Empirical analysis of cycling trends in two of Europe's most bicycle-friendly regions: Identifying the successes and the setbacks

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Short summary

We present a combined longitudinal and socioeconomic study of cycling demand in the Netherlands and Denmark from 2010 to 2021. The countries are comparable in demography and both countries have well-developed cycling cultures. The longitudinal data allow us to study successes and setbacks related to cycling uptake over time. E-bikes are successfully promoting longer cycling trips and increased cycling among elderly people, particularly in the Netherlands. However, in rural areas of Denmark, we see setbacks in the form of significant reductions in cycling among children. By applying an econometric model of the combined selection effect of bicycling and the mileage effect conditional on travelling by bike, we analyse how these effects are related to, e.g. increased distances to school, increased work distance, car ownership, changes in urbanisation and other socio-economic factors. We show that these factors cannot explain all of the decline for childrens cycling in Denmark.

Keywords: Cycling demand Mode choice Cycling behaviour Longitudinal analysis Cohort study

1 Introduction

Research show that cycling leads to better health, reduced congestion and better accessibility (Rich et al., 2021) and thus Bicycle research has received increasing awareness in recent years (Heinen & Götschi, 2022). Several studies have studied cycling across countries (Schneider et al., 2022; Goel et al., 2022; Buehler & Goel, 2022; Pucher & Buehler, 2008). Longitudinal studies are rare and typically from few countries with available data. Harms et al. (2014) found increasing cycling volumes in the Netherlands in urban areas and decreasing volumes in rural areas between 1996-2012. Van Goeverden et al. (2013) foundt hat national bicycle shares on average were stable, whereas Harms et al. (2014) showed that educational trips experienced a significant increase from 1994-1996 to 2007-2009. A more recent study by Kroesen & van Wee (2021) found that the level of urbanisation was the strongest predictor of cycling distance.

It is yet unclear how different effects are related to the cycling uptake for different groups in areas with different degree of urbanisation when considered in a longitudinal perspective. Better insight is needed to meet unfavourable tendencies with the right policy measures. As an example, if younger age groups have a low cycling uptake locally, but not globally, it suggest that there are local conditions that prevent young people from cycling. Global trends on the other hand, may signal wider behavioural tendencies that could result from social media usage (Meyer et al., 2021) or other factors. These tendencies require a different set of actions.

In this paper we present a combined longitudinal and socioeconomic study of cycling demand in the Netherlands and Denmark in the period from 2010 to 2021. The two countries are among the most successfully cycling nations in the world and are by all means comparable economically and socially. The two countries also host and maintain two of the most comprehensive trip diaries in the world (Christensen, 2020; Boonstra et al., 2022). The trip diaries are very similar in structure and scope and are of high quality. This allows a comparison of the cycling uptake across socioeconomic groups and over time.

Year	NL N	Trips All	Trips Bike	Trips E-bike	Km Bike	Km E-bike	DK N	Trips All	Trips Bike	Trips E-Bike	Km Bike	Km E-Bike
2010	44165	2.81	0.76	NA	3.28	NA	23705	2.90	0.43	0.01	3.08	5.72
2011	38722	2.72	0.78	NA	3.44	NA	18009	2.92	0.44	0.01	2.94	4.58
2012	43307	2.72	0.79	NA	3.31	NA	9696	2.97	0.46	0.01	3.14	5.94
2013	42350	2.73	0.76	NA	3.41	NA	8912	2.72	0.44	0.01	3.45	5.47
2014	42600	2.73	0.81	NA	3.60	NA	9581	2.76	0.45	0.02	3.62	5.02
2015	37350	2.64	0.74	NA	3.45	NA	8720	2.81	0.41	0.02	3.39	6.44
2016	37229	2.59	0.72	NA	3.45	NA	8794	3.03	0.44	0.02	3.21	4.10
2017	38127	2.54	0.70	NA	3.48	NA	9920	3.11	0.41	0.03	3.36	5.16
2018	57260	2.8	0.76	0.15	3.46	6.01	11087	2.90	0.42	0.03	3.41	4.38
2019	53380	2.73	0.66	0.17	3.39	5.86	10204	2.84	0.39	0.03	3.31	4.71
2020	62940	2.34	0.51	0.18	3.53	6.34	12161	2.98	0.38	0.05	3.53	4.71
2021	67083	2.52	0.50	0.23	3.56	5.83	10153	3.14	0.33	0.05	3.41	3.88
Total	564513	2.66	0.71	0.18	3.45	6.01	140942	2.92	0.42	0.03	3.32	5.01

Table 1: Number of observations and average trips per year in the two trip diaries. Trips are calculated as weighted averages based on the official sample weights. 'Bike km' represent the corresponding weighted bicycle mileage per biked trip excluding e-bikes.

2 Data

In Denmark, The Danish National Travel Survey (TU) (Christensen, 2020) constitutes a representative cross-sectional sample of the Danish population between the ages of 10 and 84.The survey collects information concerning the daily travel habits of approximately 1,000 Danish respondents per month. In the Netherlands, the Dutch national travel survey has been conducted since 1985, but only since 2018 in its current format. During the course of the whole year, approximately 45,000 individuals aged 6 and older currently participate, which corresponds to approximately 0.2% of the Dutch population. In both surveys one individual per household is selected. In Table 1 we present key bicycle descriptive variables in the period between 2010-2021.

It is notable that e-bikes constitute an increasing share of bicycles and travel significantly longer. However, the share in Denmark is small compared to the Netherlands. It is also interesting to see that, by-and-large, trip frequencies for bicycles (when combining electric bicycles and conventional bicycles) are largely constant, while bicycle mileage seems to increase slightly.

3 Methodology

With the absence of panel data a first and straightforward measurement of bicycle trends over time can be based on age-cohorts (Rich et al., 2022). The idea is to study how a group of people at a given age (e.g., 10-20 years of age) behave in different years. This allows us to examine if 10-20 year old's in the year 2010 behave differently compared to those in the same age group observed in the year 2021.

In Rich et al. (2022), bicycling demand was decomposed into a selection effects and a mileage effect. The selection was measured as a binary variable if the person travelled by bike on the day of the interview. The mileage effect was measured as the total bicycle mileage on the day provided that the interview person travelled by bike. In the paper, the two effects was modelled in a Hurdle-type model (Cragg, 1971) and it was found that the selection effect was the main driver of changes while the conditional mileage effect were largely inconclusive. This paper is inspired by the same idea but develops models for both countries separately.

In addition, we include more explanatory variables in order to assess whether the trends in bicycle demand can be explained by external factors. These factors include car ownership, household characteristics, urbanisation and distance to school and work. In case we still see a significant trends, it suggest that other factors not included in the model are at play.

When modelling the development in bicycle demand, we use a decomposition of the probability of cycling on a given day, and conditionally on people cycling, the total mileage. This selection process is estimated using a logistic regression as shown in Eq. (1). In Eq. (1) $y = 0$ indicates that a person did not cycle, whereas $y > 0$ indicates that the person engaged in cycling activities on the day.

The mileage model in Eq. (2) is modelled as a standard generalized linear model. The aim is to classify the variables that drive the bicycle demand rather than predicting bicycle demand (Efron, 2020).

$$P_{n,t}(y=0|x) = 1 - \frac{1}{1+e^{-(-x_{n,t}\cdot\beta_s)}} \tag{1}$$

$$g_{n,t}(y) = x_{n,t}\cdot\beta_m + u_{n,t}, \quad u \sim N(0,\sigma_u) \tag{2}$$

In this case we apply a link-function $g(y) = ln(y)$, which corresponds to the assumptions in a log-normal Hurdle model.

For each country, we estimate a logistic regression (Eq. 1) and a mileage model (Eq. 2) for all individuals $n = 1, ..., N$ and all years $t = 1, ..., T$. In all models and for all countries, the following set of explanatory variables are used:

$$\begin{aligned} x_{n,t}\beta = {} & k_t + \beta_f \cdot Female_{t,n} + \beta_c \cdot Cars_{t,n} + \beta_{sd} \cdot School\_dist_{t,n} \\ & + \beta_{ch} \cdot Children\_dist_{t,n} + \beta_{wd} \cdot Work\_dist_{t,n} + \beta_e \cdot Ebiket,n \\ & + \beta_{u1} \cdot Urban_{n,2} + ... + \beta_{u4} \cdot Urban_{n,5} + \beta_{a1,t1} \cdot Age\_group_{n,t1,1} \\ & + ... + \beta_{a4,t11} \cdot Age\_group_{n,t11,4} \end{aligned} \tag{3}$$

With the variables defined as.

- k_t: Dummy variables for each year, of which $T-1$ can be identified. Hence, 2010 is set as the reference.
- $Female_n$: If the respondent is a female person.
- $Cars_{n,t}$: The number of cars in the household in which n belongs.
- $School\_dist_{n,t}$: The distance to school for those respondents who go to elementary school (age $\leq$ 16 years).
- $Children_{n,t}$: If small children under the age of 6 is present in the household.
- $Ebiken,t$: For the selection model, this variable cannot be included as we do not know the type of bicycle owned by the respondent. However, for the mileage model, it makes sense because we know if the specific trip is carried out by electric bike.
- $Work\_dist_{n,t}$: The distance to work for those who work.
- $Urban_{n,t,u}$: Urban classification dummies with $u = 1$ representing densely populated areas and $u = 5$ rural areas. $u = 1$ is the reference level.
- $Age\_group_{n,t,a}$: Age cohorts combined with years. In the simple model, we only consider age cohorts with $a = 1$ corresponding to [10-20], $a = 2$ to [20-30], $a = 3$ to [30-66] $a = 4$ to [66-]. However, in a generalized model, we allow for different age cohort parameters over the years, in order to identify if behavior is changing.

As the underlying data are micro-data we track any changes in these underlying variables over the period. Hence, if more people are moving to the cities, this will be measured in the model through the urbanization variables. If people in cities in 2010 and 2020 behave largely identically, we should be able to model these changes with a main-effect variable for urbanization.
The models help us to understand which factors that explain the development in bicycle demand over time. However, most importantly, the models will allow us to see if age groups change behavior over time when accounting for urbanization degree, car ownership, and distances to work and school. If this is the case, it will suggest that there are other factors that need to be investigated in the future, e.g. measures related to perceived or actual safety as an example.

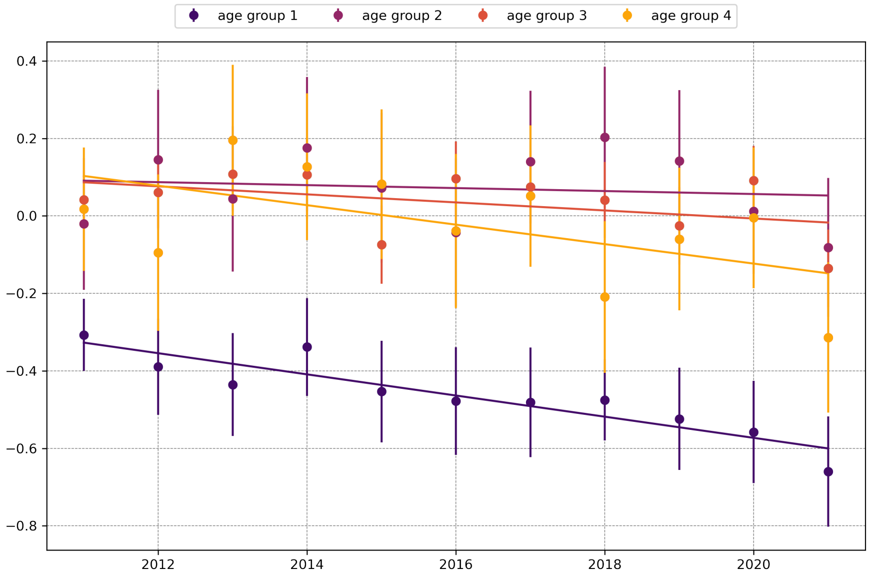

Figure 1: Selection model parameters for different age-groups and years for Denmark. Vertical bars represent 5% confidence level.

4 Results and discussion

An interesting hypothesis is if the parameters for the main effect for age groups by year change over the period. This should suggest if there are unexplained effects (beyond the attributes that are included in the simple reference) for a given age group in a given year change over the period. Therefore, for both the selection and mileage models, we combine the parameters $k_{2011}, ..., k_{2021}$ with the four age groups as well. Hence, for a given year i, we estimate not one (e.g., k_{2011}), but four main effects corresponding to the four age groups (e.g., $Age_{group}1 * k_{2011}$, $Age_{group2} * k_{2011}$, $Age_{group3} * k_{2011}$ and $Age_{group4} * k_{2011}$).

The results from the selection models indicate that distance to work and school indeed influence the preference for bicycle in a negative way. Gender, has opposite sign in the two countries. Hence, females are more likely to bike in Denmark, whereas the opposite is true in the Netherlands. We also find that the presence of cars in the household significantly reduced the likelihood of travelling by bike. Similarly, there is a increasing likelihood of using bicycle in urbanised areas. Across all years, the older people gets, the less likely they are to choose the bicycle. The same pattern is seen for both countries.

Rather than including the full table of parameters, we present only the specific main effect parameters in Figure 1 and 2. The vertical bars represent a 5% level of confidence.

It is interesting to see that for Denmark, for all age groups over the age of 20, there is no significant difference in parameters. However, for young respondents between 10-20 years of age there is a significant decline in the parameters over the years. This suggests that there are other factors in play. For the Netherlands, the pattern is slightly different. While the younger respondents also display a decline, the other age groups show an increase. Most notably for the oldest age group, where we see a significant increase.

The mileage models suggests that the conditional mileage for the youngest age group declines slightly over the period, although the parameters are not statistically different. The only systematic change is seen for the oldest age group in the Netherlands where the tendency to travel longer increases. Presumably, this trend is driven by an increase in electric bicycles for this age group.

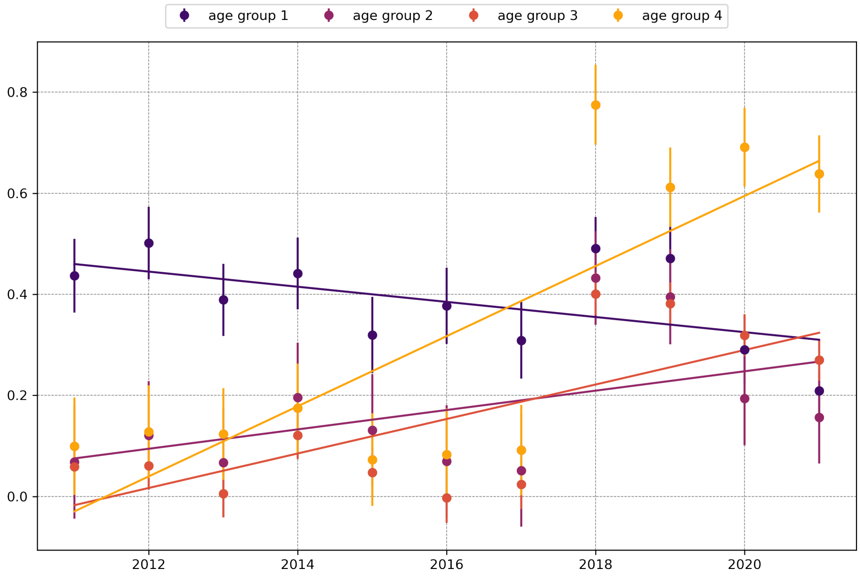

Figure 2: Selection model parameters for different age-groups and years for the Netherlands. Vertical bars represent 5% confidence level.

5 Conclusions

Based on longitudinal data from The Netherlands and Denmark, which are both countries with a high cycling demand compared to other countries, we have applied an econometric model to study how different factors are related to cycling uptake and use in these countries. In both countries, an increasing distance to school, more cars in the household, the share of households in rural areas, and higher age is related to a lower probability that a person will use a bicycle. Even when these factors are taken into account, there is a tendency of a decline in preference for cycling for younger people in Denmark. We cannot pinpoint the origin of these changes, but a possible explanation is that safety perception play an increasingly important role for kids and their parents. For the Netherlands, on the other hand, there are other positive unknowns affecting the oldest group. Whether this is related to an increasing awareness of the positive health effects from cycling is difficult to say. We find that the conditional mileage for the youngest age group declines slightly over the period, although the parameters are not statistically different. The only systematic change is for the oldest age group in the Netherlands where the tendency to travel longer increases. Presumably, this trend is driven by an increase in electric bicycles for this age group.

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