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The effect of urbanization on car ownership

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Abstract

The Netherlands is a small and densely populated country. Still, there are large differences between the population density in large cities and rural areas. In cities, all amenities are nearby and there is often good access to public transport. This could therefore affect the likelihood that someone needs to own a car. That is why in this paper, the effects of urbanization on car ownership were tested. Using datasets on car ownership by municipality for 2019, 2020 and 2022, linear regression analyses were used to form models that revealed a significant effect of the level of urbanization on car ownership. People who live in more rural areas are more likely to own a car than people who live in cities. Additionally, income and living in the Randstad, a large urban area made up of the country's largest cities, also produced significant results, albeit very small. Living distance from the nearest train station was also tested: this did not have a significant effect on a person's likelihood of owning a car. The results produced in this research could help the Dutch government to learn more about what affects car ownership in the Netherlands.

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1. Introduction

Purchasing a car is an important milestone for most people in our society. Having worked hard to save up for one, owning a car is a token of success to many people. However, the world needs to reduce its greenhouse gas emissions and one way to achieve this is to use more environmentally friendly means of travel. Whilst electric cars are better for the environment than combustion engine cars, they too are far from carbon neutral: electric cars driving on energy generated from environmentally friendly sources emit on average 70% less CO2 than conventional cars, while electric cars driving on non-environmentally friendly generated energy emit on average only 30% less CO2 than combustion engine cars (TNO, 2015). This means car usage in general should decrease. One more environmentally friendly travel mode is public transport. The Netherlands is a very small country with a high population density, which means it has high potential for having a good public transport system.

Like many countries, people in the Netherlands are moving to cities, or their vicinity. Cities and small towns around them are growing, while some less urban areas in the country are decreasing in population or growing less quickly (CBS, 2023). This increases the population with easy access to alternative transport modes. However, public transport availability is not the only factor at play: career choices also affect car ownership. Jorritsma et al. (2014) find that a growing population of young adults who follow higher education instead of work partially explains reduced car ownership among this group, because students have less money to spend than people who are employed.

Some researchers have concluded that the digital age plays a role as well. However, whether the increasing importance of the e-society for young adults affects the decrease in car ownership as well is not definitive. Jorritsma et al. (2014) are not convinced, but Sivak and Schoettle (2012) argue exactly that: they claim that the increasing online presence young people have nowadays is reducing the need for real-life encounters.

The structure of this paper is as follows:
First, the research question will be posed, accompanied by relevant literature. Subsequently, the dataset will be dissected with a descriptive analysis, after which a linear regression model will be presented that attempts to explain car ownership in The Netherlands by levels of urbanization. This base model will be expanded upon with additional variables. The results of the regression analyses will be explained, together with relevant literature. Finally, potential future research will be elaborated on.

2. Background

2.1 Literature and research question

As stated, whether a person decides to purchase a car can be attributed to many different factors. Apart from level of urbanization, there are other variables that are presumed to affect the likelihood of car ownership as well.

Economic situation

Firstly, economic changes such as income may have an effect. Clearly, a higher income gives a person the ability to afford the luxury of owning a car, which a person with a low income may not have. Additionally, Dargay (2001) did analysis on an annual survey about expenditures among some 7000 households in the UK between 1970 and 1995. She found that as income rises, people tend to buy cars, but as income falls, they do not tend to get rid of them. She concludes that there is hysteresis in the correlation between car ownership and income: the car is bought as a luxury but soon develops itself into a necessity making it difficult to live without. Sometimes this happens even when the person has serious financial problems and the costs of owning a car only exacerbate these issues, according to Curl et al. (2018). In this research, data from a survey performed in Glasgow between 2006 and 2011 on car ownership and income were gathered. Curl et al. conclude that people who face financial problems hesitate to sell their car, and sometimes even see ownership of a car as a necessity to improve their circumstances. The researchers conclude that public transport services must be inadequate in the areas these people live in, forcing them to own a car even though they practically cannot afford one.

Previous ownership

Nolan (2010) finds that previous car ownership can also affect current car ownership. She uses panel data on Irish households between 1995 and 2001 to conclude that, in accordance with Dargay (2001), it is difficult to get rid of a car once a person is used to owning one. A person who has owned a car before in his life is likely to keep owning one.

Built environment: population density and public transport

Residential environment can also affect a person's likelihood of owning a car, say Dieleman et al. (2002): in their research in the Netherlands using the National Travel Survey, they conclude that people living in more urbanized areas are less likely to own a car because this involves, among others, easier access to more public transport modes. People living in rural areas often have no other option but to own a car. This is why the researchers conclude that if the government wants to reduce car use as much as possible, a good urban transport system in rural areas would be necessary. This would be very expensive because of the large surface area it would have to cover and is therefore unlikely to become reality.

Shen et al. (2016) used data they gathered from a survey in 2010 and 2011 in four different neighbourhoods in the city of Shanghai, China, to do several findings: the proximity of living to a metro station has a positive effect on the number of people who use that mode as their primary means of transport. Additionally, they found a positive association between population density and the likelihood of people commuting by metro. However, they found no significant correlation between population density and car ownership. Thus, this study seems to suggest that people who live in an area where owning a car is not a necessity still own one.

The effect of public transport availability seems to be larger for the younger generation (18-30): Hjorthol (2016) analyses data from the Norwegian Nation Travel Survey from 1985 until 2009 and finds that young people in Norway living in large cities with good access to public transport are less likely to own a car than people living in rural areas with little or no access to public transport. Public transport is not the only mode to become more popular when automobile usage declines: According to Kuhnimhof et al. (2011), walking and cycling trips are likely to increase as well. Using survey data from the 1970s until 2011 in the UK and

Germany, this research shows a decrease in car use among young adults in the late 2000s compared to the beginning of the millennium. This decrease in car use was not only accompanied by more public transport travel: walking and cycling travel rose as well.
The trend is not limited to Europe, though: the United States, a large country where the car is seen as an essential transport mode, is now also witnessing a decrease in driver's licenses obtained among young adults (Thigpen & Handy 2018).

These preferences are different for people in developing countries: in 2013, Belgiawan et al. (2014) conducted a survey among university students in the following countries: China, Indonesia, Japan, Lebanon, Netherlands, Taiwan, and the USA. They found that young people in developing countries are more likely to desire owning a car than those in developed countries. China was also one of those countries. Although China is considered fairly developed with a Human Development Index (HDI) of 0.768 (with the world average being 0.732 and the Netherlands being at 0.941 (United Nations Development Reports, 2021)), there is more research that confirms that car ownership is not higher in rural areas in China. Zhao & Bai (2019) concluded the same and assumed this to be attributable to the income differences in rural areas compared to urban areas: China has large rural areas where the average income is much lower than in cities. While the average disposable income in the Netherlands is also higher in cities than in rural areas (De Vries, 2005), the difference is not nearly as large as in China (Zhang, 2021). Income plays a larger role on car ownership in countries that are not as developed as the Netherlands, because there are relatively more people who cannot afford one. The presumption is therefore that the results of this paper will entail that income has a significant effect on car ownership, but not to such an extent as in China where it seems to negate the effect of urbanization on car ownership.

Education

Lastly, Kuhnimhof et al. (2011) also conclude that a higher level of education plays a role in the decreasing car dependence for young people. They state that higher education causes young people to:

- Live in more urbanized areas;
- Enter the job market later in life;
- Start a family later.

Thus, economic situation, previous ownership, built environment and education are several potential factors that can affect car ownership. The focal point of this research is the built environment, leading to the following research question:

2.2 Research question

Does the level of urbanization a person lives in affect his likelihood of owning a car?

2.3 Relevance

The Dutch government is focused on reducing CO2-emissions in the future. To accomplish this goal, a climate agreement has been entered into which was signed by more than 100 Dutch governmental agencies, companies and NGOs. This agreement obliges the participating actors to reduce total CO2-emissions in the country by 49% by 2030, and by 95% by 2050. One way of reaching this goal is to reduce emissions by automobiles. The country is already making good progress in that sector: in 2021, less than 3.4% of all CO2 emissions were caused by travel by land (CBS, 2022). This includes train travel as well; thus automobiles were responsible for even less than that. Moreover, in 2020 the Netherlands had

the lowest CO2-emissions per new car of all European countries (ACEA, 2023). Still, there is always progress to be made. Whilst the government is trying hard to make people purchase electric cars, even these are not completely climate neutral (TNO, 2015). It would therefore be more beneficial for the environment if there were fewer cars altogether. As stated in the literature, there is evidence that more urban environments can reduce car ownership and this will either be confirmed or denied after this research. It is therefore in the interest of the government to investigate whether urban planning could be a viable way to help accomplish its climate goals.

3. Data and methodology

3.1 Data source

As the literature quoted above claims, there are many possible reasons for people living in more urban areas to sell their car or refrain from purchasing one. This hypothesis will be tested using data gathered by the Central Bureau for Statistics (CBS), The Netherlands' government-run data collecting agency. This includes a dataset containing the number of cars owned per municipality paired with an urbanization score. This dataset has been merged with another data set containing the population and number of cars registered in every municipality, allowing for an average number of cars owned to be calculated. Data on the number of households instead of population was deemed more suitable for this research, but such data was not available and therefore not possible. Additionally, data was added on every municipality's average disposable income along with the average distance to a train station.

The data collected covers the years 2019, 2020 and 2022. The year 2021 is not included because of a lack of accessible data.

Certain data were not used: the municipality of Almere has an abnormally high number of cars registered: in 2022, more than 257,000 cars were registered in this municipality. Since Almere has a population of only 224,000 (municipality of Almere, 2023)[1], this abnormality can be attributed to the large car leasing companies which are based in this city, meaning all the cars they own are also registered in that city. Cars registered in that city are therefore not necessarily owned by its inhabitants. For the sake of accuracy, this municipality has been removed from the dataset.

Also, average disposable income data for the year 2022 was unavailable: this means that for the regression model including income as a variable, the same model was used as in the other regressions, except that the data for the year 2022 were omitted.

3.2 Variables

Not every variable used in the manipulation of the datasets will be named; only the variables that require additional explanation or context for understanding the research are listed below.

Urbanization score

Every municipality has been assigned an urbanization score, ranging from 1 to 5. This score is based on the number of addresses per square kilometer in that municipality:

[1] https://www.almere.nl/over/aantal-inwoners-almere

1. Very high urbanization: average address density of 2,500 or more addresses per square kilometer
2. High Urbanization: average address density of 1,500 to 2,500 addresses per square kilometer
3. Moderate urbanization: average address density of a 1,000 to 1,500 addresses per square kilometer
4. Low urbanization: average address density of 500 to a 1,000 addresses per square kilometer
5. Very low urbanization: average address density of fewer than 500 addresses per square kilometer

Address density is calculated by counting all addresses within a one-kilometer radius from a random address and dividing this number by the surface of the area.

Randstad

The Randstad is an area made up of the four provinces Noord-Holland, Zuid-Holland, Utrecht and Flevoland. The region features four out of the five biggest cities and the highest population density in the country: nearly half the country's population lives in this area (Huis van de Nederlandse Provincies, n.d.). This has caused the cities in the Randstad to be interconnected very well in terms of public transport, which could affect the inhabitants' likelihood to refrain from buying a car.

Average number of cars per person

Because large cities have more inhabitants than smaller cities, there will naturally be more cars too. It is therefore not useful for this research to compare the absolute number of cars in the municipalities: the average number of cars per person will be compared.
To calculate this, the total number of cars per municipality has been divided by the number of people living there.

Average distance to (transfer) train station

The average distance from a train station, along with the average distance from a transfer station are taken into the model. These distances could play a role in one's willingness to use public transport instead of the car, because the time it takes to reach a train station is of great influence on a person's commute.

3.3 Data validity

Multicollinearity

The data must be tested for multicollinearity: if this were to be present, the independent variables would be too highly correlated. This would affect the interpretability of the coefficients from the analyses, because the independent variables would not only affect the average number of cars, but also each other. It must therefore be confirmed that there is no multicollinearity, which can be done with a variance inflation factor (VIF) test.

Table 1: VIF test for 2019-2020-2022 data

VIF values (income not included)	
Variable	VIF
Urbanization score	
2.	3.86
3.	4.07
4.	5.28
5.	3.69
Randstad	1.25
Distance train station	1.76
Distance transfer station	1.78
Mean VIF	3.10

Table 2: VIF test for 2019-2020 data

VIF values (income included)	
Variable	VIF
Urbanization score	
2.	4.23
3.	4.99
4.	6.63
5.	4.56
Randstad	1.58
Distance train station	1.87
Distance transfer station	2.03
Disposable income	1.52
Mean VIF	3.43

The highest VIF value in both tables is 6.63: all others are lower. A VIF value is considered problematic when it exceeds 10 (Vittinghof et al., 2005), thus the test gives no reason to assume multicollinearity between the independent variables.

4. Descriptive analysis

4.1 Dataset analysis

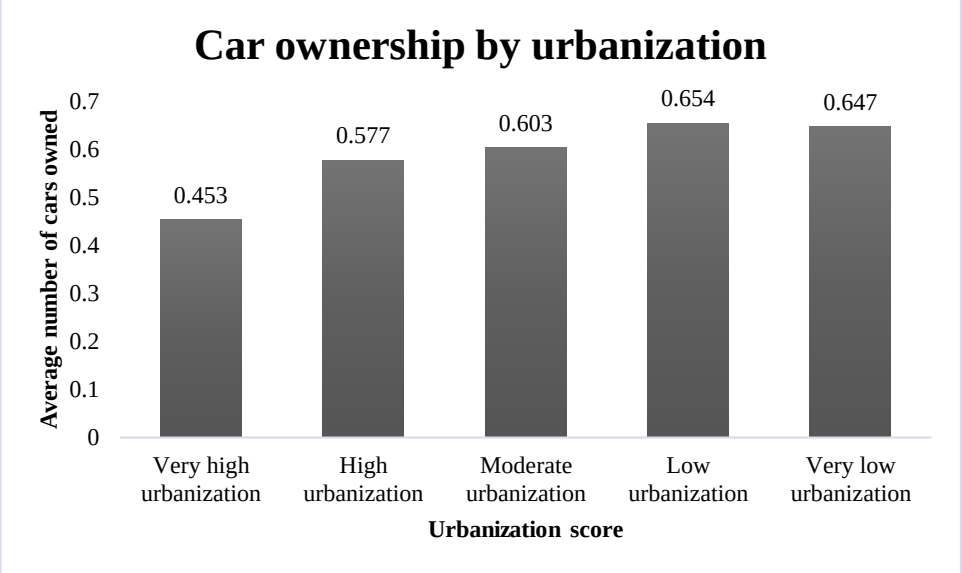
Descriptive analysis of the data shows that on average 61% of a municipality's inhabitants own a car. The average municipality features an urbanization score of 3.2, so the distribution of urbanization is not skewed to one side. There are a few municipalities with either very high or very low urbanization, but most are placed somewhere in between.

Moreover, while very highly urbanized municipalities account for less than 6% of all municipalities, they contain almost 24% of the country's inhabitants. This can be explained by the fact that highly urbanized municipalities are usually also the largest and therefore, while they are few in number, do encompass a large part of the population.
The opposite of this effect is visible in the lowest urbanization level: this group accounts for a relatively large part of the municipalities compared to its small population size.

Table 3: Data characteristics 2019-2020-2022

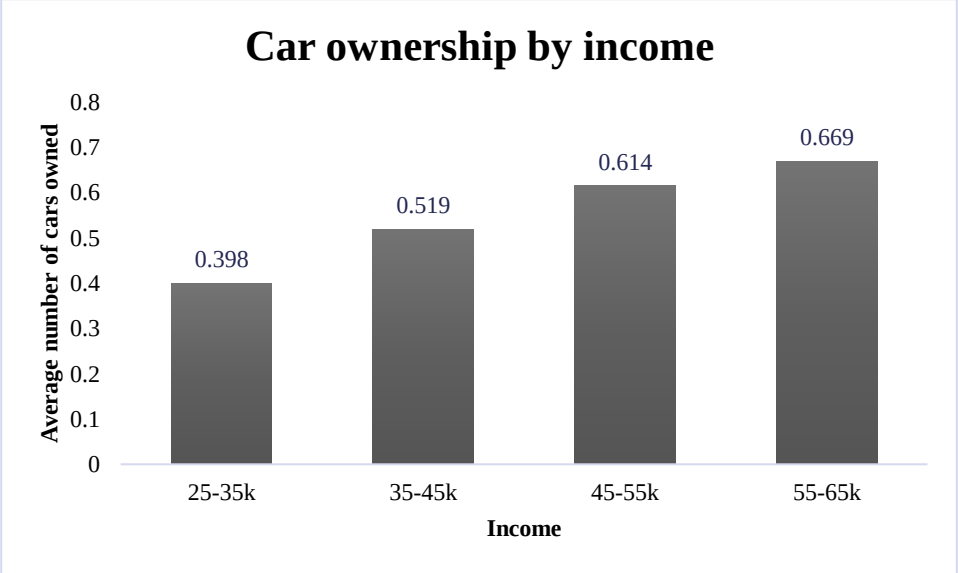
Data characteristics			
Averages	**2019**	**2020**	**2022**
Passenger cars per municipality	21,768	22,113	23,192
Population per municipality	40,438	39,958	40,834
Number of cars per person	.59	.61	0.63
Urbanization score	3.29	3.27	3.23
Distance to nearest train station (km)	7.04	7.04	7.03
Distance to nearest transfer station (km)	16.38	17.38	16.12
Municipalities per urbanization level (%)			
1. Very high urbanization	5.39	5.72	6.62
2. High urbanization	22.90	22.90	23
3. Moderate urbanization	22.56	22.90	23.34
4. Low urbanization	35.69	35.69	35.19
5. Very low urbanization	13.47	12.79	11.85
Population per urbanization level			
1. Very high urbanization	2,707,749	2,817,950	2,929,636
2. High urbanization	4,107,530	4,027,998	3,941,177
3. Moderate urbanization	2,095,929	2,058,079	1,966,741
4. Low urbanization	2,432,856	2,297,844	2,284,216
5. Very low urbanization	665,879	665,594	597,573

Graph 1: Average car ownership by level of urbanization



Graph 1 shows that the average number of cars owned in the data increases for higher urbanization scores. The trend does not hold for the most rural municipalities: the average number of cars owned is slightly lower than that in the category before it. Still, the data seem to point towards an effect of urbanization score on car ownership, as presumed.

Graph 2: Average car ownership by income



Graph 2 shows that the average number of cars owned in the data also increases with income. The difference is quite significant: a person with an income between EUR 55,000 and EUR 65,000 is 68% more likely to own a car than a person with an income between EUR 25,000 and EUR 35,000.

4.2 Additional descriptive data

Table 4 contains additional data on car ownership in the Netherlands. The data are from 2015, but nonetheless can give some context as to which variables might influence a person's likelihood of owning a car. For example, household size, income and level of urbanization appear to greatly affect this likelihood. It is likely that these variables are still significant in the present dataset for 2019, 2020 and 2022.

The table shows that the need for a car increases when a household has children. Additionally, the larger a household becomes in general, the more likely it is to own a car.

Income also seems to affect this likelihood materially: while 38% of the lowest income quintile owns a car, that percentage is nearly 93% for the highest income quintile.

The focal point of this research is the impact of urbanization on car ownership. Table 4 seems to show data that support this hypothesis: car ownership differs greatly between the levels of urbanization. While just over half of the households in very highly urbanized municipalities own a car, for the least urbanized municipalities this is almost 85%.

Table 4: Data characteristics additional 2015 dataset

Data Characteristics	
2015	Car owners (%)
Households	71,3
Type: one person household	45,1
Type: multiple person household	87,1
Type: one parent household	64,2
Type: couple, total	90,3
Type: couple, with child(ren)	93,6
Type: couple, no children	87,3
Type: multiple person household, rest	62
Household size: 1 person	44,9
Household size: 2 persons	83,9
Household size: 3 persons	87,2
Household size: 4 persons	93,3
Household size: 5 persons or more	91,4
Standardized income: 1st 20%-group	38
Standardized income: 2nd 20%-group	60,5
Standardized income: 3rd 20%-group	79
Standardized income: 4th 20%-group	88
Standardized income: 5th 20%-group	92,8
Standardized income: unknown	13,4
Very high urbanization	52,6
High urbanization	71,2
Moderate urbanization	79,6
Low urbanization	82,7
Very low urbanization	84,4

5. Regression analysis

5.1 Regression functions

To answer the research question, a linear regression model was constructed that only shows the correlation between urbanization level and car ownership.

$$average\ number\ of\ cars = \beta 0 + \beta 1 * Urbanization\ level + \varepsilon$$

In the second model, more variables were added in an attempt to give a broader view of what affects car ownership in general.

$$average\ number\ of\ cars = \beta 0 + \beta 1 * Urbanization\ level + \beta 2 * Randstad + \beta 3 * Distance\ to\ train\ station + \beta 4 * Distance\ to\ transfer\ station + \varepsilon$$

This attempt was expanded upon in the third model, where disposable income was also included. As stated in chapter 3.1, data on income for 2022 were unavailable and this year was therefore taken out of the dataset for the third model. Even though omission of the year 2022 means a smaller sample size than the other two models (nearly 35% smaller), disposable income was presumed to be too highly correlated with car ownership to not be incorporated in this research.

$$average\ number\ of\ cars = \beta 0 + \beta 1 * Urbanization\ level + \beta 2 * Randstad + \beta 3 * Distance\ to\ train\ station + \beta 4 * Distance\ to\ transfer\ station + \beta 5 * Average\ disposable\ income + \varepsilon$$

5.2 Regression models

Table 5: Regression analysis on the effect of urbanization level on car ownership

	(1)	(2)	(3)
Dependent variable: average car ownership	2019, 2020, 2022	2019, 2020, 2022	2019, 2020
Urbanization level			
(2)	.124***	.143***	.111**
	(.041)	(.041)	(.046)
(3)	.150***	.184***	.122**
	(.041)	(.042)	(.050)
(4)	.201***	.248***	.196***
	(.039)	(.042)	(.051)
(5)	.194***	.261***	.218***
	(.044)	(.051)	(.059)
Randstad		.062***	.046*
		(.021)	(.025)
Distance to train station		-.001	-.003
		(.001)	(.002)
Distance to transfer station		-.000	.001
		(.000)	(.001)
Average disposable income			.003**
			(.002)
Constant	0.453	.403	.260
Observations	881	881	580
R^2	.036	.047	.075

Note. Standard errors are in parentheses

*** p<.01, ** p<.05, * p<.1

5.3 regression results

The first model shows that urbanization and car ownership are significantly correlated. The higher the urbanization score (thus the lower the actual level of urbanization), the higher the average number of cars per person is. The average number of cars per person in the most urbanized areas is just over 45%, while this number is nearly 65% for the most rural municipalities. The R^2 value at 3.6% is quite close to zero, thus the variance of the average number of cars owned can only slightly be explained by the urbanization score. This means that urbanization score, although its coefficients are significant, plays a small role in explaining the dependent variable in the current model.

The second model builds on the first by including the following variables:

- Randstad;
- average distance to train station; and
- average distance to transfer station.

The latter two variables produced insignificant results: according to the current dataset, average living distance from a train station or a large transfer station do not affect one's likelihood of owning a car. This is in accordance with the previously stated Shen et al. (2016), who found no significant association between proximity to a train station and car ownership.

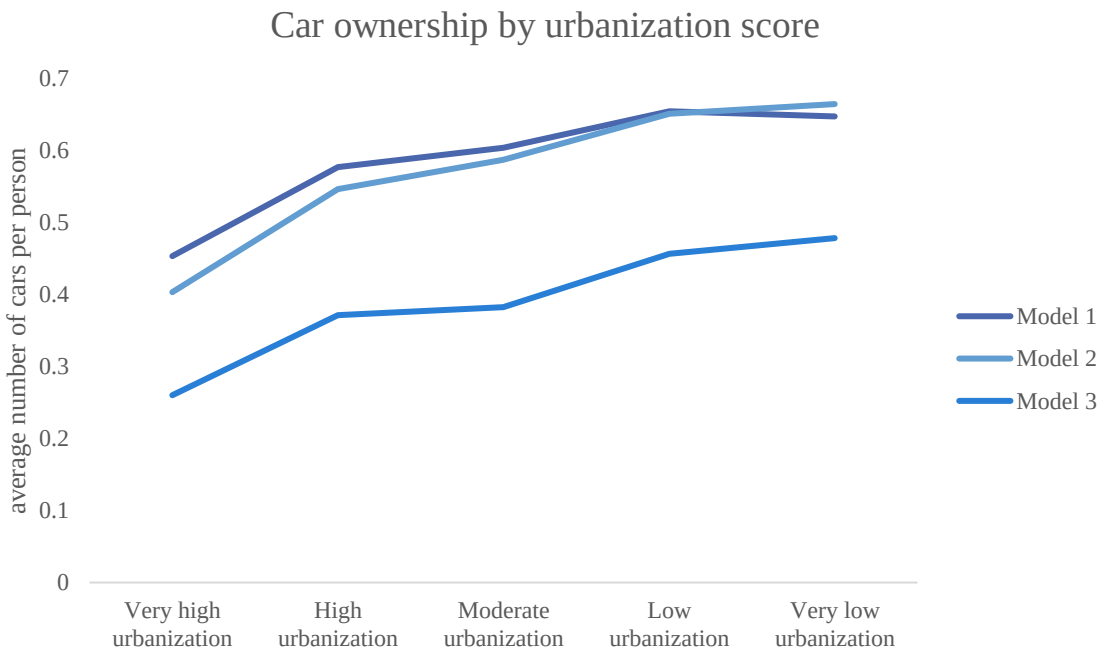
The Randstad variable does show significant results: people in the Randstad are 6% more likely to own a car. This contradicts the hypothesis that people in the Randstad would own fewer cars because of its high urbanization and extensive public transport. One explanation could be the fact that income is higher in the Randstad than outside of it: in the dataset, average disposable income in The Netherlands is EUR 49,500, while in the Randstad it is

EUR 52,500. Living in the Randstad could potentially not have a negative effect on car ownership because of good public transport, but instead a positive effect because of higher income. Therefore, average disposable income was included in the third model to investigate this.

While model 3 shows a statistically significant effect of average income, the effect is quite small. The results show a .003% increase in likelihood per EUR 1,000 of income. This means a household with an average income of EUR 49,500 is only .1485% more likely to own a car than a household with no disposable income at all. The coefficient of Randstad is smaller in the third model than in the second: it is possible that adding income as a variable is responsible for this, as was presumed. The R^2 is the largest of the three models at 7.5%. Although the added variables in Model 3 compared to Model 1 are either insignificant or barely have an effect, they do add to the explanatory value of the model, considering the model is able to explain over twice the percentage of values in the data as the first model.

Graph 3 shows that people living in more urban areas on average own fewer cars than people living in more rural areas according to the regression models. The largest difference is visible between very highly urbanized and highly urbanized for all models: the models feature a 27%, 35% and 43% increase respectively in this bracket. The difference is much smaller between low and very low urbanization, with a -1%, 2% and 5% difference respectively.

Graph 3: car ownership by level of urbanization from regression analyses



Overall, model 3 shows the largest increase in car ownership with the average in very highly urbanized municipalities being .26 and increasing to .478 in municipalities with very low urbanization (an 84% increase). This is a larger increase than visible in the dataset from table 4: the difference between very high and very low urbanization in that dataset is about 60 per cent.

The models feature quite significant results concerning the urbanization scores' influence on car ownership. The other variables encompass a smaller influence than presumed. For example: in the lowest income quintile from table 4 38% owns a car, while that percentage is 92.8% for the highest income quintile. One would therefore expect income to play a larger role in the average number of cars owned than realized in Model 3. It is possible that a variable exists that has an effect on a person's income and simultaneously influences his likelihood of owning a car, which was not incorporated in this research. For example, Bhat and Guo (2007) find that a location's built environment influences car ownership

significantly, while income in turn has an effect on a person's sensitivity to built environment attributes.

Furthermore, Belgiawan et al. (2014) and Belgiawan et al. (2017) find that social norms also have significant effect on one's likelihood of purchasing a car. A person's decision to buy or not to buy a car is influenced by his peers, especially parents and acquaintances. Additionally, according to Macfarlane et al. (2015) not only the current level of urbanization a person lives in, but also that of previous addresses can affect a person's preference to own more or fewer cars. Thus, a person who moves from a rural place to a large city is more likely to keep ownership of a higher number of cars because of the habit.

6. Conclusion and discussion

6.1 Conclusion

According to literature consulted, level of urbanization affects a person's likelihood of owning a car. Descriptive analysis of the data also suggests this effect. In this research, urbanization is therefore tested for its effect on said trend of car dependence. The analyses lead to the conclusion that urbanization plays only a tiny role in explaining the decreased ownership of cars: the relatively large coefficients could suggest there are one or more variables not incorporated in the models that influence average car ownership but are hidden under the coefficient for urbanization score. Additionally, income, living in the Randstad and living close to a train station do not explain a large portion of the data on car ownership either.

Still, the results from this research could be useful for the Dutch government to aid in its quest to reduce car ownership and**,** by extension, car use. Knowing what motivates people to own cars can help the government decide on which types of policies to consider. This is a contentious subject: while it would be beneficial for the country's climate goals to reduce the number of cars on the roads, it could also have a negative effect on the general welfare of the people if the country became even more densely populated than it already is (UN World Population Prospects, 2022) simply because of the effects it could have on car ownership. However, reducing distance between people's homes and amenities is considered an effective way to reduce car use. Making cities more walkable affects the necessity of people to own a car (Dieleman et al., 2002).

6.2 Discussion

In future research, leased cars should also be incorporated into the data. Considering more than 18% of all cars registered in the Netherlands in 2021 were leased (VNA, 2022), including this group would likely lead to more representative results.

Additionally, using the average number of cars per household instead of per person might produce more accurate results, because people often share a single car in their household. Due to unavailability of relevant data, this was not possible.

Also, average car ownership differs greatly not only between cities but within those cities as well. For example: the 30 neighbourhoods in Amsterdam with the lowest average income per person own 0.36 cars per person on average, while the 30 highest income-neighbourhoods own more than 0.77 cars per person. Furthermore, not every neighbourhood is equally densely populated either, so it is also not accurate to assign an urbanization score to a

municipality in its entirety. This leads to the conclusion that analysing entire municipalities could produce inaccurate results: research that considers individual neighbourhoods could produce a more complete insight into the influence of urbanization on car ownership.

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