# Effects of the Covid-19 pandemic in the area of tension between the economy and climate change: A case study at rural and city district level in Southern Germany

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Abstract:
Working from home (WFH) is meanwhile a technologically feasible solution for regular employment in many sectors and with positive impacts on health, resource consumption and the environment. The paper addresses the Corona crisis as a situation where working people are forced to switch to teleworking. A global secondary perception analysis and a subsequent econometric analysis for Southern Germany at district level confirms teleworkability to be a significant tool for more climate protection if implemented in real life (WFH). Higher infection incidence seems to indicate lower levels of teleworkability or less acceptance or less responsiveness during the pandemic. Teleworkability translated into true WFH might also strengthen regional resilience against contagion. It is thus a potential instrument of safer public infrastructure.

ROBUST receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727988.

# Effects of the Covid-19 pandemic in the area of tension between the economy and climate change: A case study at rural and city district level in Southern Germany

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## 1. Introduction

In recent months, since the beginning of the COVID-19 pandemic outbreak, several surveys and research studies have been conducted to explore the effects and the consequences of the global crises on the labour market and the economy during and after the on-going pandemic. Simultaneously, thousands of businesses and institutions are trying to figure out how to remain operational despite the crisis.

Perhaps one of the immediately observable consequences of the crisis is the relocation of some of the activities of companies and institutions to the private home. Working from Home (WFH) proved to be an outstanding alternative for partially maintaining the functionality of many businesses. Interestingly, the results of many relevant analytical efforts indicate that most employees as well as employers foresee unprecedented positive opportunities for WFH after the pandemic, particularly with regard to productivity, competitiveness and life quality [1]. Further to that, WFH has a demonstrable impact on the environment (Issa and Bergs 2020). There is a slowdown of economic activity, less commuting and less international transport; all this leads to a rapid reduction of greenhouse gas (GHG) emissions. All this is well visible in recent satellite imagery from Copernicus-Sentinel. It shows a major recovery impact of the slowdown on air quality.

Certainly, WFH has a predominantly economic function; it has evidently alleviated the already predicted devastating mechanisms of the crisis, even though the pandemic staggered national and global economies in a rigid state with a deep uncertainty about future developments. In the forthcoming months, many countries are likely to suffer significant economic imbalances. Based on estimations during the crisis, the global economic growth is expected to shrink by 2.5 per cent, after growth of 3.5 per cent had been forecast in the pre-Corona phase (Michelsen et al. 2020, p. 201).

The coronavirus pandemic is currently causing massive changes in wide areas of the economy, labour force and society in almost all parts of the world (CNBC 2020): Among others, fewer vehicles are

[1] Currently, during the crisis around 8 million people in Germany work from home in a home office, almost 18 percent of the total labour force (Federal Labour Minister 26.04.2020). According to provisional calculations by the Federal Statistical Office (Destatis), around 45.0 million persons resident in Germany were in employment in March 2020. Destatis: Pressemitteilung Nr. 150 vom 30. April 2020 https://www.destatis.de/DE/Presse/Pressemitteilungen/2020/04/PD20_150_132.html

driven because commuters now work from home, public transport is largely paralyzed, airplanes stay on the ground, heavyweight industries close factories, tourism and business travel comes to a standstill.

The German economy and the economy of all individual federal states are also strongly affected by the fast spread of the Covid-19 (e.g Wollmershäuser et al. 2020; Wollmershäuser and Wohlrabe 2020). It is to be stressed that without the technological opportunities of WFH the economic crisis would be even considerably stronger. Since the pandemic has forced employers and employees to make more use of home-office-based work, specific potential efficiency gains have become visible in terms of the cost-output ratio in the private (and public) sector and for the consumption of natural resources (such as clean air). This deserves further attention.

The study at hand addresses the peculiar effects in the area of tension between the economy and climate change from two points of view, (i) a general sociological one by viewing the acceptance of a changing working life (more WFH) linked to the relationship between working life and the environment by secondary data (surveys) and (ii) a specific spatial one by exploring higher resolved primary data. As regards the latter viewpoint, the authors look at the German Bundeslaender Hessen, Bavaria and Baden-Württemberg, which are among the wealthiest and economically most active regions in the EU. Also here, the primary implications of the pandemic have been a massive decline of economic activity in the majority of sectors. Short-term work, redundancy and bankruptcy of firms have become rampant as anywhere worldwide. Hence, any positive outcome of this massive reduction of economic activity on the environment and the climate has to be weighed against the welfare loss, i.e. the economic costs of Covid-19. Cleaning of the air during March and April 2020 thus stems from less production and less traffic. Less traffic consists of less commuting, less carriage and less passenger travelling by aircraft, train and ferry. With the easing of the lockdown, emission outputs have immediately resumed, so the time horizon of this study is just mid-March to mid-April 2020.

The study is structured into a methodological introduction including the description of data, a descriptive analysis of the situational perception by secondary data (surveys) and an econometric analysis of the perceived relationships by exploring data for different predictors of the reduced greenhouse gas GHG emission during March to April 2020. Further to that there is a brief conclusion (showing the "what" of the study) and an outlook (discussing the "so what" of the results).

## 2. Methodology and data

The emergence of the pandemic crisis has affected various sectors in the German economy and might have already subtly changed specific perceptions of the working life. In the global descriptive analysis these effects will be reflected. Results of three surveys are reviewed to demonstrate the effects of the crisis on the labour conditions from the perception viewpoint. Based on data from international health and environmental institutions, the global current as well as the pre-pandemic health and

environmental situation will be regarded to direct our attention to the relationship between lockdown, the pandemic and the peculiar environmental reaction (GHG emissions) from a spatial viewpoint.

With a more technical focus we then examine the situation on the ground by merging several spatial datasets available with a view to inspect different possible predictors (representing the current slow-down of economic activity) that could have an immediate effect on GHG reduction at the level of rural and city districts in Hessen, Bavaria and Baden-Württemberg. We selected those three geographically contiguous Bundeslaender because together they represent a large growth pole of the German economy with several major urban agglomerations. The model introduced above is first cast into a simple OLS log-linear regression and then subsequently augmented within more advanced spatial econometric procedures in order to capture neighbourhood effects that are quite likely is such a context. The simple OLS model is:

$$\ln(E) = a + b_1 \ln(I) + b_2 \ln(T) + b_3 \ln(S) + \varepsilon$$

where E means the reduction of $NO_2$ reductions in percent during March and April detected by image analysis of Copernicus-Sentinel satellite imagery. The RGB colour images (March and April 2020) were transformed into 16-bit ones. NUTS-2 regions were cropped from those two image data files; $NO_2$ emission differences in percentage (March to April 2020) were calculated for every region by ImageJ[2]. The variable I means the local total incidence of Covid-19 infection; data for that are ready-made at district level and taken from the Robert-Koch-Institute (SurvStat@RKI 2.0 application). T means "teleworkability" of a regional economy, i.e. the specific potential of working from home. During the pandemic it is assumed that the levels of teleworkability and true WFH tend to equalise. This concept recurs to Fadinger and Schymik (2020). The data background for that is the production statistics (NACE) at the NUTS-3 level of the three Bundeslaender viewed. The teleworkability index is based on the calculation of Dingel and Neiman (2020)[3] and then merged with the regional production data published by Eurostat (table "namq_10_a10"). The variable S represents the change of short-term work at district level in percent. These data are ready-made available at district level from the Federal Agency of Labour. We have not deemed the change of unemployment a meaningful predictor because during March to April 2020 most companies have used short-term work to bridge the economic downturn and to resume full production within weeks or few months. The variables I and S on the one hand and T on the other are to be distinguished in their characters. While T is a lasting independent variable, I and S are predictors that just take effect during the pandemic. They just measure whether infection incidence or short-term work leads to more or less GHG emissions. The variable I is not

[2] The variable has some important limitations: Within NUTS-2 regions data are invariant, hence some error may be induced by comparing a NUTS-2 resolved dataset with NUTS-3 resolved predictors. Due to typical seasonal fluctuations, weather and underlying secular trends of air quality, the simple comparison of two consecutive months is imprecise. However, in contrast to the sharp decrease in 2020 the average $NO_2$ pollution (µg/m³) of the two months in 2019 had been at the same level for rural and urban areas and traffic routes (German Environment Agency 2020, p. 14). Therefore, the simple direct comparison of March and April 2020 is deemed feasible for that purpose.
[3] Cf. Supplementary replication package: column „teleworkable_emp" in file „NAICS_workfromhome.csv" stored in the sub-folder „national_measures" (Internet link: see references)

expected to directly influence GHG emissions but it could shed light on how timely and appropriately people have reacted with lockdown and sufficient protection against contagion. It is to be stressed that infection incidence only represents cases confirmed by PCR tests and not those many undetected cases. Since the proportion of confirmed to undetected cases may vary across the spatial units, inconsistency in estimation cannot be fully ruled out. Apart from I, T and S there are however important spatial effects to be expected; such rural districts are close or distant to each other, and particularly a change of GHG emission is also influenced by spatial spillover effects. We therefore address those effects within an augmented spatial autoregressive and spatial error model (Anselin and Florax 1995; Dubé and Legros 2014).

$$\ln(E) = a + \rho\omega \ln(E) + b_1 \ln(I) + b_2 \ln(T) + b_3 \ln(S) + \varepsilon \qquad \textbf{(SAR)}$$

or

$$\begin{cases} \ln(E) = a + b_1 \ln(I) + b_2 \ln(T) + b_3 \ln(S) + \nu \\ \nu = \lambda\omega\nu + \varepsilon \end{cases} \qquad \textbf{(SEM)}$$

where ω represents a row-standardised spatial weight matrix, ρ and λ are the spatial coefficients. The error term ε is i.i.d. with mean zero and a constant variance: $\varepsilon \backsim N(0, \sigma^2)$. In the SEM case ν is the sum of spatial (λων) and non-spatial error (ε). The right choice between both models is determined by different tests, such as Moran's I of the residuals and (Robust) Lagrange multiplier (LM) tests.

In addition to the above standard spatial procedures we also explored the context in a Spatial Durbin model in that spatial lags of both, the dependent variable and the predictors are included, and a SLX model where instead of the spatial lag of the dependent variable the lags of predictors are considered. In case of the Spatial Durbin model the log-likelihood function did not converge to a maximum, therefore we had to drop this approach. The SLX model (Halleck Vega and Elhorst 2015) to be efficiently and unbiasedly estimated by OLS is formulated as follows:

$$\ln(E) = a + b_1 \ln(I) + b_2 \ln(T) + b_3 \ln(S) + \theta_1\omega \ln(I) + \theta_2\, \omega \ln(T) + \theta_3\omega \ln(S) + \varepsilon$$

The coefficient $\theta$ represents spatial spillover effects of the predictors which are indirectly implied by respective average forces from neighbour regions, hence $b_i + \theta_i$ shows direct plus indirect (=total) effects of an independent variable. The log-linear form allows to directly interpret coefficients as elasticities, thus if e.g. the sum of coefficients of predictors X and ωX is 0.5, a one percent increase of X in region i, and on average in the neighbour regions, would lead to a total 0.5 increase of the dependent variable Y when keeping the other influences constant.

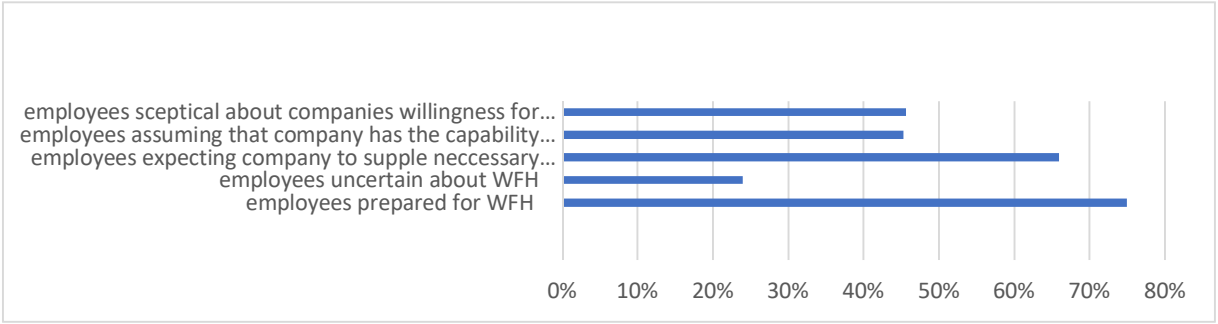
Our study addresses the actual determinants of the changes in air pollution. We hypothesise that teleworkability is a general predictor, while the other are specific ones that accrue from the current constraints in public life. It should be noted, however, that there could be also reverse relationships, namely (i) air pollution (particulate matter) as a suspected carrier of outdoor contagion, so that GHG emissions are also a potential predictor of the geographical distribution of the pandemic (Setti et al. 2020) or (ii) that the infection rate I depends on teleworkability T (Fadinger and Schymik 2020). Since there is only the proof of a virus concentration on particulate matter but no respective evidence of contagion, a further investigation in this direction would be speculative by now. Fadinger and Schymik (2020) estimated the infection rate in an epidemiological model after first estimating the impact of WFH on the contact rate at a NUTS 2 resolution (non-spatial). They found strongly significant negative effects of WFH on the infection rate. We also tested this model with a spatial regression procedure for our data at NUTS-3 level but had to conclude with an insignificant estimate[4].

## 3. Results

### 3.1 Acceptance of Teleworking and its possible impact on the environment and public health

A sustainable reduction of GHG emissions needs teleworkability (the potential of WFH) to materialise. Apart from legal and technical preconditions this largely depends on readiness on the part of employers and employees. The Corona crisis has forced people to WFH and may have changed minds simply due to their newly acquired experience with WFH. In the following section three consecutive recent surveys among potentially teleworking employees are illustrated. An early survey conducted in March 2020 by the BVDW (Bundesverband Digitale Wirtschaft) predicted up to 75 percent of the employees to be prepared for WFH during the pandemic.

*Fig. 1: BVDW Survey (March 2020)*




Data source: Statista (2020)

Regarding the expectations of the employees toward their employers, over 66 percent expect their employer would undertake adequate technical measures for WFH, 45.3 percent assume that their

[4] Data and estimates are available from the authors on demand. We suspect a mismatch between teleworkability and WFH or different spatial resolution levels to be reasons of such strikingly different results.

employer is technically capable to provide the necessary WFH facilities, and 45.7 percent are still sceptical about the willingness of the employer (Statista 2020)

Another survey executed by Bitkom mid-March 2020 (Bitkom 2020) found that already one out of two gainfully employed is working entirely or at least partially at home as a result of the Corona pandemic. Advanced communication technology has vastly contributed to digitize business activities and has strongly facilitated the rise of WFH, as responders argued. Meanwhile, many activities could be carried out from a digitalized home office such as web conferences, transfer of legal documents, organizing customer and supplier meetings and a lot more. However, still 62 percent of employees with a home office permit preferred the company's office as their place of work. Now it would be interesting to see how those perceptions and standpoints have changed in these times of classical uncertainty, namely the Corona crisis.

According to a representative survey implemented in April 2020 by the BITD (Bavarian Research Institute for Digital Transformation), already two-thirds of the employees surveyed would prefer to have more home office after the Corona crisis than before. This suggests that there may have been some habituation effect and an acceptance of WFH well increased during the early weeks of the pandemic (Stürz et al. 2020). Further to that and unexpectedly, the majority of employers seem to be technically well prepared for the home-office option, and a growing number of employees is satisfied with this new way of working arrangement. They favour to continue working from home after the crisis.[5]

The surveys reviewed above clearly confirm a growing readiness among employers and employees, triggered by the Covid-19 crisis, to make more use of WFH. Still, there is some uncertainty about sustainability of this mutual readiness in post-Corona times. But apart from a possible protection against contagion during lockdown, WFH has definitively a beneficial and immediately perceivable impact on the environment and public health in general.

Through strong multiplier effects along the production chain GHG emissions in Germany may decrease by at least 50 million tons of GHG by the end of this year compared to 2019. Depending on further development in the Covid-19 pandemic, there may be up to 120 million tons of $CO_2$ reduction. This would result in a reduction in emissions by 40 to 45 percent compared to 1990 (Agora 2020). In this connection, it can be estimated that factories' shutdown will inevitably reduce the demand for steel, cement and chemicals and if the production discontinues over a few weeks, the GHG reduction will be around 10 million tons. Given that the shutdown activities are going to continue for three further months, the emissions will be reduced by around 18 million tons as a result of production

[5] Nonetheless, there is still a widespread uncertainty among various firms operating in specific sectors that the situation may again change after the pandemic, due to unknown changes in the economic framework conditions, particularly with regard to productivity and competitiveness. These arguments are countered by several studies, which predicted more advantages for companies than disadvantages. A 2015 study conducted by the Stanford University found that productivity among call-center employees at Chinese travel agency Ctrip went up by 13% when they worked from home (Bloomberg 2020).

stoppages. If the crisis lasts longer, the GHG emission reduction of about 25 million tons is likely to occur (Agora 2020).

The environmental situation and the status of public health are closely interrelated. According to the World Health Organization (WHO), air pollution causes lung and respiratory diseases, cancer, heart disease and diabetes and kills about seven million people around the world every year, and unfortunately over "95 percent of the EU urban population remain exposed to pollutant concentrations above WHO air quality guidelines." Traffic noise is a further related burden (EEA 2020)

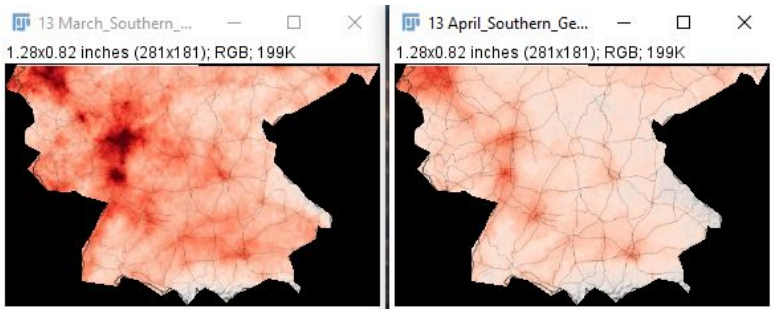
In connection with the Covid-19 pandemic, the WHO noted that people who contract SARS-Cov-2 have much higher death rates, between 700 percent and 1,400 percent higher mortality rates if they have any of the above stated preconditions (WHO 2020). Covid-19 enters the respiratory tract, attacks the lung cells and becomes severe in almost 20 percent of cases. Pneumonia with Covid-19 can result in more severe than "normal" pneumonia because it occurs in all areas of the lung, and there is no treatment yet available. Preliminary evidence suggests that areas with poorer air quality are more vulnerable. Lombardy, Italy, has one of the worst air quality levels in Europe, and it became Italy's most Covid-19 affected area with deaths. A similar environmental situation could be found in Wuhan that became the first centre of Covid-19 deaths (WHO 2020; see also: Setti et al. 2020).

Health, climate change and the patterns of our working life are thus closely interlinked. The Corona crisis provides a real-world experimental laboratory to explore exactly that context on the ground. With other words: How does teleworking (as a proxy for lockdown) affects the environment and what do most recent data at rural and city district tell us about that context?

### 3.2 The empirical analysis at a regional level

In the empirical section we aim to closer inspect the context of relationships and influences statistically. The pace of cleaning the air over Europe appears tremendous when looking at the Copernicus-Sentinel images that suggest a major reduction of GHG emissions (here represented by $NO_2$) during March to April 2020. [6]

[6] The climate change in Europe during the pandemic has been illustrated in the comparison of nitrogen dioxide emissions over Europe between March/April 2019 and 2020. Copernicus: Sentinel-5P (Precursor - Atmospheric Monitoring Mission) 2020; see also, NASA. Earth Observatory 2020



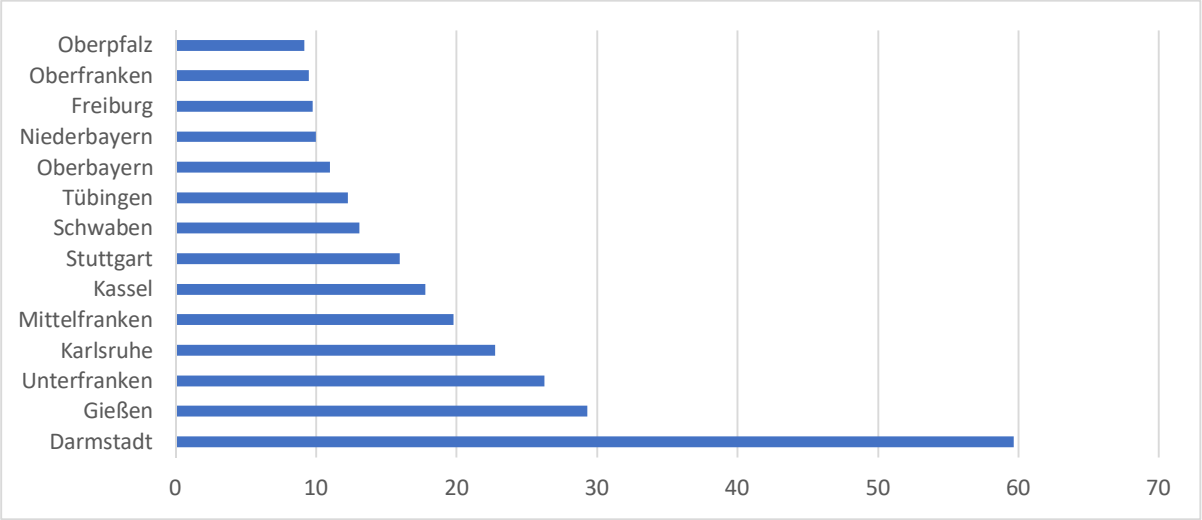

These images can be directly used as a database for statistical analysis. With image analysis (ImageJ) we transformed the coloured satellite images into 16-bit images in order to directly estimate the change of emissions with the change of the Digital Number (DN) of pixels.

*Table 1: Basic moments of $NO_2$ emissions compared (March-April 2020)*

| | Mean DN | StdDev DN | Mode DN | Min DN | Max DN |
|---|---|---|---|---|---|
| March 2020 | 179.232 | 34.915 | 193 | 30 | 249 |
| April 2020 | 210.280 | 23.192 | 226 | 52 | 250 |

The direct percentage change of mean DN for Southern Germany as shown by the two images is thus 14.8 percent. A similar estimate (daily change compared to averages in former years) is given by Le Quéré et al. (2020) at a global level. The further analysis of this dataset has been done at the level of NUTS-2. Results are displayed by the following figure:

*Fig. 2: Reduction of GHG emissions at NUTS-2 level in Hessen, Baden-Württemberg and Bavaria: Reduction of GHG emissions March-April 2020 (percent)*

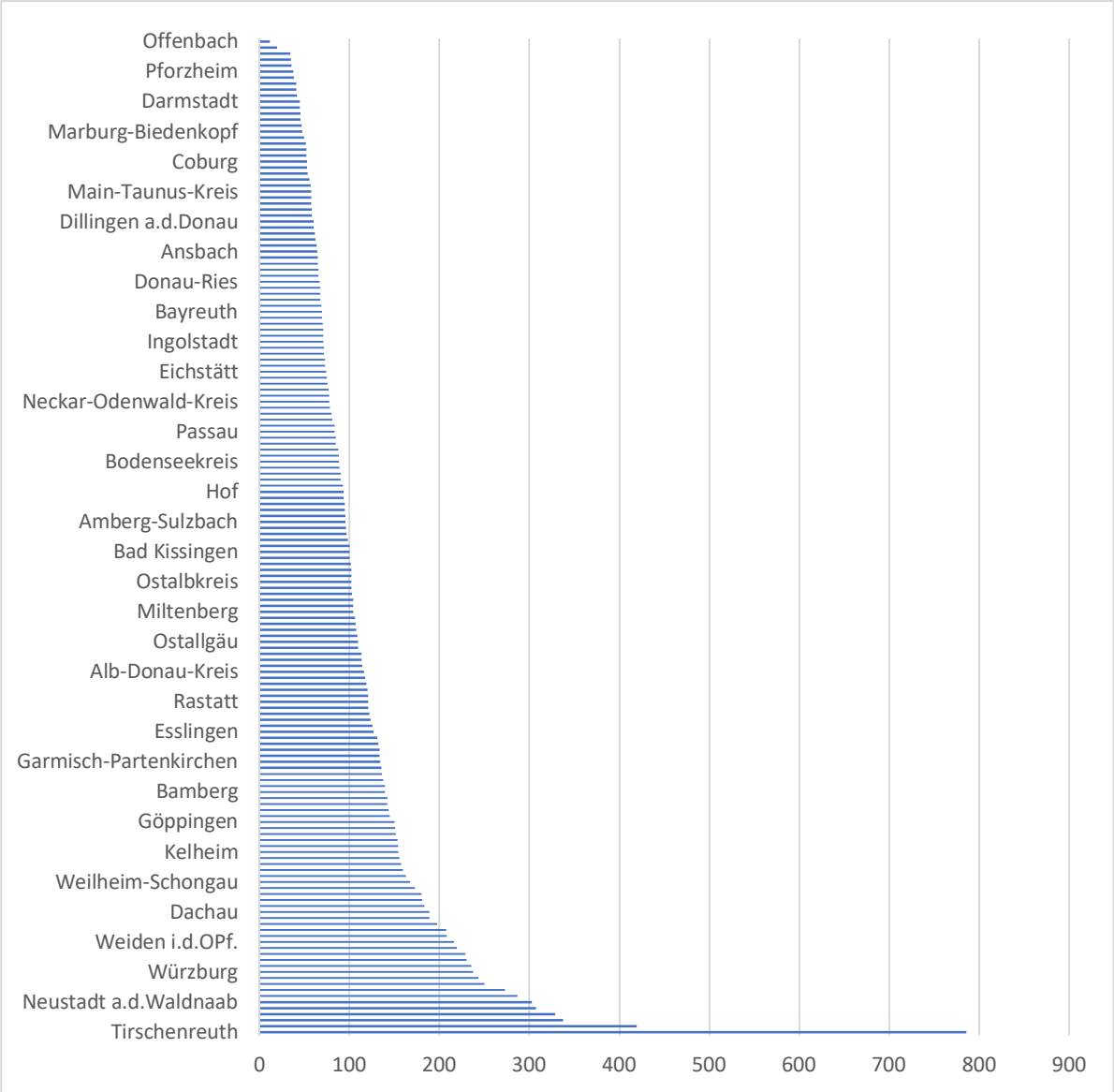



Source: Copernicus Sentinel

The distribution appears non-linear with one noticeable outlier, namely the NUTS-2 region Darmstadt. Hence, reduction of GHG emissions in the Frankfurt/Rhein-Main region are by far the

largest in Southern Germany. Interestingly, the images suggest a levelling in the distribution of GHG emissions. The April 2020 image appears more homogeneous than that from March. Therefore, the top and bottom ranked districts will be subject to a closer inspection by comparing observed and estimated GHG reductions. These data are used to fill the vector of the independent variable.

*Fig. 3: Covid-19: Total incidence at district level: Bavaria, Baden-Württemberg & Hessen*

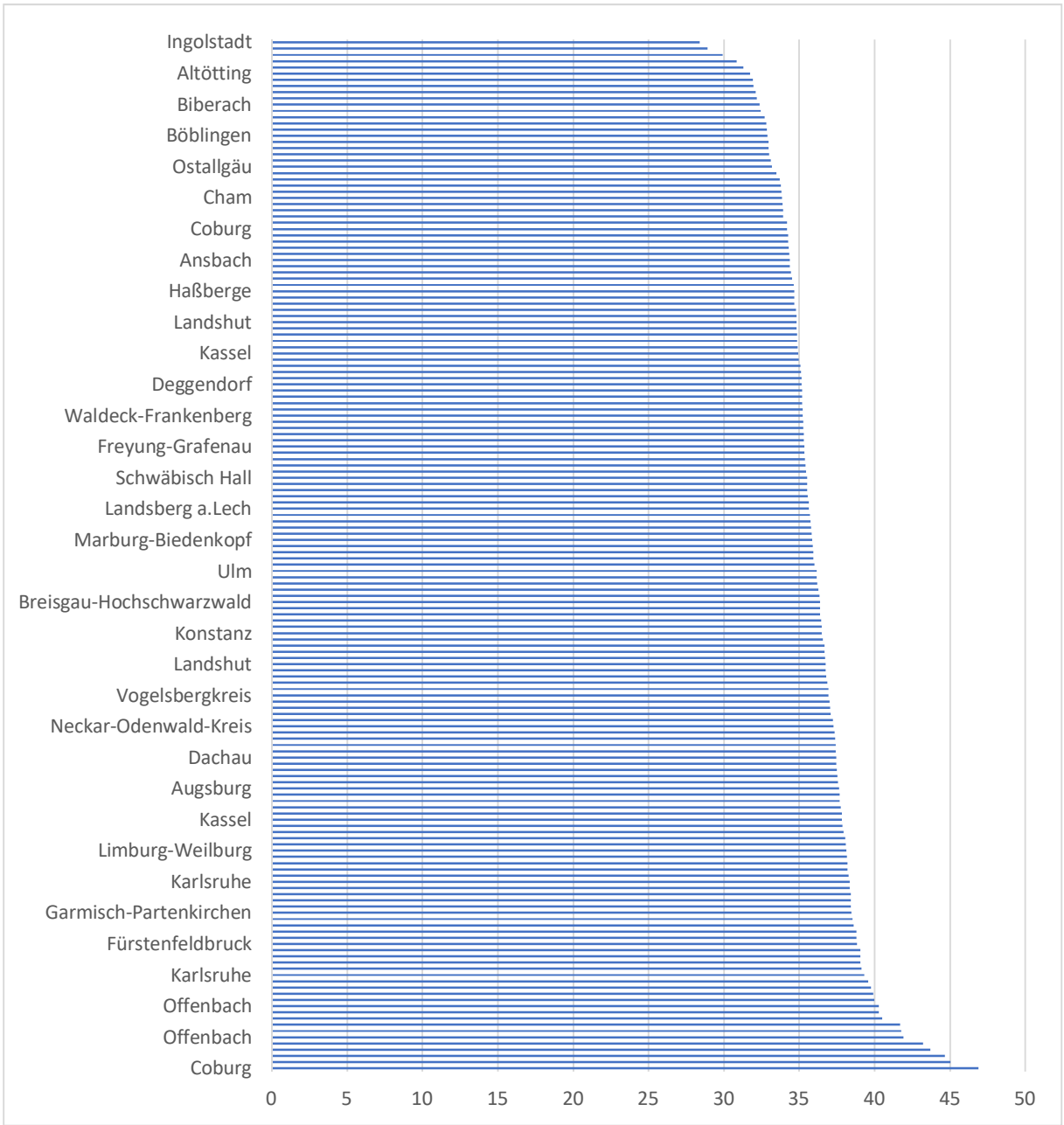



Source: Robert-Koch-Institut

Independent variables are deemed the teleworkablity (as a proxy to represent WFH during the pandemic), the sudden surge of short-term work implied by the lockdown and the local infection incidence. According to the data from the RKI, total infection incidence is significantly higher in Bavaria and Baden-Württemberg as compared with Hessen. This might stem from random incidence, but also systematic differences, at least the variation appears impressively strong which significantly less incidence in Hessen (Figure 3). As regards teleworkability the variation ranges between ‹30 and

more than 45 percent. Those cities and districts with higher share of financial services and services for enterprises have a higher potential of teleworking than regions with more agriculture, local trade, crafts and industry. But not only bigger cities and peri-urban regions around show a stronger potential of teleworking as figure 4 shows.

*Fig 4: Teleworkability in Southern Germany at district level*




Source: Own calculation based on Eurostat NACE data and supplementary files from Dingel and Neiman (2020)

The distribution of the third predictor (S=short-term work) is dropped because it is insignificant and thus meaningless for the estimation (see below Table 3); Variance inflation factors are low (< 2.0)[7], so there is no multicollinearity of I, S and T. The related basic moments of all variables are displayed in Table 2.

*Table 2: Descriptive statistics of the variables entering the econometric analysis*

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Ln(E) | 166 | 2.761608 | 0.5353325 | 2.216558 | 4.089379 |
| Ln(I) | 166 | 4.58767 | 0.5793791 | 2.456164 | 6.667173 |
| Ln(T) | 166 | 3.587622 | 0.0761771 | 3.347257 | 3.848355 |
| Ln(S) | 166 | 11.370160 | 1.7252620 | 7.496708 | 13.815510 |

At a first glimpse, the simple OLS estimates show that there are two significant estimates, namely infection incidence and teleworkability. Hence there is reason to assume that the incidence of Covid-19 has a negative effect on greenhouse gas reductions, while teleworkability has supported the reduction of GHG emissions. The estimate for I says that regions with a higher Covid-19 incidence seem to have reacted less intensely in economic and social activity, or there was no chance to react correspondingly. The strong increase of short-term work is insignificant. This could have to do with different starting levels in March, in many rural districts at zero, while in others at higher levels. There might be anyway a strongly distorting statistical base effect.

By comparing the preliminary OLS estimates with the observations we can now show that observations for a majority of districts and cities in Hessen outperform estimates while for the majority of districts and cities in Bavaria and Baden-Württemberg estimates outperform observations. When inspecting the margins, the top seven ranks are districts of the NUTS-2 region Darmstadt. All districts and cities of the NUTS-2 region Darmstadt belong to the top 20. At the lower end, most districts are Bavarian ones. Waldshut and Werra-Meißner are lowest scoring for Baden-Württemberg and Hessen.

[7] The VIF threshold for Multicollinearity is <10.

*Fig. 5: Selection of observed versus estimated changes of GHG emissions during the pandemic*


Source: Own estimates (non-spatial regression)

By further inspecting the spatial extensions of the model we notice that coefficients of both spatial models are highly significant, a simple OLS estimation is thus inefficient and biased. In both extended models (SAR and SEM) spatial considerations imply a reduction of the absolute value of coefficients for incidence and teleworkability, but both are still highly significant. The spatial autoregressive model appears slightly more appropriate than the spatial error model, specifically due to the insignificant Robust LM test for the latter model (p=0.79).

*Table 3: Regression results I*

| Dependent variable: ln (E) | OLS | ML-SAR | ML-SEM |
|---|---|---|---|
| Constant | -2.52 | -3.55 | -0.63 |
| (Standard error) | (1.78) | (1.24) | (2.01) |
| ln(I) | -0.37 | -0.24 | -0.22 |
| (Standard error) | (0.06) | (0.04) | (0.05) |
| ln(T) | 2.01 | 1.32 | 1.07 |
| (Standard error) | (0.49) | (0.34) | (0.37) |
| ln(S) | -0.02 | 0.00 | 0.00 |
| (Standard error) | (0.49) | (0.01) | (0.02) |
| λ | - | - | 0.98 |
| (Standard error) | - | - | (0.02) |
| ρ | - | 0.98 | - |
| (Standard error) | - | (0.02) | - |
| Log-Likelihood | - | -49.54 | -59.88 |
| Wald-test ($\chi 2$) λ or ρ = 0 | - | 3427.90 | 2827.52 |
| p | - | 0.00 | 0.00 |
| Moran's I resid. (z-score) | - | - | 18.83 |
| p | - | - | 0.00 |
| Lagrange multiplier (LM) | - | 307.23 | 233.09 |
| p | - | 0.00 | 0.00 |
| Robust LM | - | 74.21 | 0.07 |
| p | - | 0.00 | 0.79 |
| Obs. | 166 | 166 | 166 |

A further refinement of the analysis comprised the Spatial Durbin model (SDM) and the Spatial-Lag-of-X model (SLX). The SDM turned out to be inappropriate in our context. The SLX model (distance threshold for both spatial lags: 30 kilometres) however reveals a strong and highly significant influence of the spatially lagged predictors, even stronger than the original variables alone. Hence, the total effect (direct plus indirect effect) of teleworkability is at 3.96, with other words, an increase of one percent more teleworkability in a district and on average in its neighbourhood areas would result in roughly further four percent of the relative reduction in GHG emissions, when keeping the Covid-19 incidence constant and assuming a zero influence of seasonal fluctuations, weather and $NO_2$ emission

trend. For regions with a strong level of teleworkability this effect is substantial (e.g. for the NUTS-2 region Darmstadt). As mentioned above, we dropped the variable S (short-term work) because of insignificance.

*Table 4: Regression results II*

| Dependent variable: ln(E) | OLS-SLX |
|---|---|
| Constant | -9.23 |
| (Standard error) | (2.51) |
| ln(I) | -0.22 |
| (Standard error) | (0.07) |
| ln(T) | 1.07 |
| (Standard error) | (0.46) |
| lag ln(I) | -0.28 |
| (Standard error) | (0.08) |
| lag ln(T) | 2.89 |
| (Standard error) | (0.59) |
| Adj. $R^2$ | 0.43 |
| Obs. | 149 |

The SLX model thus well reveals the vital spatial dependence in the mechanisms of the recent observations of reduced GHG emissions over Europe including Southern Germany. Teleworkability appears to be an infrastructural factor with important implications for climate protection at a regional level.

## 4. Conclusion

Evidence of the data suggests that teleworkability of a regional labour market has an important and significant impact on the reduction of GHG emissions. During the Covid-19 pandemic most private and public sector entities have made use of WFH and subsequently there has been a dynamic change of perception of WFH among employers and employees within weeks. Consequently, the GHG emissions have dropped abruptly during the few months since the beginning of the year because of the global economic slowdown. Based on recent estimations the daily global $CO_2$ emissions have decreased by –17 percent, due to the worldwide forced confinements (Le Quéré et al. 2020). The average magnitude can be confirmed by our analysis on Southern Germany; at district level there are pronounced variations. The southern German Bundeslaender have shown remarkable different levels of adaptability toward the pandemic and the shutdown. The GHG emissions dropped much more in the Rhein-Main region as a result of the lockdown than other regions in Bavaria, Hessen or Baden Württemberg. Still, evidence suggests that more efficient use of the potential of teleworkability has a strong and significantly positive influence on GHG reduction. Further to that, the infection incidence has had a significantly negative impact on reduction of GHG emissions. This might reveal that in those regions with a high

incidence of Covid-19, there were probably less opportunities to react timely with protection measures and possibly to switch regular work to more teleworking.

## 5. Outlook

To avert the looming economic crisis and the social imbalances after the pandemic, many politicians and policy makers around the world are about to make substantial financial sources available. Multiple fiscal and monetary stimulus packages with trillions of Euro are being prepared worldwide to stave off these predicted crises. In view of the approaching threat of a global economic recession, some of the current post-Covid-19 efforts appear to be completely neglecting climate-friendly measures. The positive changes in the climate conditions occurred after the beginning of the pandemic are being at times intentionally or unintentionally downplayed in favour of economic priorities. There is thus a major risk of falling behind recent lessons learned including the WFH experience. In light of this, leading national and international environmental agencies emphasize the necessity of climate protection-oriented economic and investment policy after the pandemic (Deutsche Welle 2020)

Teleworkability is a potential supporting factor for public health when translated into real WFH, at the moment specifically protecting against infectious diseases such as Covid-19, and at the same time increasing resilience of local economies. The challenge for policy is however not confined on just propagating WFH but to support information technology, efficient allocation of artificial intelligence, motivate an adequate legal framework for WFH and increasing welfare by adjusting prices of clean environment and public health representing their scarcity relations, such as on the markets for products and services. WFH is thus a potential instrument of safer public infrastructure. Perhaps, even though not yet empirically provable, Covid-19 is not at least an effect of excess passenger transport, globally and locally.

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## Acknowledgement

The study was funded under the Horizon2020 research grant 727988 "Rural-Urban Outlooks" (ROBUST)

## Supplementary data

The complete dataset of the empirical analysis is available on demand

Draft version
1 July 2020