Relationships between coworking spaces and CO₂ emissions in work-related commuting: first empirical insights for the case of Switzerland with regard to urban-rural differences

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Abstract

Today in transport policy it is assumed that new forms of work are producing falls in greenhouse gas (GHG) emissions from work-related commuting. So far, research on the effects of teleworking generally report positive environmental outcomes. However, no study has so far compared and contrasted the greenhouse gas (GHG) mitigation potential of the new phenomenon of coworking spaces with regard to urban-rural differences. Our results based on a representative sample of Swiss coworkers indicate that CO₂ emissions from commuting for work are significantly lower for urban coworking spaces (350 kilograms/year) than for rural coworking spaces (940 kilograms/year). If coworkers only would have worked in their coworking spaces, there would be a 10% reduction in CO₂ emissions of their commutes. Overall, our results indicate that coworking spaces, especially in urban areas, have the potential to support Switzerland’s commitment to reduce greenhouse gas (GHG) emissions in the transport sector in line with the Paris Climate Agreement.

1. Introduction

The Paris Climate Agreement (UNFCCC 2015) sets the framework for Switzerland to adopt an energy-reduction strategy to reduce greenhouse gas emissions (GHG), including the transport sector (SFOE 2018a). Transport has consistently accounted for one third of all energy consumption in Switzerland (SFOE 2018b, p. 5). In order to achieve a reduction in carbon dioxide (CO₂) emissions, one main strategy in Switzerland’s transport policy is to reduce the number of trips and distances associated with work-related commuting. In fact, work-related travel accounts for 24 percent of daily distances travelled in Switzerland (SFOS/ARE 2017, p. 38).

Coworking spaces are flexible, shared workspace settings in an open-plan office environment where desks can be rented on a daily, weekly, monthly, or yearly basis (Spinuzzi et al. 2019). The Work Smart Initiative, an alliance of Swiss government institutions and companies, assumes that new forms of flexible work have a positive effect on CO₂ emissions by reducing or even eliminating work-related travel. In this context, the relatively new phenomenon of coworking spaces is one example of flexible forms of working being supported by the authorities.

However, from an academic perspective, the positive outcomes of coworking spaces for GHG mitigation that are claimed in public are still subject to debate. So far, empirical research on teleworking in general, with a main focus on home offices, has revealed that these debates tend to overestimate the relevance of reducing GHG (see, e.g., Helminen and Ristimäki 2007, Le Vine Polak and Humphrey 2016). However, in general positive environmental outcomes have been reported (Hook et al. 2020). Is this the same for the case of coworking spaces in Switzerland? Yet, no study has compared and contrasted CO₂ emissions generated by coworkers’ work-related commuting differentiated by workplace and the locations of coworking space.

In this paper, initial empirical insights for the case of Switzerland will be presented. We investigate how coworking spaces have the potential to reduce commuting distances by replacing trips to regular places of work. Our empirical study is based on representative quantitative data on coworkers in Switzerland. The theoretical
background is the research stream of the mobility biographies approach (Scheiner 2007, 2018). Mobility biographies account for the complex dynamics between relocations or changes of jobs, households and daily and residential mobility, and link these to aspects of the life-course that address, for instance, employment biographies. Thus, theoretically it could be argued that the commitment to work in a coworking space can be understood as key event in the employment biography that leads to social and spatial restructurings (Ohnmacht et al 2020). This can result in lower CO₂ emissions for a work-related commute by reducing or even eliminating work-related trips.

In order to research this assumption, the remainder of this paper is structured as follows. In section 2, theoretical considerations in light of the mobility biography approach and a literature review on the environmental effects of teleworking will be presented, generating a number of hypotheses that guide our empirical work. In section 3, the methodology and data collection process we used to gain insights into work-related travel to coworking spaces and regular workplaces will be presented. In section 4, the quantitative data will be analysed against the background of our hypotheses, derived from our theoretical considerations and literature review with a special focus on the potential of coworking spaces to reduce GHG emissions from commuting. In section 5, a brief discussion of the limitations, policy implementations and recommendations for further research is presented.

2. Theoretical considerations, literature review, and theses for empirical investigation

2.1. The rise of new flexible forms of work

The American futurist Alvin Toffler predicted back in the 1970s that personal computing would make it possible for workers to do their work from home (Toffler 1970). According to Toffler (1970 p. 407) ‘human work will move out of the factory and mass offices into the community and the home’. In Switzerland, the structural change in the economy in the direction of a service economy can be seen as an opportunity to adopt teleworking arrangements. ‘White-collar workers’, or employees who do professional, desk, managerial or administrative work, can roughly be classed as belonging to the tertiary sector, which accounted for two thirds of all Swiss employees in 2019, indicating the great potential for teleworking (SFOS 2020). Judging by the recent shift to digitalization and the rise of the service economy, Toffler’s predictions have come true: according to the latest figures from the Swiss Federal Office for Statistics (SFOS), working from a home office more than quadrupled between 2001 and 2018, rising from 250,000 to over one million employees and self-employed persons, or roughly a quarter of all Swiss employees. The number of people spending 50 percent or more of their working time working from home increased from around 30,000 in 2001 to 138,000 in 2019 (SFOS 2019). It is assumed that, due to the coronavirus pandemic (COVID-19) and the advice to work at home where possible, these figures will rise even more in the future.

2.2. The rise of coworking

In the context of the rise of new flexible forms of work with a focus on teleworking, coworkers rely on digital infrastructure in their work and can therefore work in multiple locations or on the move (Boucnenk and Reuschl 2017). Spinuzzi (2012) defined coworking spaces as an open-plan office environment in which people work alongside non-aligned professionals and pay a fixed fee per month for use of the coworking space. While there were only 75 coworking spaces worldwide in 2007 (Deskmag 2017), the number increased to 2,500 in 2013 (Moriset 2014) and to 18,700 in 2018, and the number is still rising (Mazareanu 2019). For the end of 2020, 26,300 coworking spaces are forecast worldwide (Mazareanu 2019). This development can also be observed in Switzerland, where coworking spaces also emerged in 2007 (Thao et al 2019). At the beginning of the 2010s, there were 25 coworking spaces throughout Switzerland. By 2018 the number had already risen to 155, serving a total of 10,000 coworkers (Coworking Switzerland and Deskmag 2018). In recent years, moreover, there has been a noticeable trend towards creating coworking spaces not only in urban but also in rural areas, such as tourism-related mountain regions of Switzerland. Since 2019 many coworking spaces have been created in these regions, supported by government initiatives (Thao et al 2019). At present, about fifty of more than two hundred coworking spaces in Switzerland are located in rural areas (Z’Rotz and Ohnmacht 2020).

2.3. New forms of work as a key event in the mobility biography

Mobility biographies (Scheiner 2007, 2018) focus on the so-called key events within an individual’s life-course. It is assumed that changes in one’s environment and circumstances weaken routines and serve as a ‘window of opportunity’ for changes in travel behaviour (Müggenburg et al 2015). The main focus of job-mobility biographies has so far been entry into the labour market, changes to jobs and incomes, and retirement, and how these affect travel behaviour (ibid., p. 159). However, new possibilities for flexible forms of work within a coworking space can also be considered a key event within a professional career (Ohnmacht et al 2020). In this
context, we argue that the commitment to working in a coworking space can be understood as a key event in one’s employment biography that leads to new social and spatial restructurings. This can result, for example, in fewer CO₂ emissions for a work-related commute by reducing work-related trips or even eliminating them altogether.

Ohnmacht, Vu, and Von Arx (2020) suggest that the key event of joining a coworking space may affect one’s residential mobility. Because working in a coworking space enables spatial independence between home and regular work locations, it may increase the overall distances between living and working that can be described as ‘sprawl development’ within the spaces of the individual activity. In general, the key event of joining a coworking space reduces the distances one travels to perform work-related activities and reduces the number of commuting trips to regular workplaces. However, due to new dynamics and freedom of choice in the domain of residential mobility, per-trip distances between home and regular workplaces may increase (for Switzerland, see Ravalet and Rérat 2019). Moreover, the key event of joining a coworking space may save kilometres travelled on commuting trips to regular workplaces, but these savings may be offset by non-work trips (rebound effect) or increased consumption in other areas of life (spillover effect).

Against this background of mutual dependencies between daily and residential mobility and travellers’ activity plans, numerous studies have researched the positive environmental outcomes of new forms of work.

2.4. Positive (environmental) outcomes of new forms of work

With regard to the environment, new flexible forms of work, such as coworking, working in a home office environment or teleworking on the move in bars, restaurants and trains, were found to reduce harmful emissions (Hook et al. 2020).

The WWF estimates the global reduction potential through teleworking at one billion tons of carbon dioxide emissions by 2030. This is as much as the total of annual carbon dioxide emissions in the United Kingdom and Italy. It is further estimated that by 2050 teleworking could even reduce as much as 3.5 billion tons of emissions, equivalent to more than half the CO₂ emissions produced annually by the United States (WWF 2009).

For the United States, Lister and Harnish (2011) estimate that 45% of the workforce would be capable of working from home at least occasionally. In 2014, about 3.9 million workers in the United States telecommut ed. It is estimated that telecommuters save between 17 and 23 kilograms of CO₂ emissions per day (Burrell et al. 2014). Similarly, Roth et al. (2008) state that teleworking by four million US workers (3% of the total workforce) at least one day per week could reduce annual primary energy consumption by between 0.13% and 0.18% and CO₂ emissions by between 0.16% and 0.23%. Several studies show that the vehicle miles travelled (VMT) by an employee are 53% to 77% lower for teleworkers than for non-teleworkers, which results in a significant reduction of greenhouse gas emissions (GHG) (Mokhtarian and Varma 1998, Van Lier et al. 2014). Mokhtarian and Varma (1998) found that on teleworking days compared to non-teleworking days, emissions were reduced by 15% for organic gases, 21.5% for CO₂, 35% for NOx and 51.5% for particulate matter (PM).

In the ‘eco ideas’ report issued by the Panasonic Group, it is claimed that all its 330,000 employees were encouraged to telecommute and have online meetings instead of travelling. By doing so, CO₂ emissions could be reduced by 3.4 kilotons (Panasonic 2012). Similarly, Microsoft encourages its employees to work from home frequently and to use web conferencing. It is estimated that employees have avoided about 100 million miles of airplane travel annually, a saving of 17,000 metric tons of CO₂ per year (Microsoft 2010).

Pflueger et al. (2016) explored flexible employment schemes, such as variable working hours and working from home, at the Dell Company. The authors found that flexible forms of working helped to avoid 6,700 metric tons of greenhouse gas emissions. Overall, the potential to reduce emissions by establishing smarter forms of working, such as coworking or telecommuting, is estimated to be about 10% of total global direct and indirect CO₂ emissions (Malmodin et al. 2010).

Beside the reported potential reductions, other results claim that the travel time saved by shorter trips for work reasons may be reinvested in travel for other reasons (rebound effects). Moreover, there may be a trend towards longer commutes if people commute less often to regular workplaces. For example, fewer but longer-distance commuting trips have been observed in commuting trends in England (Le Vine, Polak, and Humphrey 2016, p. 6) and Finland (Helminen and Ristimäki 2007).

2.5. Summary and theses for empirical investigation

Today in transport policy it is assumed that new forms of work that take place in coworking spaces instead of regular workplaces reduce carbon dioxide (CO₂) emissions from work-related commuting. So far, research on the effects of teleworking generally report positive environmental outcomes (Hook et al. 2020). Nevertheless, public and scientific debates tend to overestimate the potential for reductions resulting from, for example, home-office working due to rebound and spill-over effects and the lengthening distances between home and work locations, which are being intensified by flexible forms of working.
However, no study has so far compared and contrasted the greenhouse gas (GHG) mitigation potential of the new phenomenon of coworking spaces. We argue that, key events within a job–mobility biography, such as the commitment to work in a coworking space, reduces the amount of CO₂ emissions produced for work commuting. In this research stream, the following hypothesis can be put forward for empirical investigation:

first, it is hypothesized that coworking spaces are closer to the home location than the regular working place.
Second, it is hypothesized that in our descriptive analysis coworkers need less CO₂ than the Swiss average.
Third, since the public debate on coworking spaces assumes that in rural areas they reduce commutes into the cities, CO₂ emissions are different between urban and rural locations based on our modelling approaches.
Fourth, coworking spaces enable spatial independence between home and regular work locations and thus may increase per-trip distances.
Fifth, there is a considerable saving potential if workers only worked at their coworking space and not commute at their regular working place.

In the following section, the methodology, data-gathering process and statistical analysis used in our initial empirical investigations for coworkers in Switzerland will be presented.

3. Methodology

3.1. Sampling frame, data preparation and questionnaire

The statistical universe of the study is formed by coworkers in Switzerland who are members of Swiss coworking spaces. So far, no official list of coworkers in Switzerland exists from which a simple random sample might be drawn for statistical purposes. Thus, using the list of 219 registered coworking spaces in Switzerland a cluster sample was applied. First, invitation letters were sent to the official operators. The invitation was then forwarded by the operators of the coworking spaces to their members via internal mailings (newsletters). The field time of the survey was limited to five months, starting in July 2019. Overall, 249 randomly chosen coworkers completed the survey fully (after data-cleansing of inaccurate answers and outliers).

Before the survey was sent out to the coworking spaces, a pre-test was conducted, including consulting the official operators of six coworking spaces in order to test the appropriateness and functionality of the structure and the content of the questionnaire.

Figure 1 shows the locations of the 219 coworking spaces that fall within the scope of the study (universe for the cluster sample). Overall, around 20 percent can be located in rural and 80 percent in urban areas respectively. The obtained responses tend to cover the share of urban and regional coworking spaces as to be found in the population (80–20 split). On respondents level one third are rural coworkers and two third are urban coworkers in our sample. Since we compare and contrast urban–rural differences re-weighting of the data is not considered as necessary and will possibly produce shifts in other dimensions of the data. The questionnaire consists of a set
of question that collect information about socio-demographic characteristics, profiles of the mobility biography (home location, work location(s), coworking space locations), frequencies of use, mode of transport and likert-scales on statements on work-life balance and towards coworking spaces in general.

3.2. Geocoding and routing
Data on the municipality of the (main) home location, the regular work location and the location of the coworking space of each respondent were collected. Municipalities are the lowest level of Swiss administrative division. Each municipality can be linked to a Swiss canton (states), which form the Swiss Confederation. For international readers, Swiss municipalities can be seen as cities or villages. Since distance relations fall within the scope of the study, first, the centroids (consisting of x and y coordinates) of all Swiss municipalities were calculated using the QGIS program and the swissBOUNDARIES3D data from Swisstopo of the Swiss Federal Office of Topography (Swisstopo 2020). These centroids were then used to geocode the municipality (home, working and coworking locations) that were retrieved from the survey. Secondly, information on the mode of transport used for the commute was added. Thirdly, the data were divided into different relations for a commute on the rail network (if the commute was by train) and the road network (if the commute was by car or human-powered mobility). In order to obtain data on distances, a routing was performed based on each community’s centroid coordinates. The dataset, including the distance relations, was transferred to the GIS program ‘Mapinfo’ and routed to the road or rail network by the routing add-in ‘Routefinder’. The routing process produced the routing distances in kilometres per relation. In addition, a penalty of 1.2 kilometres was imposed on cases where coworking space and working location, coworking space location and place of residence, or workplace and place of residence were located in the same municipality. The penalty value was applied because the exact coordinates of the addresses within the municipalities were not available for the survey, as well as to establish a distance figure where the locations are in the same municipality. This value was chosen with reference to the Swiss national transport model based on average commuting distances within the traffic zones. Figures 2 and 3 give examples of the routing process from the home location to the coworking space using public transport, car travel or human-powered mobility. This process was carried out for all the relations in the sample.

Figure 2. Examples of street routing from home location to coworking space.
Once we had measured the distances for various modes of transport, CO2 emissions per commute were calculated. Each routing distance was assigned a CO2 value depending on the means of transport. The values were based on the mobitool factors (Mobiltool & treeze Ltd 2020), which are widely used to assess the energy efficiency and environmental impact of different means of transport. The CO2 values per person-kilometre of each means of transport include direct operation, indirect CO2 emissions caused by the provision of energy, vehicle maintenance, vehicle manufacture/disposal and the CO2 emissions used for the infrastructure (road/track). Table 1 gives the CO2 value per person-kilometre for each means of transport included in the survey.

Using the CO2 value per distance, it was possible to calculate an annual equivalent that reflects the CO2 emissions for the commutes both to work and to the coworking space. To compare the results, a full-time job was assumed to be equivalent to 240 working days per year. Using the variables that indicate how often a coworking space is visited per person, the number of trips per year was determined. If the coworking space is not used daily and the respondent has a regular place of work, it was assumed that the latter was visited on the remaining days. For example, a respondent uses the coworking space at least once a week. This means that, according to our assumptions, he or she makes 96 trips to the coworking space in a year. On the other 144 days, this person would go to his or her regular workplace. An additional assumption was that respondents would not be at their place of work and coworking space on the same day.

### Table 1. CO2 in grams by means of transport.

| Means of transport | CO2 in gram per person-kilometre |
|--------------------|---------------------------------|
| Public transport   | 24.56                           |
| Car                | 197.23                          |
| Motorbike          | 145.02                          |
| Bicycle            | 7.64                            |
| By foot            | 0.00                            |

Source: mobitool factors (Mobiltool & treeze Ltd 2020).

#### 3.3. CO2: key figures and annual equivalent for a full-time job

Figure 3. Examples of public transport routing from home location to coworking space.
3.4. Modelling approach

The analytical dimensions in table 2 are used for the modelling approach as independent variables: job characteristics, characteristics of coworking use and socio-demographic characteristics. The dependent variable for the statistical modelling is CO2 emissions (total, only for coworking space, only for regular working place) for work commuting per year (equivalent to a full-time job with 240 working days and 480 working trips). Table 2 summarizes the independent and dependent variables for the statistical analysis. Table 3 presents the operationalization of data, measurement, and sample characteristics.

The statistical models used to explain CO2 emissions per year are based on linear regression models with logarithmic transformations of the dependent variable (linear-log models) (see Christensen 2000). Therefore, the coefficient values of these models are predicted for logarithmic transformations of dependent variables. These logarithmic transformations are necessary to satisfy the assumptions of regression analysis (mainly multivariate normality). Overall, three models are specified as follows: total (1), only coworking space (2), and only regular working place (3). The correlation matrices revealed that there is no correlation higher than Pearson r > 0.7 among the metric independent variables.

In a further step, simulations based on the models were performed to generate predicted impacts of the significant influences. Based on these, we can illustrate the effects of significant influences on CO2 emissions and are able to rank the effect sizes more clearly.

4. Results

4.1. Descriptive and bivariate statistics

The Swiss mean of greenhouse gas pollution is around 5.4 tons per person per year (FOEN 2020). According to the Federal Office for the Environment, 32% of this comes from traffic, and 24% of traffic is work-related (SFOS/ARE 2017, p. 38). Thus, in Switzerland four million work-commuters are responsible for roughly 8% of greenhouse gas pollution in the country. In 2017, the latest statistics show that 52% use a private car as main means of transport for their commute and 31% public transport, while 9% travelled on foot and 7% used a bicycle (table 4). The average distance of their trip to work is 15 kilometres (FSOS 2020). Based on our approach,
Table 3. Operationalization: data, measurement and sample characteristics.

| Independent variables                     | Nominal                                      |
|-------------------------------------------|----------------------------------------------|
| Location coworking space                  | Nominal                                      |
| 0: rural—34.6%                            |                                              |
| 1: urban—65.4%                            |                                              |
| Regular workplace available               | Nominal                                      |
| 0 = only coworking—76.0%                  |                                              |
| 1 = coworking and regular workplace—24.0%|                                              |
| Frequency of usage of coworking space     | Nominal—5 categories.                        |
| Daily (25.6%); several times a week (39.4%); at least once per week (18.7%); several times a month (10.2%); less (6.1%) | |
| Reasons for coworking                     | Ordinal—5 categories                         |
| Separation living and working             | not relevant; rather not relevant; neither; rather relevant; highly relevant |
| Professional environment                  | 6.1%; 12.6%; 12.6%; 37.0%; 31.7%             |
| Reducing commuting                        | 0.8%; 4.5%; 15.9%; 46.3%; 32.5%              |
| Proximity to work place                   | 16.3%; 13.8%; 22.0%; 24.0%; 24.0%            |
| Proximity to place of residence           | Nominal—yes/no                               |
| Community; exchange, feedback             | 0 = no—92.3%, 1 = yes—7.7%                   |
| Gender                                    | 0 = Woman—31.7%, 1 = Man—68.8%               |
| Age                                       | Ordinal—4 categories (years)                 |
| below 30;                                 | 31–40; 41–50, 50 +                           |
| 11.4%                                     | 48.0%; 22.4%; 18.3%                          |
| Education                                 | Nominal                                      |
| 0 = no PhD/university degree—22.8%        |                                              |
| 1 = yes PhD/university degree—77.2%       |                                              |
| Gross household income (Swiss Francs, CHF)| Metric—Exemplary 4 categories:              |
| Below 4,000                               | 4,000–6,999; 7,000–9,999; More than 10,000  |
| 19.5%                                     | 35.4%; 25.6%; 17.1%                          |
| Jobs                                      | Nominal                                      |
| 0 = one job—67.5%                         |                                              |
| 1 = more than one job—32.5%               |                                              |
| Household structure                       | Nominal                                      |
| 0 = no children—58.1%                     |                                              |
| 1 = children—41.9%                        |                                              |
| Gender                                    | Nominal                                      |
| 0 = Woman—31.7%, 1 = Man—68.8%            |                                              |
| Age                                       | Ordinal—4 categories (years)                 |
| below 30;                                 | 31–40; 41–50, 50 +                           |
| 11.4%                                     | 48.0%; 22.4%; 18.3%                          |
| Education                                 | Nominal                                      |
| 0 = no PhD/university degree—22.8%        |                                              |
| 1 = yes PhD/university degree—77.2%       |                                              |
| Gross household income (Swiss Francs, CHF)| Metric—Exemplary 4 categories:              |
| Below 4,000                               | 4,000–6,999; 7,000–9,999; More than 10,000  |
| 19.5%                                     | 35.4%; 25.6%; 17.1%                          |
| Jobs                                      | Nominal                                      |
| 0 = one job—67.5%                         |                                              |
| 1 = more than one job—32.5%               |                                              |
| Household structure                       | Nominal                                      |
| 0 = no children—58.1%                     |                                              |
| 1 = children—41.9%                        |                                              |

Table 4. Comparison of key figures for Swiss Mean and Coworkers.

| Modal split: main mode of transport [%] | CO₂ emissions [kilograms] |
|----------------------------------------|---------------------------|
| Car                                    | Public transport          | Bike | Foot | Others |               |               |
| Swiss mean                             |                           |      |      |        |               |               |
| 52                                     | 31                         | 9    | 7    | 1      | 797            |
| Coworkers                              |                           |      |      |        |               |               |
| to coworking space                     | 24                         | 34   | 23   | 18     | 1              | 554            |
| to regular work location               | 32                         | 53   | 11   | 3      | 1              | 1200           |

Source: coworkers, n = 259 (own data), Swiss mean, own calculations based on FSOS (2020).
the average consumption of CO₂ emissions by a Swiss commuter is 797 kilograms a year for a full-time position (table 4). This figure serves as a baseline for our interpretation of the descriptive results.

The commuting distance between the home location and the coworking space are covered by bicycle (23%) or by foot (18%) more often than to the regular workplace (table 4, 11%, 3%, t-Test for proportions, p < 0.01) (table 4). With regard to coworking spaces in the cities, the data show that car use (24%) is significantly lower in comparison to coworking spaces in rural areas (32%, t-Test for proportions, p < 0.01) (table 4). The average commuting distance from home location to coworking space is 18 kilometres, while from home location to work place it is 51 kilometres (t-Test, p < 0.01). This indicates that coworking spaces tend to be significantly closer to the home location. Coworkers in rural areas do not have statistically significant longer commuting distances to their coworking spaces than urban coworkers (22 km versus 15 km, t-Test, p = 0.11). Likewise, the average distances between home location and regular working place are not statistically significantly different from each other when urban (48 km) and rural coworkers (56 km) are compared.

Overall, 161 (65.4%) of the participants live in cities and 85 (34.6%) in rural areas. There is a relationship between mode of transport for the commute and place of living. Those who live in cities use more public transport (39%) and bicycles (30%) to commute to their coworking spaces than coworkers who live in rural areas (28.8%, 13.5%, chi-square test for independence, p < 0.01).

In our data, in commuting, coworkers produce 554 kilograms of CO₂ on average per year (table 4). By applying a one-sample t-test, statistically we find a significance difference in comparison to the Swiss mean of 797 kilograms (p = 0.008). We therefore conclude with regard to the descriptive analysis that the CO₂ consumption of coworkers while commuting is significantly lower compared to the Swiss mean of all employees. By dividing this figure into coworking spaces in urban and rural areas, this figure differs considerably: coworkers in urban coworking spaces produce 350 kilograms of CO₂, coworkers in rural coworking spaces 940 kilograms (t-Test, p = 0.002).

Given the fact that distances to regular places of work and to coworking spaces do not differ statistically between urban and rural coworkers, the overall figures differentiating on the basis of the location of the coworking space show significant differences. Moreover, the values for coworking spaces in both rural and urban areas is significantly different from the mean value for Switzerland of 797 kilograms (one-sample t-test, p < 0.01).

In addition, table 4 shows that for all coworkers CO₂ emissions from commuting to a coworking space are 265 kilograms and to a regular work location 1200 kilograms. It should be noted that these figures are affected by the frequency of location visits, the mode of transport used and whether the coworker has a regular workspace or not. Table 3 shows that 24% of our sample reported having a regular workspace besides their coworking workspace. This is in line with other research results, Bouncken and Reuschl (2017) stated that the main users of coworking spaces are the self-employed, freelancers and micro-businesses.

4.2. Multivariate statistics
In order to verify the consistency of the descriptive and bivariate statistics, a multivariate analysis based on linear-log models was applied with regard to location choices of coworking spaces (see table 5).

4.2.1. Coworking and regular work places
The results in table 5 show that the location of the coworking space has a significant effect on CO₂ emissions. If the coworking space is located in an urban area, it will reduce the annual CO₂ emissions from commuting. The negative effect of the urban location of the coworking space can be explained by previous results showing that shorter distances are covered, and in particular that a more CO₂-neutral means of transport such as a bicycle or public transport is used more often. If the co-worker has a regular work place, CO₂ emissions increase due to longer distances to the work place. Furthermore, the preference for the coworking space to be close to the place of residence significantly reduces CO₂ emissions in the model. This result shows that the coworking space is used to reduce a time-consuming commute and thus avoid CO₂ emissions. In addition, the variable ‘importance of community and exchange’ has a significantly negative effect on average CO₂ emissions. The possibility of coworking stimulates the interest in participation if a community is close-by.

On the other hand, the variables ‘importance of separation between living and working’ and ‘importance of professional environment’ have a significantly positive effect on the average CO₂ emissions in the model. A preference for a professional environment and the need for a separation between living and working could lead users not to choose the nearest coworking space, but to choose a coworking space that better suits their needs.

In addition, in the model, average CO₂ emissions increase significantly with rising gross household incomes. Conversely, as the level of education increases, CO₂ emissions fall. These results suggest that, although more trips are possible with rises in incomes, awareness of CO₂ emissions also increases, and users try to reduce them.
Table 5. Modelling results for CO₂ emissions associated with yearly commuting in total, only coworking and only regular work place.

| Variable                                      | Coworking & regular workplace | Only coworking | Only regular workplace |
|-----------------------------------------------|--------------------------------|----------------|------------------------|
|                                               | b     | S.E. | t values | Pr(>|t|) | b     | S.E. | t values | Pr(>|t|) | b     | S.E. | t values | Pr(>|t|) |
| Intercept                                     | 1.448 | 1.106 | 1.310    | 0.192 | 5.977 | 1.577 | 3.789    | 0.000 | 12.732 | 2.308 | 5.517    | 0.000 |
| Location coworking space                      | Urban | −0.834 | 0.300 | −2.777 | 0.006 | * 0.811 | 0.428 | −1.894    | 0.060 | −1.713 | 0.654 | −2.620    | 0.012 | *
| Regular workplace available                   | Yes   | 2.449 | 0.350 | 7.002 | 0.000 | **12.732 | 2.308 | 5.517    | 0.000 | ***    | 1.577 | 3.789    | 0.000 |
| Preference Variables (Importance of)          |       |       |         |       |       |       |         |       |       |       |         |       |       |
| Separation between living and working         | Yes   | 0.260 | 0.118 | 2.203 | 0.023 | * 0.344 | 0.168 | 2.044    | 0.042 | * −0.159 | 0.308 | −0.518    | 0.607 |
| Professional environment                      | Yes   | 0.415 | 0.166 | 2.495 | 0.013 | * 0.757 | 0.237 | 3.191    | 0.002 | ** 0.058 | 0.285 | 0.205    | 0.839 |
| Reducing commuting                            | Yes   | 0.013 | 0.109 | 0.120 | 0.904 | −0.038 | 0.155 | −0.244    | 0.807 | 0.195 | 0.208 | 0.938    | 0.354 |
| Proximity to workplace                        | Yes   | 0.386 | 0.530 | 0.728 | 0.468 | 1.174 | 0.756 | 1.553    | 0.122 | −3.105 | 1.318 | −2.355    | 0.023 |
| Proximity to place of residence               | Yes   | −1.216 | 0.315 | −3.862 | 0.000 | *** −1.913 | 0.449 | −4.259    | 0.000 | ***    | 0.079 | 0.638    | 0.123 |
| Community exchange, feedback                  | Yes   | −0.830 | 0.292 | −2.843 | 0.005 | ** −1.159 | 0.417 | −2.781    | 0.006 | **    | 0.331 | 0.778    | 0.683 |
| Sociodemographic characteristics              |       |       |         |       |       |       |         |       |       |       |         |       |       |
| Gender                                        | Men   | −0.073 | 0.331 | −0.221 | 0.825 | −0.141 | 0.472 | −0.298    | 0.766 | −1.361 | 0.886 | −1.536    | 0.132 |
| Age (years)                                   |       |       |         |       |       |       |         |       |       |       |         |       |       |
| below 30 (Reference)                          |       |       |         |       |       |       |         |       |       |       |         |       |       |
| 31–40                                        | 0.266 | 0.470 | 0.565 | 0.572 | 0.283 | 0.671 | 0.422    | 0.673 | 0.403 | 1.009 | 0.399    | 0.692 |
| 41–50                                        | 0.172 | 0.516 | 0.333 | 0.740 | 0.154 | 0.737 | 0.208    | 0.835 | −0.902 | 1.048 | −0.861    | 0.394 |
| 50+                                          | 0.061 | 0.538 | 0.113 | 0.910 | 0.006 | 0.768 | 0.008    | 0.994 | −1.843 | 1.259 | −1.465    | 0.150 |
| University degree                             | Yes   | −0.653 | 0.334 | −1.953 | 0.052 | — 1.076 | 0.477 | −2.256    | 0.025 | * 0.599 | 0.353 | 1.696    | 0.097 |
| Gross household income (Swiss Francs, CHF)    | Metric | 0.409 | 0.146 | 2.797 | 0.006 | ** 0.664 | 0.209 | 3.180    | 0.002 | **    | 0.398 | 0.742    | −0.536 |
| Jobs more than one job (yes)                  | Yes   | 0.150 | 0.307 | 0.488 | 0.626 | 0.588 | 0.437 | 1.345    | 0.180 | −0.517 | 0.687 | −0.752    | 0.456 |
| Household structure                           | Yes   | 0.076 | 0.303 | 0.251 | 0.802 | 0.338 | 0.432 | 0.783    | 0.435 | 0.428 | 0.691 | 0.620    | 0.539 |
| Kids under 18 years (yes)                     |       |       |         |       |       |       |         |       |       |       |         |       |       |
| n=                                           | 246   |       |         |       |       |       |         |       |       |       |         |       |       |
| Explained Variance (adjusted-R²)              | 0.304 | 0.192 | 0.254 |       |       |       |         |       |       |       |         |       |       |

Note: ***p < 0.001, **p < 0.01, *p<0.05, .p < .1
Likewise, as the level of education increases, it is increasingly possible to work in a mobile and flexible way, thus reducing both commuting and CO2 emissions.

4.2.2. Only coworking
In the second model, ‘only coworking’, similar effects can be seen, with the exception that the availability of a regular workplace has no significant influence on average CO2 emissions. The location of the coworking space only has a significant influence on the level of p < .1.

4.2.3. Only regular workplace
Table 5 gives the results for the third model, ‘only regular workplace’. First, the location of the coworking space has a significant negative effect on CO2 emissions if the coworking space is located in an urban area. Second, the variable ‘proximity to the workplace’ also has a significant negative effect on average CO2 emissions. Furthermore, in contrast to the other models, the level of education has a low significant positive effect on CO2 emissions.

4.2.4. Simulation of predicted values
In the following, predicted values are presented, all other explanatory variables in the model being held at their mean values (ceteris paribus). A Duan smearing estimate was made, which uses a non-parametric retransformation method to obtain an unbiased estimator for the mean based on log-transformed dependent variables (Duan 1983). For more information on this procedure, see Duan (1983); for how to obtain an unbiased estimator based on linear-log models, see (Christensen 2000).

The predicted values based on our modelling clearly show the classic main impact of income as a key driver of commuting (see figure 4). The greater one’s income, the greater one’s readiness for a longer commute, which is linked to greater shares of motorized travel and thus higher CO2 emissions. Taking a differentiated view of the location of the coworking spaces, we can see that in rural coworking spaces the associated CO2 emissions are 2.7 higher (see figure 5). This finding conflicts with the policy aims of supporting coworking spaces in rural areas, since it has been found that commuting distances to regular workplaces do not differ between urban and rural coworkers. This result is based on the mixture of modes of transport associated with the location of the coworking space.
To show the potential quantity of emissions that can be saved, a scenario has been drawn up in which the participant only works in a coworking space. Given the mean value of 554 kilograms of CO$_2$ per year in our sample size and the fact that only 24% of coworkers also have a regular workplace, this figure would drop to 502 kilograms of CO$_2$ per year, a reduction of more or less 10%.

5. Discussion, limitations and recommendations for further research

In sum, our analysis reveals that CO$_2$ emissions from work commuting are significantly lower for coworkers in urban coworking spaces than those in rural ones. If coworkers only work at their coworking space, a 10% reduction of CO$_2$ would be the outcome. Our results indicate that coworking spaces, especially in urban areas, have the potential to support Switzerland’s commitment to reduce greenhouse gas (GHG) emissions in the transport sector, in line with the Paris Climate Agreement. In this context, it is assumed that the digitalization and flexibilization of the labour market can contribute to traffic redistribution or even reduction.

One explanation for this urban-rural divide might be that the car is the most common mode of transport for commuting to and from work. Switzerland has about four million commuters, slightly more than half of whom (52%) used the car as their main means of transport to get to work in 2017 (Swiss Federal Statistical Office 2019). In our data, this high share of commuting by car is associated with coworking spaces in rural areas (40.4%). Our analysis revealed that commuters who use rural coworking spaces have the highest annual amounts of CO$_2$ emissions, even though their average distance between home location and regular workplace does not differ significantly from the average distance of those who use urban coworking spaces.

Against the background of the (job-) mobility biography discourse, this study shows how the decision to work in a coworking space may come to be seen as a key event in the employment biography leading to new social and spatial restructurings. This can result in lower CO$_2$ emissions from work-related commuting by reducing or even eliminating work-related trips.

One limitation of this study is that we have no longitudinal data indicating how the commitment to work within a coworking space enables spatial independence between home and regular work locations and thus may increase the distances between home location and regular workplace (for the case of home office in Switzerland, see Ravalet and Rérat 2019). Whereas this research needs longitudinal data, we can nevertheless compare the average distance between home locations and regular work locations for urban and rural coworkers. Our data
shows that there is no significant difference between these two categories, possibly due to the high amount of city-to-city commuters in Switzerland. Based on this, one recommendation for further research is to investigate long-term decisions on home locations in relation to the freedom that coworking spaces provide.

A further research question is the link between CO2 emissions and office infrastructure. In fact, new forms of work have the potential to reduce office infrastructure. In Switzerland, active use of office space is relatively low, at around 40% (Windlinger et al. 2016). The vacancy rate for office space is about 5.6% and is steadily increasing (Stielau et al. 2015). In 2004, each square metre of office space produced 0.5 t of CO2 emissions per year. This figure is relatively high compared to the European average (Hohmann et al. 2007). Therefore, increasing office space use, reducing office space and reducing commuting are all desirable from both the economic and ecological perspectives (Hilty and Bieser 2017). If 33% of office space in Switzerland were to be used as flexible coworking spaces, thus increasing their use from 60% to 80%, then 0.17 Mt of CO2 could be avoided, given the assumption that each square metre causes 0.05 t of CO2 emissions per year (Hilty and Bieser 2017). Based on these figures, further research should look not only at the reduction in distances for work commutes by coworkers, but also to reductions in the amount of office infrastructure (at the regular work place).

One factor affecting the remote working dynamic worldwide since spring 2020 is the coronavirus pandemic, which is not only a medical, but also a social, economic and political challenge. The coronavirus pandemic temporarily shut down the entire economy and mobility. The lockdown, which was implemented in many countries, including Switzerland, led to the closure of many working places and thus a high proportion of employees moved to the home office (Kyllili et al. 2020). Coworking Spaces have experienced strong growth in recent years (Mazareanu 2019) but had to close due to the lockdown. Collaborative and creative forms of working now face the challenge of reorganising themselves. In the short term, it is therefore assumed that the corona crisis will cause some coworking spaces to disappear again, as they are suffering excessive losses. In the long term, however, coworking spaces are expected to resume their growth. Due to the corona pandemic, many employees had to work from home. Consequently, digitalisation has been pushed forward significantly (Kanda and Kivimaa 2020). This development contributes to the fact that in the future more employees will have the technical possibilities to work flexibly from other locations than their working places, so that there is great potential for coworking spaces to rise again. COVID-19 thus does not only bring challenges but also the opportunity to support environmental change (Kyllili et al. 2020). Virtual travel, the replacement of business trips and conference tourism by video conferencing, and remote working are considered to be coping strategies that will continue to have an effect and be sustainable in the long term even after the crisis has passed.

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