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Potential of the Age-Period-Cohort Model in the Analysis of the Propensity to Fly

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Abstract

The purpose of our explorative research is to examine the potential of the Age-Period-Cohort (APC) model in the analysis of the propensity to fly. The APC model is a descriptive model from the fields of epidemiology and demography. Applications in transport research are rare. We make use of the Schiphol Continuous Research Investigations, which have been taking place since 1990 and are still current. This rich source of data is not publicly available. It has 100.000 cases each year and has been held for almost 30 years. This has created a rather unique source of data about the development of the propensity to fly by age, sex and purpose of travel. This data is complemented by demographic figures for the analysis. The descriptive plots, model outcomes and modal-based plots from the APC model offer an interesting picture of the propensity to fly in recent decades. We observe a higher propensity to fly among baby boomers, those in the age groups 20 to 30 and a strong overall growth over the last 25 years. The APC model offers an interesting potential for a further analysis of trip purposes. Furthermore, it could also be used for predicting, especially in combination with the expected population growth. Limitations are the need for independent observations, the identification problem, and tabulation issues.

Keywords: *Age Period Cohort model, demographics, propensity to fly, Schiphol, the Netherlands*

1. Introduction

Flying has become a widely used form of travel in the Netherlands and elsewhere in the Western world. The past few decades have seen a very strong growth in the number of travelers. The required infrastructure for this, airports, cannot handle the demand at peak moments anymore. Eurocontrol (2013) predicts unaccommodated demand.

The question is where this growth comes from and how it will continue to develop. Will it continue unabated or are there signs of the growth levelling off? The life expectancy is going up in almost all countries, and as a result of that the age of retirement is being adjusted in a lot of them. Will people now keep using air travel until later ages? To answer questions like this experts in some other disciplines use the so-called Age-Period-Cohort (APC) model. In this paper we examine the above questions using this APC model. We focus mainly on the demographic factors related to the propensity of fly.

In paragraph 2 we briefly look at the existing literature in this area. In paragraph 3 we talk about the research methodology and the data we used. Paragraph 4 contains the results of our analysis and we finish with a number of conclusions.

2. Literature on the propensity to fly

The major factors influencing the growth of the aviation industry have been extensively studied, not only by Airbus, Boeing, the FAA or international organizations like IATA and Eurocontrol, but also by independent researchers, such as for example Burghouwt & Zuidberg (2010), Gudmundsson, Paleari & Redondi (2014), Oum, Zhang & Fu (2010). Several factors are involved, such as: demographics (the size and composition of the population); the evolution of the costs for aircraft, fuel, aircrews; economic development and security related measures. Institutional factors such as privatization, free trade and Open-Sky agreements also play a role. The development and construction of alternative transport forms like high speed rail and possibly Hyperloop also have some influence on the growth of the aviation industry.

In this analysis we only take the demographic factors age and sex into account. These are the factors that are addressed in many of the aviation studies. These studies are often based on airport surveys among travelers, such as the German ADV (Arbeitsgemeinschaft Deutscher Verkehrsflughafen), the *Enquête nationale des passagers aériens* conducted by French DG Aviation Civile and the surveys of the UK Civil Aviation Authority. These type of surveys also started at Amsterdam Schiphol in 1990 and are still being conducted there.

More rare are studies based on more general surveys in which people that do not fly at all are also represented. In this paragraph we give extra consideration to these because much of the available literature is based on surveys among people already at an airport, so we feel the information from more general surveys can offer important clues about the future development of the propensity to fly. An example is the French study “Qui prend l’avion” (DGAC, 2003). It concludes that a person's profession is the most important factor. People with a liberal profession travel the most and laborers and farmers the least. It also concludes that there is a strong correlation with income. Geographic location, such as how far from Paris someone lives, is also an important factor. The business travel segment is dominated by men (79% - 21%) whereas travel for non-business purposes is divided equally between the sexes. Socioeconomic reasons are the most important factors to explain why people do not fly at all.

Graham and Metz (2017) find that infrequent flyers make up a heterogeneous consumer group whose non-flying is influenced more by budget constraints and personal circumstances than specific aviation factors.

The Netherlands Institute for Transport Policy Research also conducted general research in 2010, (Gordijn & Kolkman, 2011), 2013 (Gordijn, 2015) and 2016 (forthcoming). These studies also find a correlation between the propensity to fly and income, education and place of living. They also identify the same differences between men and women when flying for business purposes. Fear of flying has become the most important reason not to fly, followed by costs. Health is also mentioned, especially among older age groups. Environmental concerns are barely mentioned. Fear of flying is a reason not to fly for not only for individual people, but also for their partners. Health reasons are mostly mentioned by seniors. It can be expected that with the growing life expectancy, the general health at advanced ages will improve and that people will keep continue to use air travel until later and later in life.

3. Method and data

3.1 Method

The goal of our research is not only gaining a better understanding of the propensity to fly, but also to test if the so-called Age-Period-Cohort (APC) model is a useful instrument for our purposes. We expect that there is a strong age effect in the propensity to fly, because that is strongly suggested in all the relevant literature. A periodic effect is also obvious, because the number of travelers has grown strongly in the past decades. Based on the existing literature there is little that points to certain cohort effects, such as specific generations having a higher or lower propensity to fly.

The APC model is a descriptive model for the information in a Lexis diagram. The term descriptive indicates the fact that the model is limited to summarizing information that is already included in the Lexis diagram. Is offers no explaining variables, but it does reveal patterns in the diagram. Because of the descriptive character we attach little value to the significance levels in the model for now.

The Lexis diagram, the basis for the APC models, is a well known diagram in the field of demographics. It ranks population data by age or age-group and year. Such diagrams are able to show demographic processes such as an aging population. The figures we use could also be converted into a Lexis diagram (see paragraph 3.2).

The roots of the APC model are in epidemiology, as a result, some of the terminology used sounds somewhat strange to transport scientists. Some of the terms are ‘risk’, ‘dose’ and ‘person-years’. For our purposes these are propensity to fly, population numbers and persons respectively.

A peculiar aspect in the APC model is the so-called identification problem. The three dimensions addressed are correlated, because C = P-A. In our estimation this results in the cohort effect being derived from the age and period effect. This peculiarity has led to an uncontrolled growth of different specifications and exceptions in the APC model. We confine ourselves to the regular model, where the three dimensions are estimated as factors. In the last part we reflect on this decision.

For more information about the APC model we refer to the key publications about the model (Carstensen, 2007; Holford, 1983; Clayton & Schifflers, 1987). Applications of the model in relation to transport sciences have been presented by Chanel (2014) and Sun (2009). For our estimations we used two packages included in the statistical platform “R”: Epi (Carstensen et al., 2017) and APC (Nielsen, 2014).

3.2 Data

The data to be analysed with the APC model consists of 2 components: number of travelers (D) and the population (Y). The propensity to fly (rates) for age group (A) in the period (P) can be formulated as: $D_{a,p}$ / $Y_{a,p}$. The traveler data we used in this study comes from the Schiphol Continuous Research Investigations. The population data we used consists of the population by age and sex, as published by the Dutch Central Agency for Statistics (statline.cbs.nl/).

In this article we analyze the mobility of Dutch travelers using Schiphol. Schiphol has a long term data set available which can be used for this analysis. Data like this is not available to us for regional and foreign airports. For the purpose of this study, Dutch people are considered to be travelers who live in the Netherlands, so we distinguish by country of residence, not nationality. Schiphol publishes a number of aggregated results of her surveys in her annual report, but the data file itself is not publicly available. The survey is being held continuously, and consists of roughly 100.000 respondents on a yearly basis. The respondents are being surveyed in person before departure.

We confine ourselves to the total group of travelers, and the groups of males and females within. Other possibly useful factors to include in future expansions of this project are the reason to travel and the distinction between continental and intercontinental flights. In some cases it might be possible to further combine those factors.

The ages of the people examined in the analysis are between 15 and 90. We divide the people into age groups of 5 years that are modelled based on the group average, for example the 15-20 age group is modelled as 17. On one hand this results in a loss of information, but on the other hand it makes the model less complicated. The older versions of the Schiphol survey also do not include a finer breakdown of ages. Additionally, we noticed in the raw data that older ladies in particular seem to have the tendency to round down their age.

The period covered in our analysis spans from 1991 to 2016. As with the age groups, we divide the timespan into groups of 5 years. As a results of this we are dealing with 6 different periods; 1991, 1996, 2001, 2006, 2011 and 2016.

A consequence of condensing the age groups and periods is the existence of cohorts from 1904 till 1999. On the outer extremes of this spectrum the results of the model are poor by definition, due to a limited number of observations in our data.

Because the data we use is the data provided by Schiphol we cannot claim to speak about the propensity to fly of the entire Dutch population. Dutch air travelers departing from regional or nearby foreign airports are not included. The number of travelers at regional airports is approximately 10% that of Schiphol. It is estimated that in 2016, 0.6 to 1.0 million Dutch air travelers departed from airports located in Germany and Belgium near the Dutch border. These travelers mostly live in the South and South-East of the Netherlands. Hence, we estimate that the real propensity to fly will be 20% to 25% higher than the one calculated in this study.

4. Results

When discussing the results we will first examine the insights that can be obtained based on a number of descriptive plots. We then continue to the model estimates and the plot based on the APC model. We conclude with an exploration of other interesting applications of the APC model.

4.1 Descriptive plots

When we look at the general evolution of the propensity to fly we see a strong grow in almost all age groups in the period 1991 - 2016 (Fig. 1). The propensity to fly seems to peak between the ages of 20 and 50. In the youngest age group, 15 to 20, the propensity is relatively low, especially when compared to the group 20 to 35. Past the age of 50 the propensity to fly seems to gradually decline. And for the oldest age group in our analysis (85-90) the propensity is negligible.

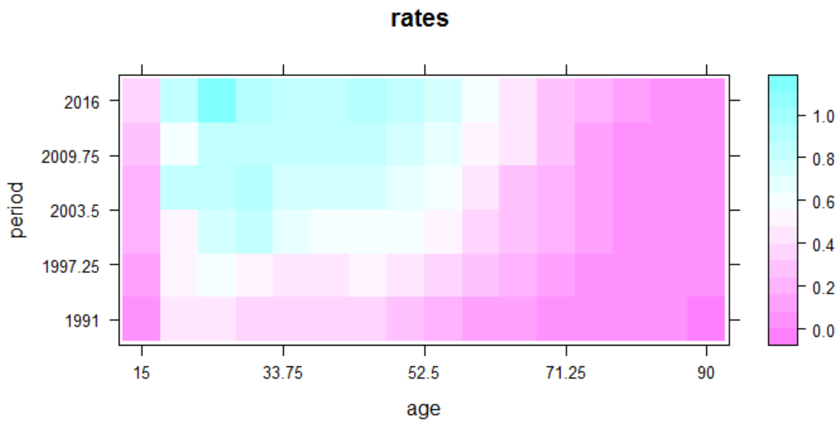

Fig. 1: rates by age and period

When we look at the differences between males and females, we can make a number of observations. The observed growth in figure 1 returns in separate plots for males and females (Figures 2 and 3). It appears the growth for females is slightly stronger and more evenly distributed over all age groups. A temporary decline can be seen for males in the age group 20-35 in 2011 compared to 2006. For females this same decline can be observed, but only for the age group 20-25. This is possibly caused by the economic crisis in that period.

A second finding is that the propensity to fly by age group follows a very different pattern for females compared to men. For men the graph is in the form of a mountain whereas for females it peaks early, then declines and has a slight comeback before entering the same long term old age decline.

A third finding is that the curves seem to move to the right too, towards the older age groups. This move is so strong that it cannot be explained by the time effect alone. This points to a cohort effect, where younger cohorts show different behaviour. This can be tested with an APC-Analysis.

A fourth finding is there is no further growth for males in the 30-40 age group between 2006 and 2016. Is this a sign of saturation? For females in the same age group and period we only see a modest growth.

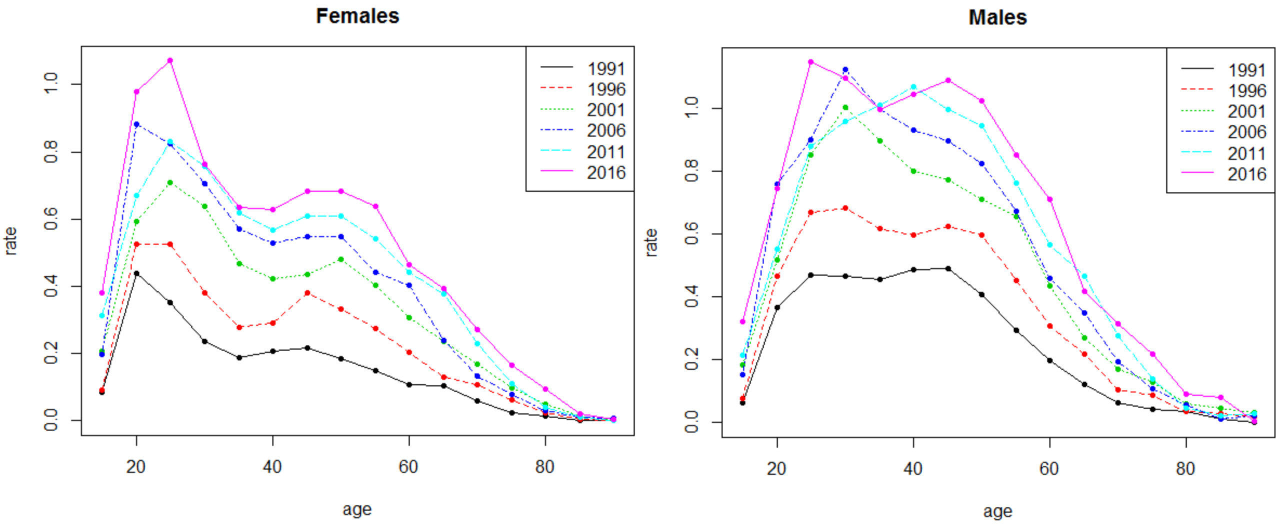

Fig. 2 and 3: rates for females and males by age and period

3.2 Output from three APC models

In Appendix 2 we present the estimates for the three APC models: total, women and men. For each model the estimates and the standard errors are provided. The estimates are strongly significant for virtually all parameters. This follows from the fact that it is weighed on the number of persons per cell; it is assumed that the data for the entire population is known. In reality this is not the case. The sample from Schiphol is only a small sample out of the necessity, on average every person surveyed in the Schiphol sample represents 250 people.

A summarization of the performance of the model is provided in Table 1. It can be seen that we used the same specifications for all three models: a Poisson model with log-link where the logarithm of the population numbers serve as offset. All three models are also converged in 4 different iterations. The considerable difference between the null and final deviance indicates a nearly perfect fit. This is hardly surprising as we used an extensive full factorial model with 39 parameters.

The deviance tables that provide the goodness-of-fit of several APC models suggest that for there are superior models available for all three estimated models. This means that we can select a model from the large family of APC models that will have a lower final deviance in relation to the amount of parameters. However, the suggested superior models differs for each estimated model.

Furthermore, we should not place too much importance on the deviance (Carstensen, 2007). That is why we chose to stick to a generic approach.

Table 1: Model performance of three APC models

	ALL	**Men**	**Women**
APC model	Poisson (log-link) with log(pop) as offset		
coefficients	39	39	39
aic	165411	97903	105835
null deviance	35365524	13931505	23404310
final deviance	164069	96613	104568
iterations	4	4	4

The output of the general APC model is in line with our prior expectations based on the literature and the descriptive plots (Appx. 2; Fig. 4). The propensity to fly (using Schiphol) peaks in the age group 25-30. The propensity to fly declines rapidly in age groups above 70.

In terms of the scope of the rates, cohort effects are the least impressive; the differences are smaller than for age and period. There do seem to be some differences between the cohorts. Extreme values can be seen in the oldest and youngest cohorts. This is where the model is least reliable because of the small sample size. The propensity to fly peaks for the generations born just after the Second World War. This is a remarkable observation. The generations born between 1980 and 1990 seem to fly relatively less. It is possible this is a result of the recent financial crisis. We expect that the propensity to fly of that generation will be adjusted upward soon.

The periodic development shows a strong and continuous growth from 1991 onward. The arc in the plot (Fig. 4) is mostly caused by the change in scale on the Y-axle. The references in the plot are chosen in such a way that they are on the same level. This improves the readability.

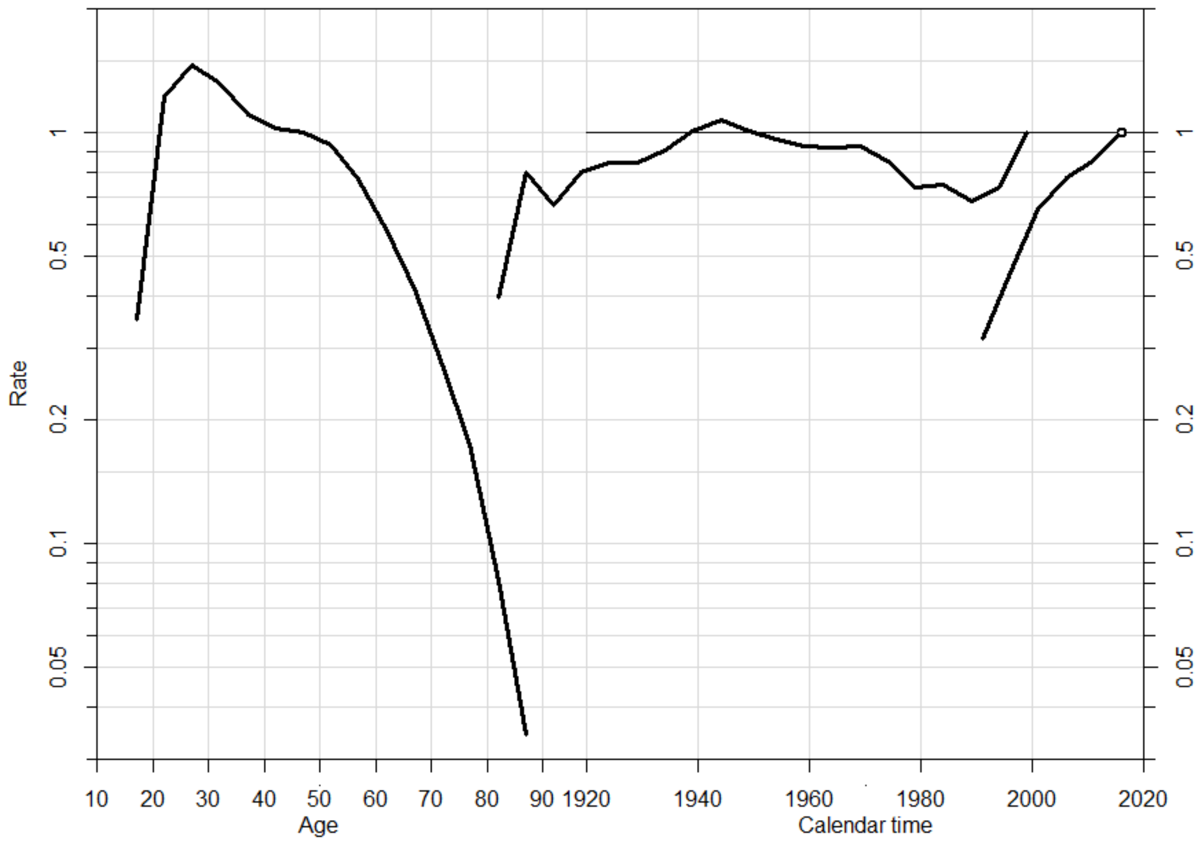

Fig. 4: output from the general APC model with the age, cohort and period effect combined in one plot. Note: reference point for the cohort is 1999, reference point for period is 2016.

Regarding the models for males and females we can conclude the following (Appx. 2; Fig. 5). Females tend to fly at a younger age. The age group 20-25 is the only group where females fly more than males. At 25 years and older men fly more. The propensity to fly also peaks at an earlier age for females compared to males. For females the peak is placed in the age group 25-30. For men this is 30-35. The drop at around age 40 in the combined picture is almost exclusively caused by the lower propensity to fly of females in that age group.

In terms of cohorts we see that the patterns for males and females are more or less the same. This fits with the notion that cohorts have limited added value in the analysis. The seemingly substantial differences in the plot are mostly caused by the fact that we used the generation of 1999 as a reference.

Looking at the period we can see a strong and continuous growth for both males and females. The growth for females is remarkably stronger. Between 1991 and 2016 the propensity to fly for males grew by a factor of 2.5. For females with a factor of 3.5. If this trend continues the propensity to fly for females will be the same as for males soon.

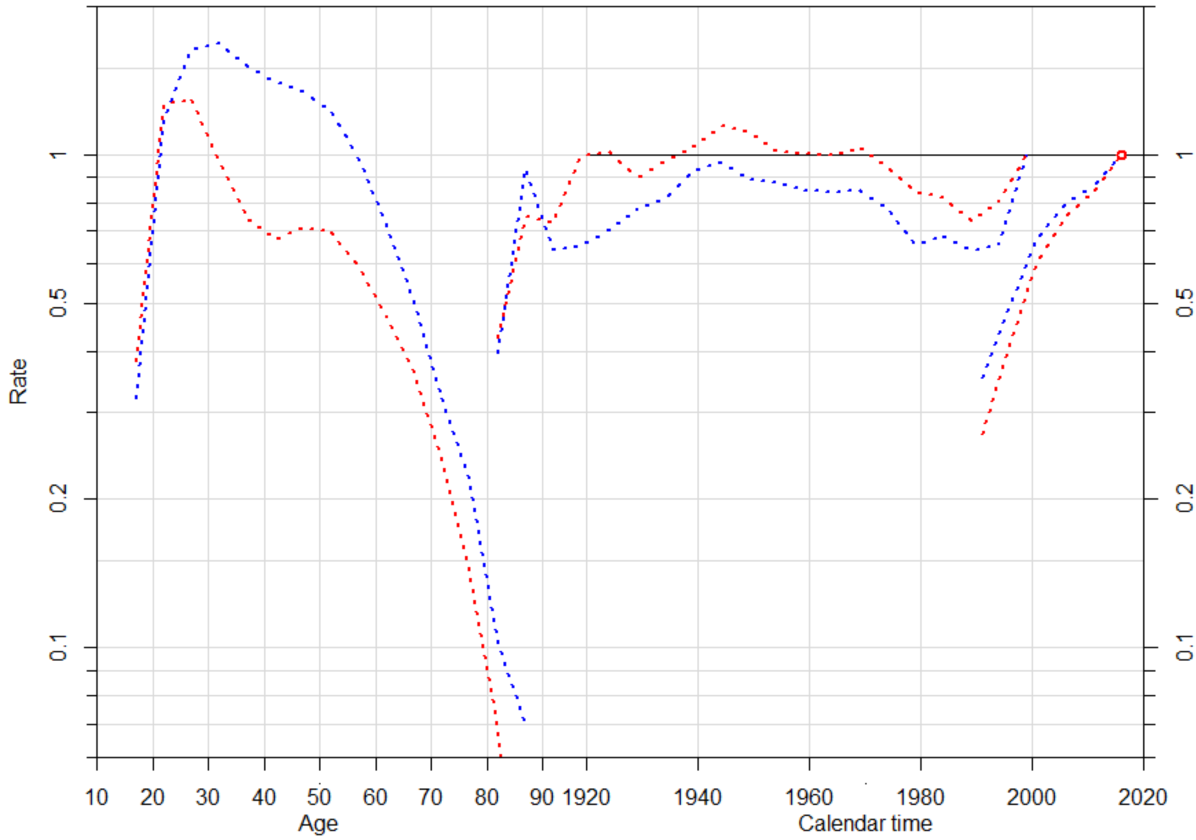

Fig. 5: output from the APC model for women and men. Note: reference point for the cohort is 1999, reference point for period is 2016. Male is blue and female is red

3.3 The potential of the APC model for travel purpose

The exploratory application of the APC model turns out to offer useful insights. That is why we want to study if analysis also including motive to fly will provide even more insights into the propensity to fly. The Schiphol survey has the extra data available for this expansion in scope. For illustrative purposes we use the year 2011 as an example.

The below graphic displays the propensity to fly rates for the different motives the Dutch population that flies from Schiphol have (Fig. 6). This shows that the age groups 20-25 and 25-29 have the highest mobility for *Leisure* (LEI) and *Visiting Friends and Relatives* (VFR) reasons.

Another conclusion is that young females most often fly for leisure and visiting friends and family reasons and that from age group 30 and upwards there are almost no differences with males. The biggest difference is in business travel: females go on business trips significantly less than males. Regarding business travel, the mobility is highest among males in the 40-45 age group.

We suspect that the age profiles can provide a better insight into the background of the mobility by sex and age group. Because business mobility is linked to the employed period in someone's life. We also expect that business mobility has developed different in time (period effect) than the two other motives. Business mobility can possibly be correlated to the volume of worldwide trade (CPB, 2016).

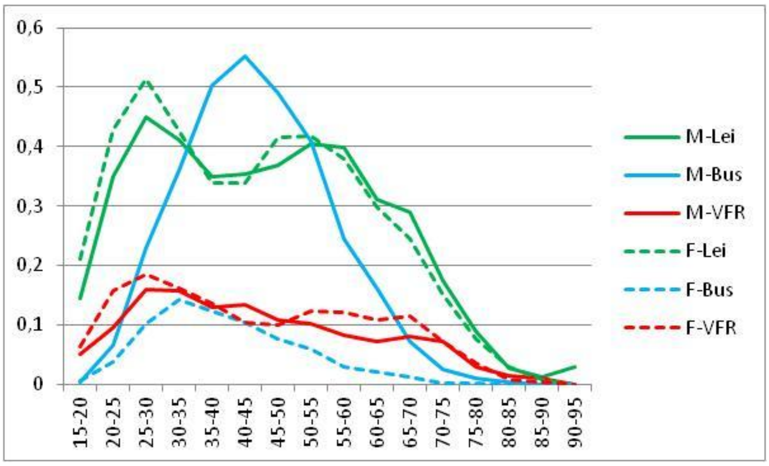

Fig. 6: Travel purposes for female and males at Schiphol airport in 2011. Notes: M is Male; F is Female; Lei = Leisure; Bus = Business; VFR = Visiting Friends and Relatives.

5. Discussion and Conclusions

The goal of our study was to get a better picture of the propensity to fly of Dutch people and additionally to answer the question if the APC model is useful for this purpose. For this we used passenger data provided by Schiphol and combined them with Dutch population figures by sex and divided into five-year age groups from the period 1991 to 2016.

Regarding the results, we can conclude that the age group between 20 and 30 years shows the highest propensity to fly. For females the propensity to fly between the ages 30 and 45 is relatively low compared to males or different age groups. A possible explanation for this is females in this age group having and being responsible for young children. An additional explanation can be found when looking at the reasons for travel. In the age group where business travel peaks, females are heavily underrepresented on business flights. At age groups older than 65 or 70 the propensity to fly strongly declines until almost zero for ages 90 and older.

The results for both the very youngest and very oldest cohorts in our data are surrounded by uncertainty due to a small sample size. For the cohorts we do have enough data for we can make two interesting observations. The first is that baby boomers, people born just after the Second World War, have an above average propensity to fly. The second one is that people born in the period between 1980 and 1990 have a relatively low propensity to fly. We attribute the latter to the recent economic crisis. Just when the propensity to fly should have peaked among this group, people were worried about their job, their income and their future. The increase of leisure flights from regional airports is another possible explanation, as those flights are not included in our data.

In the period between 1991 and 2016 there was a strong growth in the aviation sector and this can be seen in the results of our model. We see a stronger growth for females than for males. It's possible this will mean that the differences between males and females regarding the propensity to fly will be reduced to zero in the short term. However, especially in relation to business travel there is still a big gap to bridge.

Regarding the usefulness of the APC model for the analysis of the propensity to fly we can draw the following conclusions. We are generally satisfied about this instrument. The model was able to reveal patterns that could not be seen in the dataset without any assistance. This is an important advantage, especially once we will expand the dataset. The descriptive and model-based plots that are provided as standard with the APC software offer attractive visualizations of the data. This benefits the legibility. The reading of the plot is also very intuitive.

For now the APC models also have a few drawbacks. The language used is not very suited for our field of expertise. This increases the risks of communication errors. The standard APC models assume a maximum of one event per person among the population. From an epidemiological viewpoint this makes sense; a person can only be diagnosed with cancer once, and they will only die once. In our case it is possible that one person takes several flights a year. As a result, the distribution of the propensity to fly on the biggest scale remains unclear. Does every person in the age group 50-55 fly once per year or does 50% fly twice and year and 50% not at all? A question such as that cannot be directly answered, but the distribution between males and females can offer more of a clue however. Furthermore, as scientists we feel the need to explain occurrences, not just describe them. The use of the APC model is therefore mostly an interesting first step in the analysis process.

The APC models we used for this paper displayed a remarkably good model fit. This is mainly a result of the overfitting of the data. There were a significant amount of parameters in relation to the available data. This is a direct result of the utilization of a full factorial model. Simplification of this model in this regard seems sensible. Firstly because period, cohort and age are not categorical variables, primarily they can be understood as continuous variables. The current approach also gives little credit to the model as a simplification of reality. An additional advantage from an alternative approach using lines or splines is the possibility to extrapolate trend lines. These trends in combination with the Dutch population forecasts make it possible to use the APC model to predict the future propensity to fly.

We expect to continue our research with additional years from the Schiphol datasets and we will add travel purpose to the equations. In the process we aim to reduce the numbers of parameters used. As a result we hope to present forecasts based on the extended and simplified versions the APC-model[1].

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[1] Researchers interested are invited to contact the authors toon.zijlstra@minienm.nl or hugo.gordijn@xs4all.nl

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Appendix 1: Summary of data used

Table A.1: Rates for male air travelers via Schiphol

Age group	1991	1996	2001	2006	2011	2016
15 to **20**	0,06	0,08	0,18	0,15	0,22	0,32
20 to **25**	0,37	0,47	0,52	0,76	0,55	0,75
25 to **30**	0,47	0,67	0,85	0,90	0,88	1,15
30 to **35**	0,47	0,68	1,00	1,13	0,96	1,10
35 to **40**	0,46	0,62	0,90	1,00	1,01	1,00
40 to **45**	0,49	0,60	0,80	0,93	1,07	1,05
45 to **50**	0,49	0,63	0,77	0,90	1,00	1,09
50 to **55**	0,41	0,60	0,71	0,83	0,95	1,03
55 to **60**	0,29	0,45	0,66	0,67	0,76	0,85
60 to **65**	0,20	0,31	0,43	0,46	0,57	0,71
65 to **70**	0,12	0,22	0,27	0,35	0,47	0,42
70 to **75**	0,06	0,10	0,17	0,19	0,28	0,32
75 to **80**	0,04	0,09	0,13	0,11	0,14	0,22
80 to **85**	0,04	0,04	0,06	0,06	0,05	0,09
85 to **90**	0,01	0,03	0,04	0,01	0,02	0,08

Table A.2: Rate for female air travelers via Schiphol

Age group	1991	1996	2001	2006	2011	2016
15 to **20**	0,08	0,09	0,21	0,20	0,31	0,38
20 to **25**	0,44	0,52	0,59	0,88	0,67	0,98
25 to **30**	0,35	0,52	0,71	0,83	0,83	1,07
30 to **35**	0,24	0,38	0,64	0,71	0,76	0,76
35 to **40**	0,19	0,28	0,47	0,57	0,62	0,64
40 to **45**	0,21	0,29	0,42	0,53	0,57	0,63
45 to **50**	0,22	0,38	0,43	0,55	0,61	0,68
50 to **55**	0,18	0,33	0,48	0,55	0,61	0,68
55 to **60**	0,15	0,28	0,40	0,44	0,54	0,64
60 to **65**	0,11	0,20	0,31	0,40	0,44	0,46
65 to **70**	0,10	0,13	0,23	0,24	0,38	0,39
70 to **75**	0,06	0,11	0,17	0,13	0,23	0,27
75 to **80**	0,02	0,06	0,10	0,08	0,11	0,17
80 to **85**	0,01	0,02	0,05	0,03	0,04	0,09
85 to **90**	0,00	0,00	0,01	0,01	0,01	0,02

Appendix 2: APC model estimates

		All		Men		Women	
Cat	Label	est.	s.e.	est.	s.e.	est.	s.e.
Age	*Base*	-2,947	0,008	-2,660	0,010	-3,995	0,012
	15 to 20	1,899	0,007	1,524	0,009	3,032	0,012
	20 to 25	3,180	0,007	2,825	0,009	4,233	0,011
	25 to 30	3,387	0,007	3,154	0,009	4,252	0,011
	30 to 35	3,315	0,007	3,183	0,009	3,972	0,011
	35 to 40	3,170	0,007	3,071	0,009	3,695	0,011
	40 to 45	3,121	0,007	3,003	0,009	3,604	0,011
	45 to 50	3,134	0,007	2,954	0,009	3,655	0,011
	50 to 55	3,097	0,007	2,864	0,009	3,637	0,011
	55 to 60	2,933	0,007	2,652	0,009	3,481	0,011
	60 to 65	2,672	0,007	2,335	0,009	3,237	0,011
	65 to 70	2,379	0,007	1,972	0,009	2,971	0,011
	70 to 75	1,982	0,007	1,524	0,009	2,574	0,011
	75 to 80	1,565	0,007	1,151	0,010	2,055	0,011
	80 to 85	0,837	0,008	0,379	0,010	1,315	0,012
Period	*Base*	0,035	0,000	0,040	0,000	0,051	0,000
	1991	-0,384	0,002	-0,332	0,003	-0,465	0,003
	1996	-0,169	0,002	-0,138	0,002	-0,217	0,003
	2001	0,030	0,001	0,042	0,002	0,009	0,002
	2006	0,054	0,001	0,056	0,001	0,050	0,001
Cohort	*1904*	4,908	0,058	6,963	0,079	3,167	0,089
= P - A	*1909*	5,303	0,039	7,406	0,057	3,520	0,054
	1914	4,809	0,036	6,614	0,053	3,287	0,049
	1919	4,688	0,033	6,219	0,049	3,379	0,045
	1924	4,435	0,031	5,878	0,046	3,189	0,042
	1929	4,127	0,029	5,560	0,042	2,856	0,039
	1934	3,886	0,026	5,187	0,039	2,727	0,036
	1939	3,687	0,024	4,902	0,036	2,582	0,033
	1944	3,447	0,022	4,533	0,033	2,466	0,030
	1949	3,076	0,020	4,037	0,029	2,224	0,027
	1954	2,721	0,018	3,604	0,026	1,926	0,024
	1959	2,382	0,016	3,152	0,023	1,702	0,021
	1964	2,066	0,013	2,734	0,020	1,483	0,018
	1969	1,768	0,011	2,325	0,017	1,301	0,015
	1974	1,370	0,009	1,824	0,013	1,004	0,012
	1979	0,920	0,007	1,244	0,010	0,670	0,009
	1984	0,626	0,005	0,863	0,007	0,438	0,007
	1989	0,232	0,003	0,380	0,004	0,112	0,004