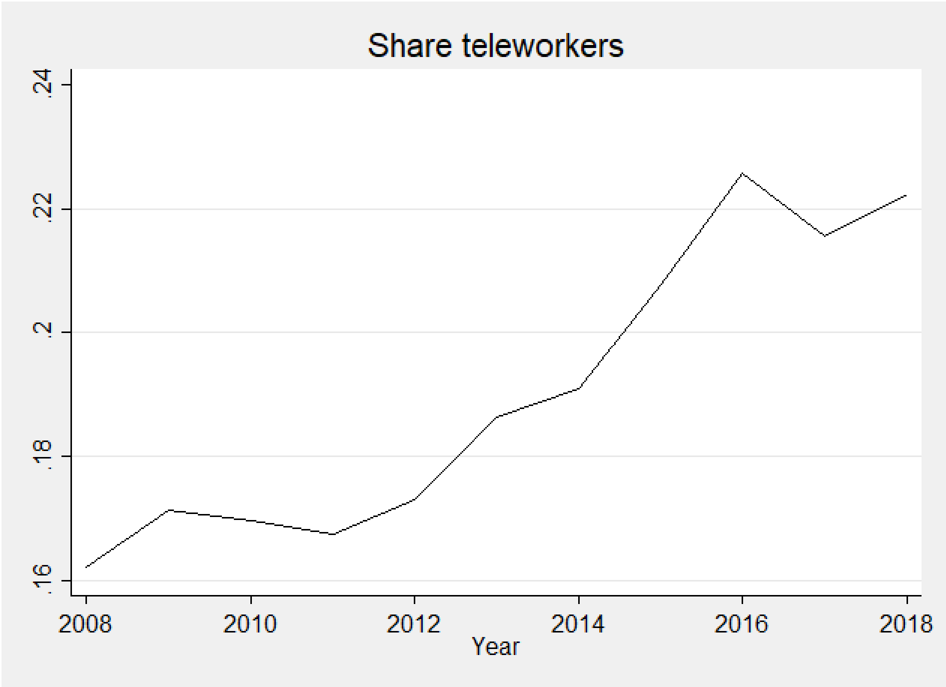

Figure 1: Share of teleworkers over time

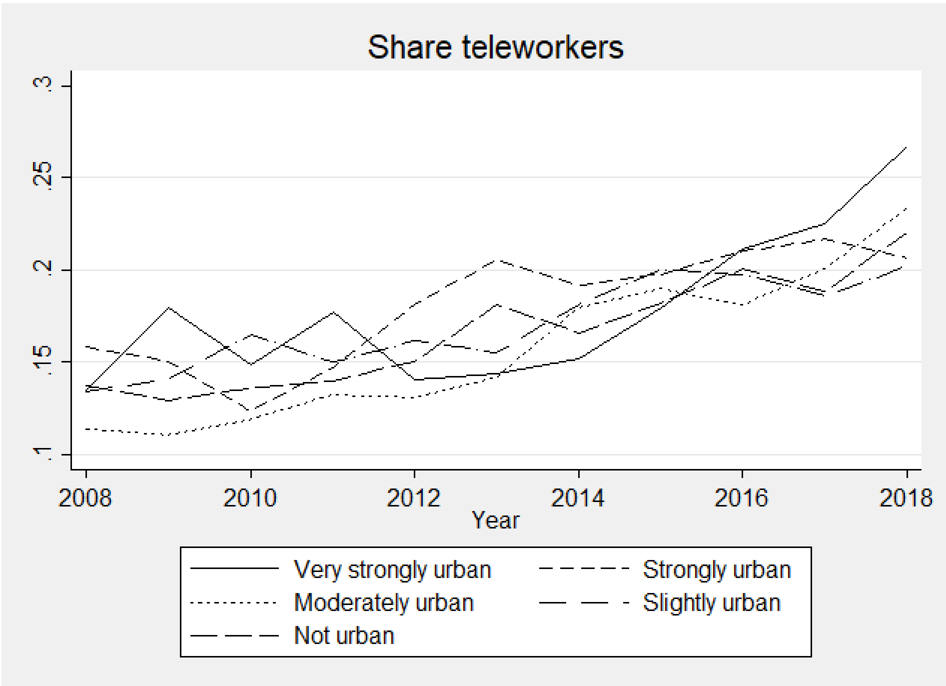

Figure 2: Share of teleworkers across urban levels over time

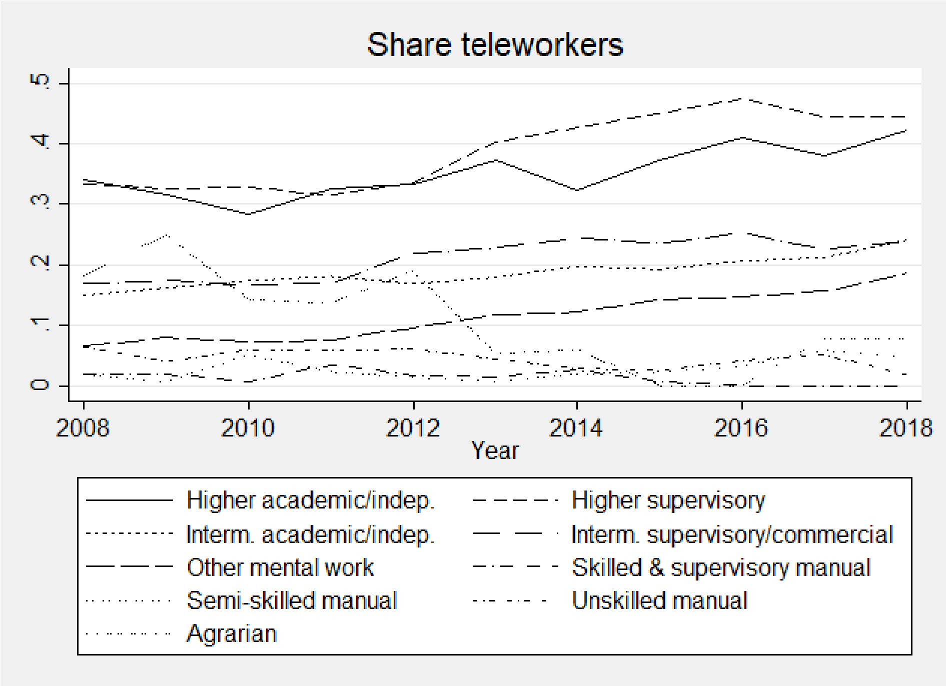

Figure 3: Share of teleworkers across occupations over time

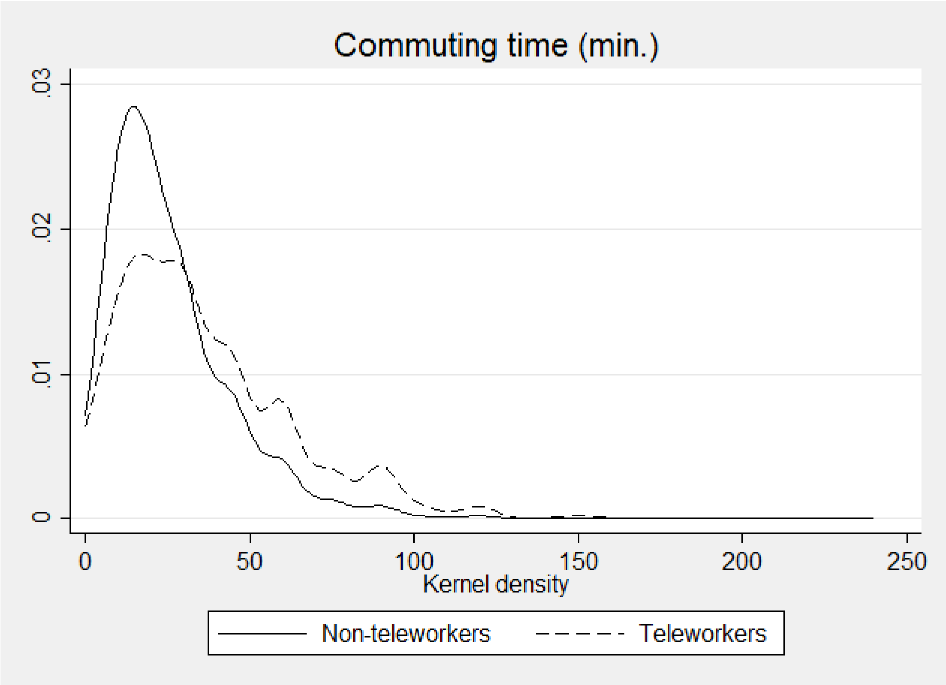

Figure 4: Distribution of commuting time

Table 1: Summary statistics

VARIABLES	(1) mean	(2) sd	(3) min	(4) max
Telework dummy	0.167	0.373	0	1
No telework	0.829	0.377	0	1
Telework < 1 d/w	0.0878	0.283	0	1
Telework 1 d/w	0.0569	0.232	0	1
Telework > 1 d/w	0.0263	0.160	0	1
Commuting time (min)	27.72	21.67	0	240
Age	44.55	11.21	18	65
Female	0.360	0.480	0	1
Children	0.462	0.499	0	1
Partner	0.758	0.428	0	1
Weekly hours worked	31.81	9.441	0	137
Basic education	0.236	0.425	0	1
Lower education	0.367	0.482	0	1
Medium education	0.257	0.437	0	1
Higher education	0.139	0.346	0	1
Occupation				
Higher academic/independent	0.0786	0.269	0	1
Higher supervisory	0.0794	0.270	0	1
Intermediate academic/independent	0.261	0.439	0	1
Intermediate supervisory/commercial	0.134	0.341	0	1
Other mental work	0.251	0.434	0	1
Skilled & supervisory manual	0.0719	0.258	0	1
Semi-skilled manual	0.0707	0.256	0	1
Unskilled manual	0.0434	0.204	0	1
Agrarian	0.00939	0.0964	0	1
Industry				
Agriculture	0.0137	0.116	0	1
Mining	0.000354	0.0188	0	1
Industrial	0.108	0.310	0	1
Utilities	0.0112	0.105	0	1
Construction	0.0435	0.204	0	1
Retail	0.0705	0.256	0	1
Catering	0.0222	0.147	0	1
Transport	0.0477	0.213	0	1
Financial	0.0510	0.220	0	1
Business services	0.0627	0.242	0	1
Government	0.107	0.309	0	1
Education	0.0963	0.295	0	1
Healthcare	0.207	0.405	0	1
Environmental/culture	0.0202	0.141	0	1
Other	0.139	0.346	0	1
N		22,577		

4. Results

4.1 Reproduction of earlier estimates

Table 2 shows the results of regressions of commuting time on teleworking and control variables. The dependent variable is the natural logarithm of commuting time, so coefficients can be interpreted as $(e^{\beta} - 1 * 100\%)$ percentage change in the dependent variable due to a unit change in the independent variable. This also means that the analysis is only based on observations with a commuting time greater than zero. Column (1) shows the results of an OLS regression with year dummies. The coefficient of the telework dummy is 0.218, which means that those workers that start teleworking increase their commute by 24 percent. In column (2) we include individual fixed effects that should control for all time-invariant characteristics of people, including to a large extent (commuting) preferences (De Vos et al., 2018). The coefficient in this model is smaller than in the previous model, and the point estimate of 0.117 suggests a 12 percent increase in commuting times due to teleworking.

In column (3) we include a more flexible measure of teleworking, that distinguishes between less than one, one, and more than one day a week of teleworking. Consistent with expectations, the point estimate increases with more teleworking. Those that start to telework less than a day a week, shorten the commute by about 10 percent, compared to non-teleworkers. Those that telework one day a week see an increase of 16 percent, and those that start teleworking more increase their commute by about 17 percent.

In columns (4) and (5) we replicate two sensitivity checks from De Vos et al. (2019). Column (4) shows the results of a lagged dependent variable model, that does not include individual fixed-effects but instead includes the lag of commuting time (log). Consistent with De Vos et al. (2018) we use the 2 year lag. This model controls for selection bias due to commuting history. The results from this model show a smaller effect of teleworking on commuting. Teleworkers have 7 percent longer commutes. In column (4) we show the results of a long differences model that only includes the first and last year of the dataset, together with individual fixed effects. This model shows a greater effect of teleworking on commuting. Those workers that started to telework between 2008 and 2018 had on average 22 percent longer commutes in 2018.

Table 2: Regression results

	(1)	(2)	(3)	(4)	(5)
Telework dummy	0.218***	0.117***		0.0682***	0.199***
	(0.0143)	(0.0155)		(0.0110)	(0.0658)
Telework < 1 d/w			0.0948***		
			(0.0177)		
Telework 1 d/w			0.149***		
			(0.0229)		
Telework > 1 d/w			0.160***		
			(0.0476)		
Commuting time (log) (t-1)				0.834***	
				(0.00749)	
Age	-0.00948**	0.0124	0.0125	-0.00813**	0.0561**
	(0.00399)	(0.0119)	(0.0119)	(0.00373)	(0.0223)
Age^2	0.000118**	5.69e-05	5.74e-05	8.36e-05**	0.000122
	(4.59e-05)	(6.34e-05)	(6.34e-05)	(3.97e-05)	(0.000180)
Female	-0.0368***	-	-	-0.0191**	-
	(0.0122)			(0.00930)	
Children	-0.0374***	0.00483	0.00503	0.00272	-0.118**
	(0.0119)	(0.0115)	(0.0114)	(0.00845)	(0.0570)
Partner	0.0280**	-0.00244	-0.00193	-0.00442	0.121
	(0.0120)	(0.0200)	(0.0199)	(0.00850)	(0.0990)
Weekly hours worked	0.0124***	0.00604***	0.00598***	0.00174***	0.00443
	(0.000713)	(0.00112)	(0.00112)	(0.000604)	(0.00435)
Basic education	-0.170***	0.0294	0.0293	0.00914	-0.0808
	(0.0208)	(0.0290)	(0.0291)	(0.0162)	(0.177)
Lower education	-0.186***	0.0421	0.0425	-0.00600	-0.00962
	(0.0181)	(0.0262)	(0.0263)	(0.0146)	(0.139)
Medium education	-0.0515***	0.0163	0.0174	0.00820	-0.0499
	(0.0169)	(0.0204)	(0.0205)	(0.0132)	(0.0990)
Higher education	-	-	-	-	-
Constant	2.923***	2.275***	2.269***	0.680***	-0.164
	(0.106)	(0.455)	(0.456)	(0.0998)	(0.827)
Model	OLS	FE	FE	LDV	LD
Year dummies	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes
Control dummies	Yes	Yes	Yes	Yes	Yes
Observations	21,859	20,519	20,519	11,796	1,228
R-squared	0.119	0.859	0.859	0.749	0.823

Dependent variable: Commuting time (log). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The FE models include individual and year fixed effects. The LDV model includes a lagged dependent variable. The LD model is a long-differences model based on 2008 and 2018 data alone. Control dummies include occupation and industry dummies.

The patterns we find in the data are overall consistent with De Vos et al. (2018). For instance, we find that sorting based on preferences biases OLS results upwards, as the FE estimate is smaller than the OLS estimate. There are important differences however. First, we tend to find greater effects in both the OLS and FE models (24 and 12 percent, vs. 12 and 5 percent respectively). Second, in contrast to De Vos et al. (2018) we do find that more teleworking leads to even longer commutes. Third, the spread between the FE and LDV model is greater in this study, although the effects are significant, and greater than earlier estimates. And finally, the long differences model in this study suggests a smaller effect of teleworking (22 vs. 32 percent).

4.2 Heterogeneity analysis

In this subsection we allow the effect of teleworking to differ across time, space, and occupations. The previous section has shown that our estimates with recent data, from 2008-2018, are higher than estimates from De Vos et al. (2018) who used data from the years 2002-2014. In column (1) we interact the telework dummy with a period indicator that distinguishes between 2008-2013 and 2014-2018. The effects are remarkably similar: between 2008 and 2013 the effect is 12.2 percent, and between 2014 and 2018 it is 12.6 percent.

In column (2) we estimate the effect of teleworking separately for 5 levels of urbanization, as measured by address density of municipalities. The estimates show that the effects of teleworking on commuting are most pronounced (22 percent) in Moderately urban areas, with an address density between 1000 and 1500 per square kilometre. The effects are smallest (6 percent) in slightly urban areas, with an address density of 500-1000 per square kilometre. Across the other categories the effects are similar (between 10 and 13 percent).

Figure 3 has shown that there have been differential growth patterns of teleworking across occupations, and that there was a clear difference between occupations where teleworking remained stable or diminished between 2008 and 2018, and occupations where teleworking has grown. The latter occupations are ‘Higher academic’, ‘Higher supervisory’, ‘Intermediate academic’, ‘Intermediate supervisory/commercial’, and ‘Other mental work’. In columns (3) we interact the telework dummy with and indicator of these two groups. For ‘growth occupations’, the effect we find is close to the estimate in Table 1 column (2) (13 vs. 12 percent). For ‘other occupations’ there is no significant effect. It should be noted that a large part of the (representative) sample is employed in growth occupations. Considering that the FE coefficients are estimated based on changes in teleworking, it is not surprising that the effects we find are driven by growth occupations where a lot of people have started teleworking.

In column (5) we focus on growth occupations, and see if there are any differences between these occupations. Among Higher academic, Intermediate supervisory/commercial, and Other mental work, the effects are high (between 19 and 23 percent) and do not significantly differ from each other. Higher supervisory workers show a commuting time increase of 6 percent due to teleworking that is only significant at the 10 percent confidence level, and intermediate academic occupations show no significant relationship.

The results from this subsection show that although our estimates are higher than estimates with older data, between 2008 and 2018 the effect of teleworking on commuting was stable. There is however considerable spatial heterogeneity, and what stands out is that the effect of teleworking on commuting is most pronounced in moderately urban areas. Figure 5 in Appendix A shows that these Moderately urban municipalities include municipalities within the core area, between and around cities in the *Randstad*¸ and between cities along another urban corridor known as the *Brabantse stedenrij*. The analysis further shows that the effects of teleworking on commuting are concentrated in occupations where teleworking grew between 2008 and 2018. Even among these occupations, there is considerable heterogeneity in the relationship between teleworking and commuting. Specifically, ‘Higher supervisory’ and ‘Intermediate academic’ occupations show a strong significant relationship, as opposed to ‘Higher academic’, ‘Intermediate supervisory/commercial’, and ‘Other mental work’.

Table 3: Heterogeneity regressions

	(1)	(2)	(3)	(4)
*Telework * Period*				
*2008-2013	0.115***			
	(0.0177)			
*2014-2018	0.119***			
	(0.0184)			
*Telework * Urbanization*				
*Very strongly urban		0.0923**		
		(0.0449)		
*Strongly urban		0.122***		
		(0.0324)		
*Moderately urban		0.198***		
		(0.0381)		
*Slightly urban		0.0575*		
		(0.0318)		
*Not urban		0.108***		
		(0.0373)		
*Telework * Occupation*				
*Growth occupations			0.120***	
			(0.0158)	
*Other occupations			0.0494	
			(0.0855)	
*Higher academic				0.201***
				(0.0462)
*Higher supervisory				0.0608*
				(0.0347)
*Intermediate academic				0.0303
				(0.0240)
*Intermediate supervisory/commercial				0.176***
				(0.0353)
*Other mental work				0.209***
				(0.0335)
Constant	2.276***	2.302***	2.285***	2.525***
	(0.455)	(0.475)	(0.454)	(0.469)
Control variables	Yes	Yes	Yes	Yes
Sample	Full sample	Full sample	Full sample	Growth occ.
Model	FE	FE	FE	FE
Observations	20,519	15,952	20,519	16,523
R-squared	0.859	0.847	0.859	0.861

Dependent variable: Commuting time (log). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The 5 Growth occupations are included in the interactions. Other occupations are skilled and supervisory manual, semi-skilled manual, unskilled manual, and agrarian work.

5. Conclusion and policy implications

This paper gives updated estimates of the effect of teleworking on commuting time, and it is the first to examine heterogeneity in this effect – across time, space, and occupations – with the use of panel data. We use a novel longitudinal data source from the Netherlands, for the years 2008-2018, and find that workers who start teleworking increase their commute by 12 percent on average. This estimate is higher compared to studies that use older data, although we find that during our study period the effect has remained stable. A potential explanation for this stability is that between 2008 and 2018 teleworking technologies in the Netherlands have not improved a great deal, in the sense that teleworking has become a better substitute for working at the job location. This is supported by data from the OECD (2019) that shows that by 2009 already 90 percent of the Dutch population had access to internet, and growth rates of internet access were higher before 2009 than after. Given this stability in a situation with matured technology, we expect that this 12 percent will remain a good estimate of the relation between working from home and commuting.

We find considerable spatial variation in the effect of teleworking on commuting, and the effect is largest in Moderately urban municipalities, largely situated between cities belonging to the urban core. Given that teleworking increases the acceptance of a longer commuting distance, a tentative explanation for this spatial pattern is that these municipalities profit from a combination of proximity to larger cities, and the presence of good quality infrastructure between large cities. For Moderately urban municipalities situated between larger cities, an increase in spatial reach may disproportionately affect job accessibility as a consequence.

We finally show that the effect of teleworking on commuting is driven by occupations in which teleworking has grown. These are occupations that are characterized by intellectual rather than manual work, and even within these occupations there are differences. The notion that the ability to telework, and the relation between teleworking and commuting time differs between occupations is not new, but this is the first paper to give clear-cut estimates of the effects by occupation, based on time-variation in teleworking.

We distil three policy implications from this research. First, policymakers should not underestimate the effects of teleworking on commuting distance, especially if teleworking is promoted as a means to reduce harmful emissions. Our results suggest that 1 day of teleworking per week increases commutes by 16 percent on average (Table 2 column (3)). For people who work 4 days a week (about the average 31 weekly hours), introducing a working at home day leads to a reduction in travelling for work, but only by 13 percent instead of the naively expected 25 percent. For those that work 5 days per week, there is a 7.2 percent reduction instead of 20%. It should be noted that on average, teleworking still reduces work travel.

Second, teleworking may improve the fortunes of remote areas, as it increases job-accessibility. Even in the least urban areas, we find that people who start teleworking increase their commutes by 11 percent on average. Teleworking makes it easier to live in remote places, and have a job at a longer distance. However, the effects are most pronounced for places situated in urban regions, between larger cities. This suggests that access to high-speed internet is not a complete substitute, but also a complement of proximity to thick labour markets. More generally, telecommuting increases the size of labour markets. Our average of 12% longer commuting times, increases the area of the labour market with 25%. Assuming that jobs, infrastructure and transport are equally spread and that commuting times translate neatly into commuting distances, this means a substantially larger labour market, which is even larger for certain professions and some areas.

Finally, in projecting the consequences of teleworking policies on commuting distance, policymakers should be aware that the effects differ between intellectual and *manual* occupations. This result may not only be driven by the nature of occupations, but also by the geography of job-types. Our data shows that the share of intellectual occupations increases with the level of urbanization, while the share of manual occupations increases. It should also be noted that there are stark differences even within intellectual occupations, and the effects are especially small for higher management (8 percent of workforce) and intermediate academic occupations (26 percent of workforce). This has a social impact, as the ability to work from home implies that some groups in society obtain more freedom in where they locate, whereas others do not, and are more bound to places and smaller labour markets.

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Appendix A

Table 4: Correspondence between LISS Professions and ISCO-08

LISS measure of profession	ISCO-08 codes
1 higher academic or independent profession (e.g. architect, physician, scholar, academic instructor, engineer)	2
2 higher supervisory profession (e.g. manager, director, owner of large company, supervisory civil servant)	1

3 intermediate academic or independent profession (e.g. teacher, artist, nurse, social worker, policy assistant)	3
4 intermediate supervisory or commercial profession (e.g. head representative, department manager, shopkeeper)	1
5 other mental work (e.g. administrative assistant, accountant, sales assistant, family carer)	4, 5
6 skilled and supervisory manual work (e.g. car mechanic, foreman, electrician)	7
7 semi-skilled manual work (e.g. driver, factory worker)	8
8 unskilled and trained manual work (e.g. cleaner, packer)	9
9 agrarian profession (e.g. farm worker, independent agriculturalist)	6

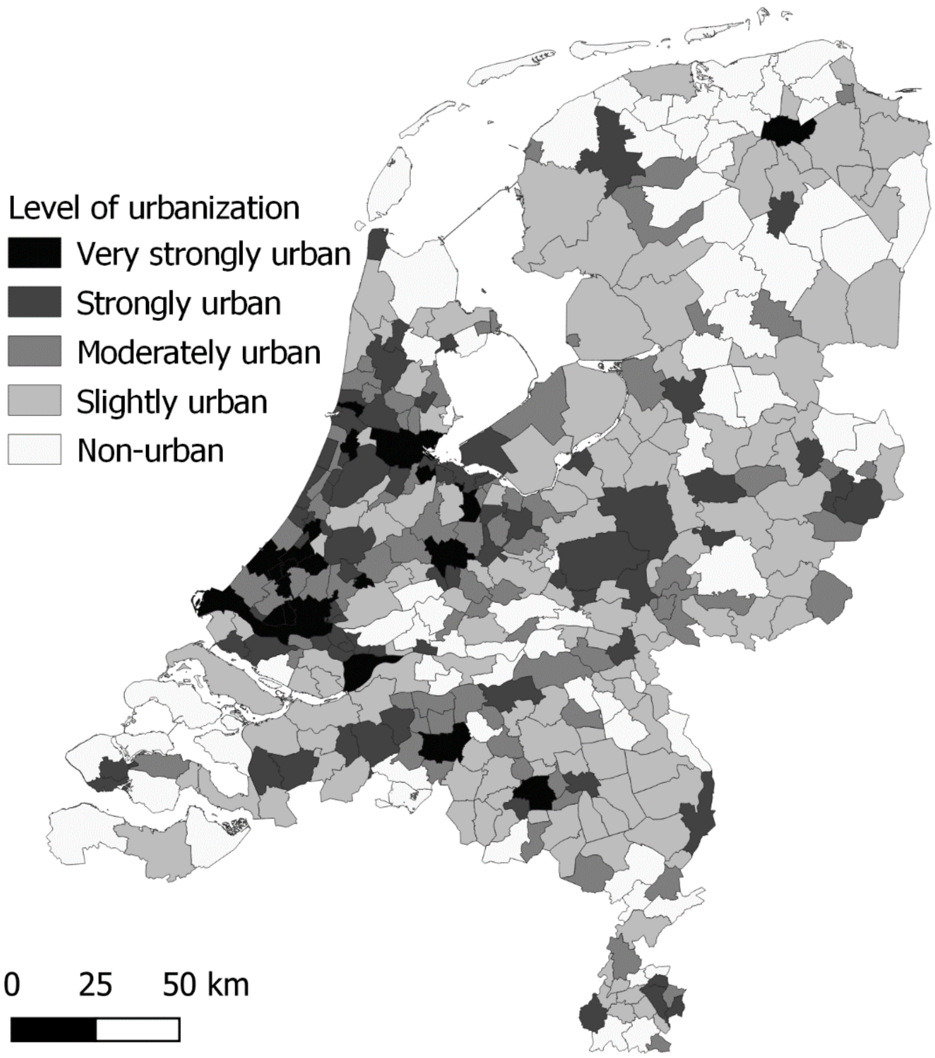

Figure 5: Map of levels of urbanization