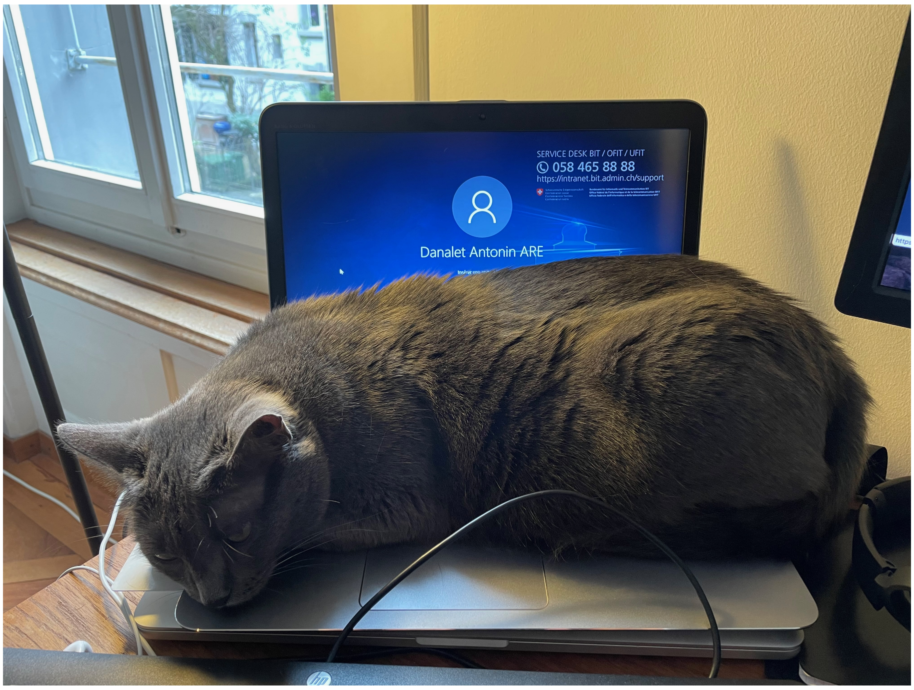

Working from home in Switzerland, 2015-2050

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Abstract

This paper presents a discrete choice model for working from home. The model is estimated on data from Switzerland collected in 2015, the Mobility and Transport Microcensus and is internally validated. It is also externally validated using a synthetic population of Switzerland for 2017. In particular, the alternative specific constant is calibrated so that the observed market shares of working from home are reproduced using the synthetic population of 2017. The calibrated model is then applied to a projected synthetic population for 2030, 2040 and 2050, forecasting work from home for these years in Switzerland.

Keywords

Working from home; home-based telecommuting; discrete choice model; forecast; Switzerland

Introduction

Telecommuting imposes lower costs to the users and takes a shorter time to be implemented as other congestion and pollution mitigation strategies, such as switching to alternative fuel vehicles, promoting public transport and shared mobility services (car-sharing, ride-sourcing, and bike-sharing) or implementing a congestion pricing (Shabanpour *et al.,* 2018, Choo *et al.,* 2005, Kim, 2017, Zhu and Mason, 2014). In particular, it directly impacts peak period traffic (Paleti, 2016). However, working from home might induce other trips e.g. for leisure (rebound effect, see e.g., Shabanpour *et al.* (2018), Zhu and Mason (2014), Koenig *et al.* (1996), Nilles (1991)) and increase the distance traveled (Chakrabarti, 2018) (but maybe not, see Andreev *et al.* (2010)).

In this paper, we focus on home-based telecommuting. Working from home is not the only way of telecommuting: one might work from other people's home, from cafés and librairies or from vehicles (Stiles and Smart, 2020).

Our goal is to forecast who will work from home among the Swiss resident population in 2050. For this, we estimate a choice model on the Swiss travel survey, the Mobility and Transport Microcensus (MTMC), that took place in 2015. These are revealed data on the actual behaviour at a national level. Then, we validate this model internally. We also validate the choice model externally by applying it to a synthetic population of 2017 calibrated on retrospective data (Bodenmann *et al.,* 2019). Finally, we apply the model to a forecasted synthetic population of 2050 in order to predict the proportion of the population doing home office.

Such results are important for the prediction of the number of trips to work. More generally, a synthetic population 2050 containing the probability for each individual to work from home and its impact on the number of trips to work and for other purposes allows us to develop better transport models, such as the Swiss national passenger transport model (Justen *et al.,* 2020, `www.are.admin.ch/npvm`) and transport forecast, such as the Transport Outlook 2050 (`www.are.admin.ch/transport-outlook`). Hence the results make it possible to test the impact of teleworking in the future on the Swiss transport system. This in turns allows to guide transport policy and focus infrastructure investments.

1 Literature review

The link between teleworking and trip generation (Drucker and Khattak, 2000) or activity-based modelling (Shabanpour *et al.,* 2018) is mentioned in several papers.

1.1 Data

According to Asgari and Jin (2015), there was a shift in the literature in the mid-1990s from stated preference data (Sullivan *et al.,* 1993, Bernardino *et al.,* 1993, Yen and Mahmassani, 1997, Yen, 2000) to revealed preference data (Olszewski and Mokhtarian, 1994, Mannering and Mokhtarian, 1995, Mokhtarian and Salomon, 1997, Drucker and Khattak, 2000, Pouri and Bhat, 2003) on telecommuting. Asgari and Jin (2015) define two types of surveys: "small organization-specific surveys and large data sets at national or statewide level". Small organisation-specific surveys are often related to a telecommuting program (Kitamura *et al.,* 1990, Mannering and Mokhtarian, 1995). The Mobility and Transport Microcensus (Federal Statistical Office / Federal Office for Spatial Development, 2017) is the largest national survey about travel behaviour in Switzerland, running every five years since 1974. In it, questions about telecommuting have been asked in 2005, 2010, 2015 and briefly in 2020, and are currently being asked in 2021. In other European countries, questions about telecommuting are present in national travel surveys in England's "National Travel Survey" (with frequency in the week, month or year) and in the Danish national travel survey (on full-day telecommuting only) (Crawford, 2021). In the Netherlands, there are no questions related to telecommuting in the national travel survey, but there is one in a mobility panel; in Germany's "Mobilität in Deutschland" and in Norway, there is a question to people travelling less than what should correspond to their work percentage, asking about the reason, which can be working from home. Ireland does not ask about telecommuting (Crawford, 2021).

The questions can ask about the preferences to telecommute, actual telecommuting (behaviour on a particular day), the frequency of telecommuting (Mannering and Mokhtarian, 1995, Drucker and Khattak, 2000) or a combination of these (Mokhtarian and Salomon, 1996b, Pouri and Bhat, 2003). Asgari and Jin (2015) suggest to ask about the choice of telecommuting on a specific, random day, and about work-related trips that might be done on this specific day even if the person telecommutes. Similarly, Deng *et al.* (2015) suggest decomposing home-based teleworking in three categories: full-day (resulting in the elimination of trips), part-day (resulting in shifts in commuting time), and overtime telecommuting - defined as working from home, e.g., in the evening, while still commuting on peak hours (resulting in no change in commuting behavior). Time use surveys show that working from home is the most common non-office work location, but people also work from third places, which might be dedicated (co-working spaces) or not (cafés, librairies, ...), or could do "itinerant telework" (working from their car or in the train) (Thomsin, 2002, Ravalet and Rérat, 2019, Stiles and Smart, 2020).

1.2 Models

Logit models (Sullivan *et al.*, 1993, Bernardino *et al.*, 1993, Mannering and Mokhtarian, 1995, Drucker and Khattak, 2000, Walls *et al.*, 2007), ordinal probit models (Yen and Mahmassani, 1997, Yen, 2000, Drucker and Khattak, 2000, Shabanpour *et al.*, 2018), binary probit models (Mokhtarian and Salomon, 1996a,b), orderd logit (Drucker and Khattak, 2000), Generalized Extreme Value models (Paleti, 2016) and count models (Singh *et al.*, 2013) were used to analyse commuting behaviour.

The unit of observation are mostly individual employees, but also sometimes the dual-earner household (Paleti and Vukovic, 2017) or of the employer (Yen and Mahmassani, 1997). Pouri and Bhat (2003) jointly model the adoption and frequency of home-based telecommuting, while Asgari *et al.* (2014) sequentially model telecommuting choice, frequency and daily engagement.

Constraints were incorporated into the utility function or used to define the choice set (see below, Section "Influencing factors"). Models incorporating constraints in the utility function appear to be superior according to Mokhtarian and Salomon (1996b).

1.3 Influencing factors

Mokhtarian and Salomon (1994) define two types of influencing factors: constraints/facilitators ("external factors related to awareness, the organisation, and the job, and internal psychosocial factors") and drives ("work, family, leisure, ideology, and travel"). Among the observed constraints, Mokhtarian and Salomon (1996a) cite lack of awareness, job unsuitability and manager disapproval.

The influencing factors mentioned in the literature are presented in Table 1. These factors influence telecommuting participation, telecommuting frequency or both (see e.g., Paleti (2016)).

Table 1: Influencing factors mentioned in the literature

Influencing factors	**References**
Presence of small children in the household	Mannering and Mokhtarian (1995), Drucker and Khattak (2000)
Number of people in the household	Mannering and Mokhtarian (1995), Shabanpour *et al.* (2018)
Gender of respondent	Mannering and Mokhtarian (1995), Drucker and Khattak (2000), Singh *et al.* (2013), Paleti and Vukovic (2017), Shabanpour *et al.* (2018)
Number of vehicles in the household	Mannering and Mokhtarian (1995), Paleti (2016), Paleti and Vukovic (2017), Shabanpour *et al.* (2018)
Access to vehicles	Shabanpour *et al.* (2018)
Being a driver	Drucker and Khattak (2000)
Whether the respondent recently changed departure time for personal reasons	Mannering and Mokhtarian (1995)
Flexibility of work schedule	Mannering and Mokhtarian (1995), Sener and Bhat (2011), Paleti (2016), Shabanpour *et al.* (2018)
Being a manager	Mannering and Mokhtarian (1995), Shabanpour *et al.* (2018)
Ability to borrow a computer from work if necessary	Mannering and Mokhtarian (1995)
Family orientation	Mannering and Mokhtarian (1995)
Price of telecommuting (small living space, costs incurred by employees)	Yen (2000)
Income	Yen (2000), Peters *et al.* (2004), Paleti (2016), Shabanpour *et al.* (2018)
Locational and accessibility variables	Drucker and Khattak (2000)
Educational attainment	Drucker and Khattak (2000), Peters *et al.* (2004), Paleti and Vukovic (2017), Shabanpour *et al.* (2018)
Lack of free parking	Drucker and Khattak (2000)
Occupation type (e.g. health care, social assistance services, manufacturing, construction maintenance, communication industry, government employees, agriculture, clerical and administrative)	Walls *et al.* (2007), Zhou *et al.* (2009), Moeckel (2017), Paleti and Vukovic (2017), Shabanpour *et al.* (2018)
Home-work distance	Mokhtarian and Meenakshisundaram (2002), Paleti (2016), Shabanpour *et al.* (2018)
Home-work travel time	Shabanpour *et al.* (2018)
Population and employment density	Shabanpour *et al.* (2018)
Immigration status	Paleti (2016), Paleti and Vukovic (2017)

1.4 Forecasts & impact on transport demand and location choice

Forecasts of telecommuting rates The need for "analysing factors affecting the individual choice to telecommute" and integrating telecommuting into transport models has long been recognised (Handy and Mokhtarian, 1996). The rate of employees working from home is nowadays sometime an input for transport models. This rate is usually defined in input scenarios (e.g., 25% or 50% of employees work from home) (Shabanpour *et al.,* 2018).

Impact on transport demand and location choice For a given individual living in a given place, full-day telecommuting directly decreases the number of trips to work, while part-day telecommuting might decrease the number of trips to work during peak hours.

Overall, when taking into account all trips, including, e.g., leisure trips, the net effect of telecommuting on the number of trips is unclear. According to Mokhtarian (2008), short-term studies show substitution effects (i.e., less trips when telecommuting), but analyses taking into account long-term and indirect effects show complementary effects (i.e., more trips when telecommuting). The author foresees a faster growth of telecommunications-based interactions than in travel. According to Hu and He (2016), telecommuting is associated with longer total daily trip duration on the days that telecommuters go to their workplaces. Working only from home is associated with a reduction in overall travel time according to Lachapelle *et al.* (2018). Working a full day from home decreases daily travel duration, while working only part time from home and going to the office on the same day but later does not (Stiles and Smart, 2020). Using the Mobility and Transport Microcensus (MTMC), the same dataset as we do in this paper, Ravalet and Rérat (2019) show that people telecommuting are making more trips for other purposes, hence a rebound effect takes place. These non-work trips are shorter.

If in the short term, telecommuting decreases the number of trips to work and might decrease the overall daily travel distance, in the long term, telecommuting might decrease the propensity for residential relocation and increase tolerance for long distance commuting (Ravalet and Rérat, 2019). Hu and He (2016) shows that less-frequent telecommuters (and their households) tend to undertake longer distances to work than frequent telecommuters and non-telecommuters. In Switzerland, teleworkers live further away from the workplace than their colleagues (Ravalet and Rérat, 2019).

2 Data

In this section, we present the three main data sources used in this paper: the Mobility and Transport Microcensus 2015 (chapter 2.1) and synthetic populations of Switzerland calibrated to real data for 2017 (chapter 2.2) and projections for 2030, 2040 and 2050 (chapter 2.3).

2.1 Mobility and Transport Microcensus 2015

For the estimation of the model, we use the data of the Mobility and Transport Microcensus (MTMC) 2015. The MTMC (`https://www.are.admin.ch/mtmc`) is the Swiss national travel survey. It is conducted every five years. Data were collected in 2015 and are currently being collected again in 2021 (originally planned in 2020, but postponed due to the coronavirus pandemic). However, data of 2021 are not yet available. The Mobility and Transport Microcensus contains information about the socioeconomic characteristics of households and individuals, mobility resources (vehicles and public transport season tickets), daily mobility (trips on a given reference day), occasional journeys (day trips and trips with overnight stays) and attitudes towards transport policy in Switzerland. In 2015, 57'090 persons were interviewed by telephone (CATI) about their travel behaviour (from 57'090 different households).

On top of the questions asked to the full sample, four groups of questions are asked only to a portion of the sample. 30% of randomly selected respondents who were working in the week preceding the interview[1] were asked three questions about working from home:

- *Working from home:* "Can you do some of your work at home?"[2]
- *Work percentage from home (if working from home):* "What percentage of your professional activity do you carry out at home?"[3]
- *Stated cause of home-based telecommuting (if working from home with percentage from home > 0%)*: "You carry out X% of your work at home. What is the main reason for this?"[4]

[1] Note that people in apprenticeship did not get the question on home-based telecommuting in the MTMC.

[2] "Pouvez-vous effectuer une partie de votre travail à la maison ?" in French; "Dürfen oder können Sie einen Teil von Ihrer Arbeit zuhause erledigen?" in German. See the full questionnaire: `https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/erhebungen/mzmv.assetdetail.5606052.html`.

[3] "Quel pourcentage de votre activité professionnelle effectuez-vous à domicile ?" in French; "Wie viele Stellenprozente pro Woche schaffen Sie zuhause für Ihren Beruf" in German. See the full questionnaire.

[4] "Vous effectuez X% de votre travail à domicile. Quelle en est la raison principale ?" in French; "Was ist der Hauptgrund dafür, dass Sie X% Ihrer Arbeit von zuhause erledigen?" in German. See the full questionnaire.

In 2015, 28.1% of people working were doing part of it from home (±0.9%; basis: 8997 persons working, selected for this group of questions and who answered the questions about working from home and work percentage from home).

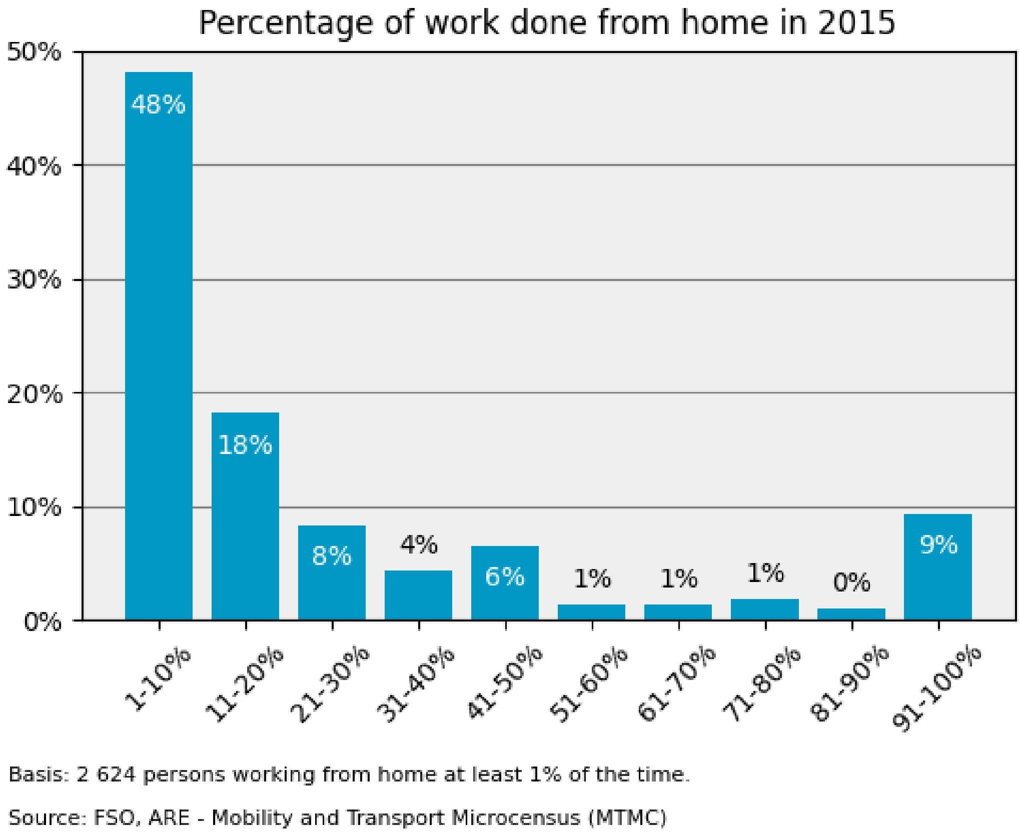

Figure 1: Percentage of work done from home in 2015

We observe that almost half (48%) of the people working from home did it 10% of their time or less in 2015. 9% of people working from home did it full time (see Fig. 1).

Nine possible reasons to work from home were read by the interviewers. Congestion on the road or in public transportation were two possible answers but have been grouped in Figure 2. The stated reason why people work from home was most often (37%) "Other". It might mean that the reason was not in the list or they could not decide for one single reason. A possible reason is that working from home represents a very small percentage of the work time for a lot of people; they work from home opportunistically, without a planned reason. The second most stated answer (25% of answers) was because their work place was at home (see Fig. 2). It is a surprising answer, since only 9% of people working from home are doing it full time (see Fig. 1).

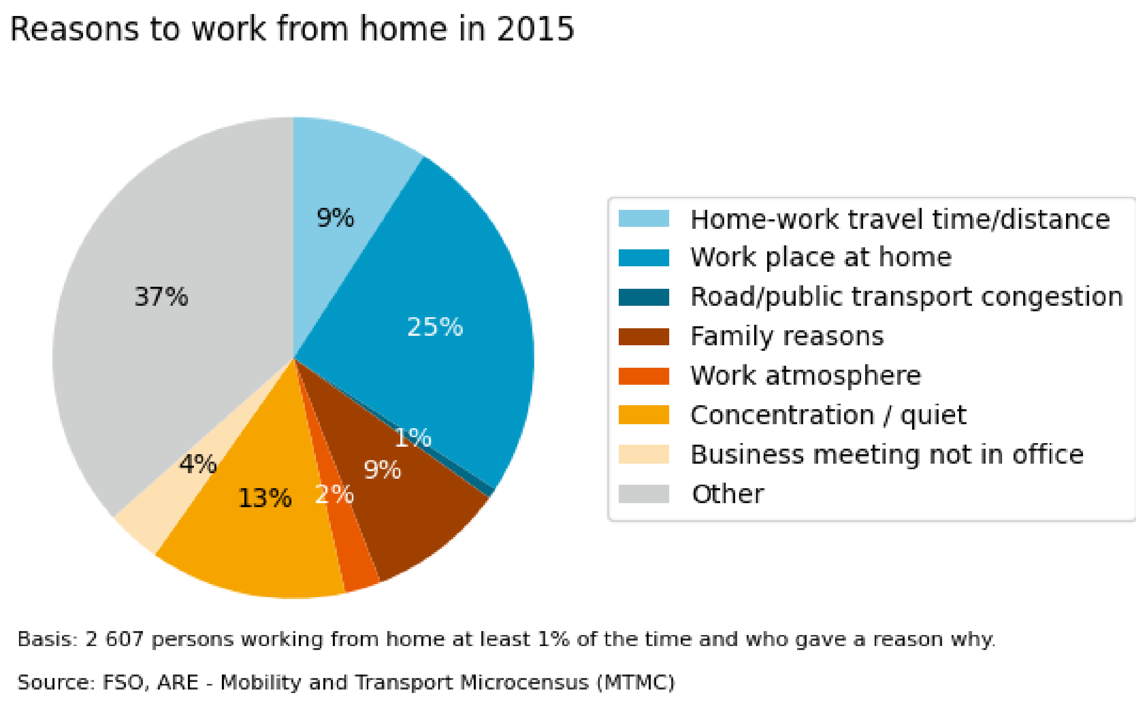

Figure 2: Reasons for working from home in 2015

2.2 Synthetic Population 2017

A synthetic population calibrated to retrospective data for the reference year 2017 was developed as an input into the transport models of the Swiss government and the Swiss Federal Railways (Bodenmann *et al.*, 2019). It contains a georeferenced dataset of the full Swiss resident population grouped in households. The demographic and socio-economic attributes include among other age, sex, education level, nationality, income, mobility tools - such as car availability and possession of public transport season tickets, work location and business sector.

The synthetic population is primarily based on the Population and Households Statistics (STATPOP) and the Structural Business Statistics (STATENT) of the Swiss Federal Statistical Office (FSO, `https://www.bfs.admin.ch/`). These register data contain the geocoordinates of households and businesses, the age and sex of individuals, the size of the household and the number of employees of businesses. Then, additional attributes are added by simulating and calibrating an agent-based land use model, "Facility Location Choice Simulation" (FaLC), on aggregate values: language, education level, work percentage, business category, position in the company, assignment of employed individuals to businesses, training status (pupils or students), income of individuals and households, mobility resources (car and public transport season tickets, also sometimes referred to as “mobility tools”), and owning or renting the place of living. For more details, see Bodenmann *et al.* (2019).

2.3 Synthetic Population 2030, 2040 and 2050

Using the official population scenarios for Switzerland and Swiss cantons up to 2050 by the Swiss Federal Statistical Office, the land use model FaLC was applied to forecast synthetic populations. It generates populations for 2030, 2040 and 2050 with the same data structure as in the synthetic population 2017. These forecasts are used as input for the Swiss transport outlook 2050. For this paper, preliminary versions of the forecasted synthetic populations were used.

3 Choice model

The choice model is a binary logit model. The two alternatives are “some home-based telecommuting” or “not working from home at all”. We define “some home-based telecommuting” as answering “yes" or “sometimes" to the question on working from home and answering a work percentage higher than 0. People answering “no” to the first question or “yes” to the first question, then “0%” to the second one are considered as not doing some home-based telecommuting. People who did not get the question or who did get the question but did not provide an answer to both questions are excluded from the sample. With this definition, we get a sample of 8997 answers from the same number of different households.

In Section 3.1, we first present the attributes that were tested and the specification of the model, i.e., how the attributes were integrated in the utility function. Then, in Section 3.2, we show the estimation results, and in particular which parameter are included in the final model. Some attributes mentioned in Section 3.1 (e.g., structure of the household) are not in the final estimation results (Section 3.2), since they were not significant.

3.1 Model attributes and specification

Attributes We have tested the attributes presented in Table 2.

Table 2: Attributes tested in the model

Attribute	**# of levels (if relevant)**
Level of education	4
Sex	2
Structure of the household (single household, couple with/without children, single parent with children, not family household)	5
Public transport connection quality of the place of living	5
Public transport connection quality of the place of working	5
Urban/rural typology of the place of living	3
Urban/rural typology of the place of working	3
Crow-fly distance from home to work	
Business sector in which the person works	10
Having several part time jobs	2
Income of the household	9
Function in the company	3
Work percentage	
Language of the interview	3
Age	

The total work percentage can be higher than 100 in the Mobility and Transport Microcensus, when people declare two part time jobs. It is not the case in the synthetic population, by definition. Therefore, the work percentage has been fixed to 100 when it was higher than 100 for the estimation of the model.

The 10 business sectors are an aggregation of the General Classification of Economic Activities (NOGA 2008). The aggregation was defined when developing the synthetic population 2017 (Bodenmann *et al.,* 2019). The correspondance between the numeric codes and the names can be found in Federal Statistical Office (2008).

Model specification The fact of having several part time jobs was significant in the model, but was removed because this information is not available in the synthetic population.

Age and work percentage are included in the model as piecewise linear specification. The income levels were tested separately and then grouped in one category including all households with 8000 CHF or less per month. The nationalities were tested separately and then grouped in one category including Swiss, German, French, Italian, Northwestern Europe and Eastern Europe nationals.

3.2 Estimation results, 2015

The model has been estimated using PandasBiogeme (Bierlaire, 2020). Table 3 shows general statistics and Table 4 shows the parameter estimates. We observe that the decision to work from home is influenced by work related factors, such as the business sector and the function in the company (chapter 3.2.1), by socio-economic characteristics, such as age and income (chapter 3.2.2) and by spatial factors (chapter 3.2.3).

Table 3: General statistics about the estimation

Init log likelihood	-6236.245
Final log likelihood	-4390.705
Rho-square for the init. model	0.296
Rho-square-bar for the init. model	0.292
Akaike Information Criterion	8829.411
Bayesian Information Criterion	8999.922

3.2.1 Work related: Business sector, function in the company & percentage

The parameters for people working in wholesale, finance and other sectors are fixed to 0 and used as reference values.

The results of the estimation of the model show that people working in agriculture tend to work more from home. This is most probably due to the fact that farmers both live and work on their farm. This was also observed by Moeckel (2017) for Germany, with workers in agriculture having the highest share of working from home.

The people working in accommodation and food service activities (“gastronomy”), in manufacturing and construction (“production”) and in professional, scientific and technical activities, and administrative and support service activities (“services”) are less likely to work from home in comparison to other sectors. This effect has already been observed for manufacturing (Walls

	Value	Rob. Std err	Rob. t-test	Rob. p-value	
Alternative specific constant$_{\text{Working from home}}$	0.612	2.38	0.257	0.797	
$\beta_{\text{Business sector: wholesale, finance and other}}$ (ref.)	0	-	-	-	
$\beta_{\text{Business sector: agriculture}}$	0.991	0.0902	11.0	0.0	***
$\beta_{\text{Business sector: gastronomy}}$	-0.574	0.102	-5.61	2.01e-08	***
$\beta_{\text{Business sector: public administration \& education}}$	1.18	0.102	11.6	0.0	***
$\beta_{\text{Business sector: production}}$	-0.244	0.107	-2.27	0.0235	**
$\beta_{\text{Business sector: retail}}$	-0.462	0.167	-2.77	0.0056	***
$\beta_{\text{Business sector: services}}$	-0.441	0.0942	-4.68	2.87e-06	***
$\beta_{\text{No management position}}$ (ref.)	0	-	-	-	
$\beta_{\text{Executives}}$	1.0	0.0573	17.5	0.0	***
$\beta_{\text{Language of interview: Italian, French}}$ (ref.)	0	-	-	-	
$\beta_{\text{Language of interview: German}}$	0.251	0.0583	4.31	1.67e-05	***
$\beta_{\text{Household income: more than 8000}}$ (ref.)	0	-	-	-	
$\beta_{\text{Household income: 8000 or less}}$	-0.421	0.059	-7.14	9.64e-13	***
β_{Women} (ref.)	0	-	-	-	
β_{Men}	0.201	0.0637	3.16	0.0016	***
$\beta_{\text{Nationality: other}}$ (ref.)	0	-	-	-	
$\beta_{\text{Nationality: CH/DE/FR/IT \& NW EU}}$	0.914	0.14	6.51	7.42e-11	***
$\beta_{\text{PT quality, home: very good to weak (A, B, C, D)}}$ (ref.)	0	-	-	-	
$\beta_{\text{PT quality, home: worst}}$	0.202	0.0688	2.93	0.00338	***
$\beta_{\text{Work place: urban or intermediary area}}$ (ref.)	0	-	-	-	
$\beta_{\text{Work place: rural area}}$	0.245	0.0904	2.71	0.00667	***
$\beta_{\text{University education}}$ (ref.)	0	-	-	-	
$\beta_{\text{No post school education}}$	-1.82	0.139	-13.1	0.0	***
$\beta_{\text{Secondary education}}$	-1.09	0.0656	-16.6	0.0	***
$\beta_{\text{Tertiary education}}$	-0.656	0.0811	-8.08	6.66e-16*	**
$\beta_{\text{Home-work distance}}$	0.0398	0.0201	1.97	0.0483	**
$\beta_{\text{Age 19-}}$	-0.157	0.121	-1.3	0.194	
$\beta_{\text{Age [20, 34]}}$	0.084	0.00982	8.56	0.0	***
$\beta_{\text{Age [35, 74]}}$	0.000129	0.00315	0.041	0.967	
$\beta_{\text{Age 75+}}$	-0.146	0.0804	-1.82	0.069	*
$\beta_{\text{Work percentage [1, 89]}}$	-0.0116	0.00164	-7.05	1.77e-12	***
$\beta_{\text{Work percentage [90, 100]}}$	0.0145	0.00926	1.57	0.117	

Table 4: Parameter estimates

et al., 2007, Zhou *et al.,* 2009, Paleti and Vukovic, 2017, Shabanpour *et al.,* 2018) and administration (Paleti and Vukovic, 2017). It might be explained by the fact that these persons perform personal services at their workplace. Hence a digital substitution is not possible.

People working in public administration and defence and education ("public administration &

education") and in retail are more likely to work from home in comparison to other sectors. This contradicts some results from Chicago showing that "government employees are among the least frequent telecommuters" (Shabanpour *et al.,* 2018). This might be related to different policies regarding telecommuting for public employees between Switzerland and Chicago.

Independent workers, owners of their own company, people working in their own family business, and employees with management position (managing a team) or members of the direction of the company (all grouped in attribute "executives") tend to work more from home than workers without management position in the company. This contradicts previous results from Chicago, showing that "managers of companies or enterprises are less likely to participate in telecommuting" (Shabanpour *et al.,* 2018).

The higher percentage people work, the more they tend to work from home, until 89%. Between 90% and 100%, this effect is not significant anymore.

3.2.2 Socio-economic factors: Language, income, sex, nationality, education & age

(1) People who did the interview on the phone in German, (2) men, (3) Swiss, German, French, Italian and North Western Europe nationals and (4) people living in households whose income is above 8000 CHF per month tend to work more from home than people (1) who did the interview in French or Italian, (2) women, (3) people with other nationalities and (4) people from poorer households. The results regarding gender and income have been observed in previous studies (Paleti, 2016, Shabanpour *et al.,* 2018), while native citizen telecommuting more has also been observed (Paleti, 2016, Paleti and Vukovic, 2017).

The level of education also has an impact. People without a diploma are the least likely to work from home, followed by people with a primary education, and then by people with a tertiary but non university education, compared to people with a university diploma (fixed to 0 in the model, as reference value). Such effects have been observed in other estimation results (Paleti and Vukovic, 2017).

We do not observe an effect of age until 19. Then between 20 and 34, people tend to work more from home with age. Between 35 and retirement, we do not observe an effect of age. Finally, when older than 74, people tend to work less from home (reminder: there are only people working in the sample; this is not a proxy effect for being retired).

3.2.3 Spatial factors: Distances, public transport quality and urban/rural typology

People with a larger crow-fly distance between home and work, with the worst quality of public transport on a 5 level-scale (as defined by the Federal Office for Spatial Development) at their home location and working in a rural area according to a 3-level scale ("Stadt/Land-Typologie", defined by the Federal Statistical Office) tend to work more from home. Similar effects have been observed in Mokhtarian and Meenakshisundaram (2002), Paleti (2016) and Shabanpour *et al.* (2018).

4 Internal validation

We have estimated the model on 80% of the data and applied it to the remaining 20%. The 80-20% decomposition of the data was random. This process was repeated 10 times. The observed proportion of people doing home office in the subsample of 20% of the observations is 27.9% on average (±2.0%) on the 10 runs (min: 26.7%, max: 28.9%), while the predicted proportion of people doing home office in the same subsample of 20% is 25.0% on average (min: 23.6%, max: 25.8%). Among the 10 runs, the largest difference is 4.6 points of percentage and the smallest 2.0. We consider these results as good enough to use the model for an external validation.

5 External validation using a synthetic population 2017

In this chapter, we present the results of applying the choice model estimated with the data of the Mobility and Transport Microcensus 2015 to the synthetic population 2017. The goal is to validate the approach before applying the model to the synthetic populations 2030, 2040 and 2050.

5.1 Calibration of the constant by simulating results for the Mobility and Transport Microcensus

The alternative specific constant is calibrated against the observed proportion of people doing home office in the Mobility and Transport Microcensus. The constant is empirically adjusted by using the heuristic method suggested by Train (2003, ch. 2.8 “Recalibration of constants”, p. 39). An iterative process is used to recalibrate the constants. The estimated alternative-specific constant (ASC_0) for the telecommuting alternative is iteratively modified so that the predicted share of decision-makers telecommuting $\hat{S}_n$ (computed using the alternative specific constant ASC_n from the n-th iteration) is equal to the observed share of decision-makers telecommuting S. We have applied Train’s adjustment:

$$ASC_{n+1} = ASC_n + \ln(S/\hat{S}_n)$$

In this process, the alternative specific constant changes from 0.61 to 0.80. With this change, the model predicts almost exactly (tolerance: 0.001) the observed shares of people working from home in the full sample of the Mobility and Transport Microcensus, when it is applied to the full sample of (employees of) the Mobility and Transport Microcensus.

5.2 Distribution of the attributes in the Mobility and Transport Microcensus and in the synthetic population 2017

Table 5 compares the distribution of the attributes of the model in the Mobility and Transport Microcensus (MTMC) 2015 and in the synthetic population (SynPop) 2017.

In the MTMC, we only know the income by household, aggregated in 9 levels/categories. We use income directly as defined in the MTMC for the estimation. As an output (see chapter 3.2), we observe that people living in households with monthly income below 8000 CHF tend do do less home office. They represent 38.9% of employees.

In the SynPop, we know the income by person, disaggregated in absolute values. For comparisons with the MTMC, we first aggregate the individual incomes by household. As we see in Table 5, the definition of income in not the same in the two datasets. In order to define a variable “low household income” for the external validation with the SynPop 2017, we fix the limit for the household income to 6509 CHF in the SynPop. This limit of 6509 CHF reproduces the proportion of employees with an household income below 8000 CHF (38.9%), the same as the proportion in the MTMC.

Table 5: Distribution of the attributes in the Mobility and Transport Microcensus (MTMC) 2015 and in the synthetic population (SynPop) 2017

	MTMC 2015	SynPop 2017
In the full population		
Employed people (excl. apprentices)	56.8%	57.8%
Among employed people (excl. apprentices)		
Executives / cadres	38.8%	36.2%
Household income:		
less than 8000 CHF	38.9%	53.7%
low (MTMC: 8000 CHF; SynPop: 6509 CHF)	38.9%	38.9%
Business sector: Agriculture	2.3%	2.0%
Business sector: Gastronomy	3.6%	3.0%
Business sector: Production	18.5%	12.0%
Business sector: Retail	5.5%	3.6%
Business sector: Non-movers	11.2%	16.0%
Business sector: Service fC	12.1%	10.7%
Crow-fly home-work distance	17.2 km	13.3 km
Nationality: CH/DE/FR/IT & NW EU	85.9%	83.1%

5.3 Results

According to the Mobility and Transport Microcensus, 28.1% ($\pm 0.9\%, n = 8997$) of employees were working, at least from time to time, from home in 2015. When applying the logit model to the synthetic population, the prediction is 25.2% (by averaging the simulated probability on all employees). We consider this result as good enough to apply the model for forecasting.

6 Forecasting 2030, 2040 and 2050 using a synthetic population

6.1 Calibration of the constant by simulating results for the synthetic population

The alternative specific constant is again calibrated against the observed proportion of people doing home office in the Mobility and Transport Microcensus, similarly as in Chapter 5.1. The constant is empirically adjusted by using the heuristic method suggested by Train (2003, ch. 2.8).

In this process, the alternative specific constant changes from 0.80 to 0.99. With this change, the model predicts almost exactly (tolerance: 0.001) the observed shares of people working from home in the full sample of the Mobility and Transport Microcensus, when it is applied to the full (employees in the) synthetic population 2017.

6.2 Definition of the household income limit for 2030, 2040 & 2050

Similarly to what we did for the external validation with the synthetic population 2017 (see Chapter 5.2), we aggregate the individual incomes by household and use a value of 6509 CHF in 2030, 6976 CHF in 2040 and 7574 CHF in 2050, so that it represents 38.9% of all households for each year.

6.3 Results: Proportion of people working from home in 2030, 2040 & 2050

According to our model, 37.3% of the population will work from home in 2030, 38.8% in 2040 and 38.6% in 2050. Figure 3 shows these results in comparison with the observed rates for 2010 and 2015.

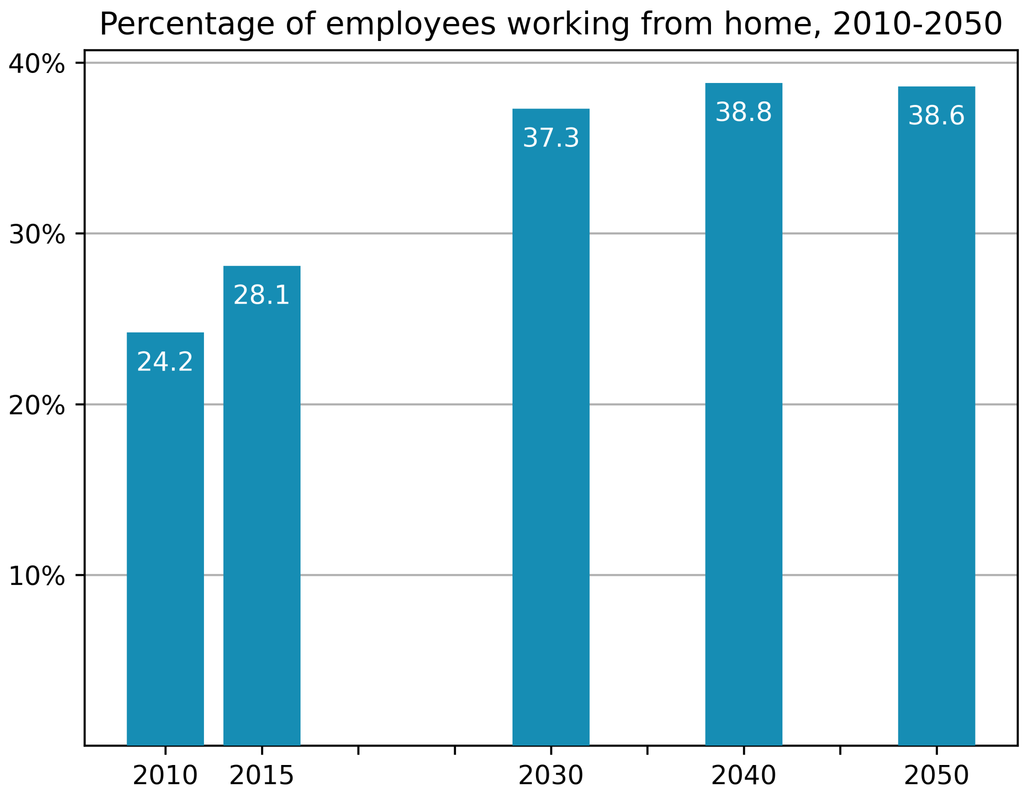

Figure 3: Observed percentage of work done from home in 2010 and 2015. Predicted percentage of work done from home in 2030, 2040 and 2050.

7 Limitations

Forecasting the proportion of people doing home office in 2050 based on data from 2015 obviously does not include the possible long-term effect of the COVID-19 pandemic of 2020 and 2021. It also does not include the possible technological developments that could change the willingness to work from home.

In the model estimated with the data of 2015, the nationality is significant. The 86% of the population with a Swiss, German, French, Italian or Northwestern European nationality tend to work more from home. This is certainly a proxy for other, more subtle, socio-economic factors, and we can doubt that this proxy will still be valid in 2030, let alone 2050. However, knowing that the synthetic population does not offer all possible socio-economic details, we believe this is the least bad approach for forecasting.

8 Future work

We are currently developing an ordered logit model of the number of trips to work. Similarly to the approach used in this paper, we use the synthetic population for 2050 in order to predict the number of trips to work. Preliminary results show that doing some home office had a significant impact on the number of trips to work in 2015 (Danalet *et al.,* 2021). Future explorations should (1) test the impact of home-based telecommuting on other trip purposes, such as leisure and (2) consider the possibility of simultaneously estimating both the model for home-based telecommuting presented in this paper and the ordered logit model of the number of trips to work presented in Danalet *et al.* (2021) and (3) more generally consider the possibility of simultaneously estimating a model of the number of trips to other purposes than work (shopping, leisure, studying).

A challenge will also be to include the data of the Mobility and Transport Microcensus 2020 (partial data collection interrupted due to the COVID pandemic) and 2021. The data of 2021 have been strongly influenced by the pandemic and include a lot more people working from home. How could we include these data in a model? And how could we know the long-term effect of the pandemic on working from home?

We have started developing a model of the percentage of work made at home, on top of the binary decision to work from home or not. Using a fractional regression approach (Clark*,* 2019), preliminary results show that the business sector, the fact of having a management position, the education and the age have significant effects (*not published yet*).

In order to test the robustness of our approach, we could do backcasting with the data of the MTMC 2010.

For a better interpretation of the results, it might be interesting to compute the probability to work from home using the model for a few typical persons, in order to give a feeling of the impact of some variables. It might also prove useful to compute some descriptive statistics using the synthetic population 2030, 2040 and 2050 and compare them, including with the results for the Mobility and Transport Microcensus. It might help better understanding the drivers of the increase of the possibility to work from home in the future in our model.

9 Conclusion

We show that 39% of the employees living in Switzerland will work from home in 2050, compared to 28% in 2015. This forecast are based on a binary logit model estimated on the data of the Mobility and Transport Microcensus 2015. The model has been internally validated, as well as externally validated using a synthetic population for 2017. The alternative specific constant has been calibrated on the synthetic population 2017, in order to reproduce the percentage of people working from home observed in the Mobility and Transport Microcensus 2015. The model has finally been applied to synthetic populations for 2030, 2040 and 2050.

The model has obvious limitations (no effect of the COVID-19 pandemic nor of possible technological developments, using nationality as a proxy). It has not (yet) been estimated together with a model of the number of trips to work nor more generally with a model of the number of trips for non-work purposes. The model also only explains the binary possibility to work from home, but not the exact percentage of work done from home, even if the data are available in the Mobility and Transport Microcensus.

However, our model provides quantitative forecasts for 2050. These were useful as a reference in developing the Transport Outlook for 2050 (see `www.are.admin.ch/transport-outlook`). The Transport Outlook 2050 draws up scenarios for how passenger and freight transport will develop up to 2050. The Transport Outlook 2050 makes the assumption that telecommuting will increase and that the number of trips to work in 2050 will decrease due to work from home. Compensation effects, e.g. more and shorter leisure trips, are taken into account. The results of the Transport Oulook 2050 will be published in November 2021.

10 Data and code availability

The data of the Mobility and Transport Microcensus 2015 are available to researchers after signing a data protection contract. Some costs might be associated with the request. The request can be done through the following form: `https://www.are.admin.ch/are/de/home/mobilitaet/grundlagen-und-daten/mzmv/datenzugang.html`.

The data of the synthetic populations 2017 and 2050 are very sensitive (it includes the exact - not synthetic - coordinates of Swiss households) and it is not possible to share it with researchers. The 2017 aggregated data are available for each zone of the Swiss national transport model after digitally signing a data protection contract on FORSbase: `https://forsbase.unil.ch/project/study-public-overview/16671/0/`.

The code of the model is available on GitHub: `https://github.com/antonindanalet/home_office_in_microcensus`.

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