Following America?
Dutch geographical car diffusion, 1900 to 1980
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Der erscheint mir als der Grösste,
der zu keiner Fahne schwört,
und, weil er vom Teil sich löste,
nun der ganzen Welt gehört.

(Rainer Maria Rilke)
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1 Introduction

This book is about the long-run, quantitative analysis of the Dutch car diffusion path set against the background of the American example. The US and the Netherlands appear to be very different in respect to car diffusion: one is the world leader, the other one is a comparatively small, European country. The car in the Netherlands had to compete against a long and well established tradition of both land transport and of inland shipping, and the Dutch car industry did not survive the international concentration of the industry. On the one hand the Netherlands is just one example of the European "laggards", and at the other end of the spectrum there is America, which was the forerunner in respect to Fordism, large-scale production, and consumer habits.

In the field of social car history, scholars have been puzzled by the fact that European countries have lagged behind the US when it comes to car diffusion. Thorough efforts to explain the European lag have been made on both qualitative as well as quantitative grounds.\(^1\) The available literature provides a rich picture of the structural differences between Europe and the US. In this literature, the penetration level expressed in the agglomerated diffusion curves of countries is taken as proof of the European lag. The differences and similarities between the long-run, geographical diffusion patterns between Europe and the US, however, have not yet been subjected to a systematic and comprehensive investigation. We do not know in which ways and in which periods European countries differed from the American example in respect to their geographical diffusion paths. Before one looks into this, there should be no doubt that the perceived lag is really of any long-run importance when car density figures are put in a broader context.

In this study we shall compare the nationally aggregated car diffusion curves of twenty countries, both European and Non-European, which include the US and the Netherlands. In order to take aspects of the diffusion environment into account, we further include two other modern transport modes in the comparison. Following this, we narrow our research down to a comparison between the US and the Netherlands. We

shall systematically investigate the claim that the US and the Netherlands showed diverse geographical diffusion paths. For this purpose, we repeat the comprehensive study on the long-run geographical diffusion path of the US as conducted by G. K. Jarvis in broad lines for the Netherlands. We shall show on quantitative grounds that the long-run diffusion paths of these two countries show numerous similarities as well as that a perception of the Netherlands as late in respect to geographical car diffusion is one-sided.

In the remainder of this chapter we shall place our study in the research tradition of social car history. We shall report on why the Netherlands was to be expected to display the delay in car diffusion in respect to the US, both on the aggregated as well as on the disaggregated, geographical level. Finally, we shall give an account of the structure and methods of this study.

1.1 The background

The sheer number of cars bought in the US before the Second World War is impressive in comparison to all other (European) countries and seems to tell an unambiguous story of the US' leading position in car diffusion. This is why diffusion graphs in books on car history take the possible form of fig. 1-1. a) to d), reproduced below:\(^3\)


\(^3\) e.g. Reiner Flik, "Von Ford lernen?", Automobilbau und Motorisierung in Deutschland bis 1933, (Köln: Böhlau, 2001). 4.
Fig. 1-1. Car diffusion in 21 industrialized countries\textsuperscript{4}

a) Anglo-Saxon countries

b) Southern Europe with France

\textsuperscript{4} Credit goes to Luisa Sousa, who has completed the data series used here.
These graphs show that the US had got a penetration rate of almost 200 cars per thousand inhabitants already in 1925 - a penetration rate, which most European countries did not reach before 1965.
The opposition between the US as leader and laggard Europe is a well-covered topic in social car history. We shall consider social car history a branch of transport history. The guiding questions in this kind of literature are: (1) what were the country-, time-, and technology-specific barriers to diffusion? (2) how did individuals and society overcome these diffusion barriers? and (3) who were the (first) users of cars? These guiding questions invited research on the first 30 years of diffusion. The questions clearly express an interest in the demand side of diffusion. The term social in social car history indicates that authors in this field are concerned about the societal conflicts, which were raised around the coming of the car, and that they look at agents that promoted or else rejected the integration of the car in society. It is puzzling why Europe, which was leading in car production before the turn of the twentieth century, fell back in the diffusion of the automobile in regard to the US after the fin de siècle. After all, cars were first invented, developed, and sold in Europe. When it comes to social car history, the reasons for the time lag between the US and Europe are to be found in the barriers to diffusion. Moreover, the lag can be explained with regard to the social processes through which the agents found solutions to the social conflicts, which emerged with the proliferation of the car. One might expect that the curiosity about the European time lag invited comparative studies, e.g. between one or more European countries and the US, however, such comparative studies have hardly been conducted. Instead, studies on individual countries are the convention. Exceptions are Christoph M. Merki’s comparison of Germany, France and Switzerland, and the comparison between the US and Germany by Reiner Flik. The choice to study a single country might be motivated by enthusiasm about the successful breakthrough of the car in one’s own country. The questions of why and how the technologically immature vehicle succeeded in finding a niche for itself in the transport market, despite of its numerous technical deficiencies, form another pillar in social car history. The gist of what has been written on the subject

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can be summarized by saying that structural differences between the US and Europe existed and that they caused the European lag. The character of the structural differences is further elaborated upon in the next section.

1.2 The US and the Netherlands in social car history

Out of all possible European countries, we chose the Netherlands for our geographical study, because it seems to fit the idea of a structurally different Europe very well. The choice then is really for a comparison between two seemingly different cases. A more practical consideration in the choice of country is that the Netherlands lends itself to a comparison with the US, because data about car diffusion exists for small geographical units, i.e. municipalities, and reaches back as far as the year 1900. In this section I shall deal with the image of the two countries, which we can draw from the literature.

1.2.1 The Netherlands as a motorization latecomer

The Netherlands can be regarded as one of the laggards within Europe. As Fig. 1-1. a) to c) shows, the Netherlands’ adoption level up to the Second World War was clearly lower than that of European leaders Great Britain and France. From the literature we can derive a lot of arguments which support the idea that the Netherlands was one of the laggards in car diffusion.

One structural difference between the laggard European countries and the US seems to be that taxes and fees related to car ownership and use were drastically lower in the US than they were in Europe. By this we mean costs such as fuel tax, car ownership tax, car insurance, or other types of contributions such as to the costs of parking space, or the building of roads. Flik argues that many of these costs are generally higher in highly urbanized countries than in relatively scarcely populated countries.

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serve to internalize negative externalities. Negative externalities are negative effects of social behavior, which the person who causes these effects does not pay as part of an economic exchange. Examples of negative externalities of car use are damage to roads, or to the health of others, or noise. In dense areas, these negative externalities can be felt much more intensely than in scarcely populated areas. The Netherlands has been one of the most densely populated countries in the world.\textsuperscript{10} We can expect that running costs in the Netherlands were particularly high and dampened car diffusion.\textsuperscript{11} Not only the overall population density, but also in particular the lack of scarcely populated areas, may have contributed to low adoption levels in the Netherlands. In the large, scarcely populated areas in the US with little or no public transport, people demanded cars in order to overcome their isolation. Some European countries, like Sweden or France, also possess vast hinterlands, while the Netherlands does not. We may assume that in the densely populated Netherlands this additional demand was lacking because of its well-developed public transportation systems.\textsuperscript{12} Since the car

\textsuperscript{10} In 1896, the Netherlands showed the second highest population density in comparison with Belgium, France, Germany, Italy, and Sweden. In 1911, this had become the case compared to Belgium, Denmark, Finland, France, Greece, Germany, Italy, and Great Britain. And in 1957, the Netherlands showed the highest population density of all countries used in the analysis in chapter 2, except for West-Germany (for which there is a lack of data). See list of sources for chapter 2.

\textsuperscript{11} There are other types of running costs which are not related to negative externalities, such as costs for chauffeurs, tires, and car reparation. We do not possess sufficient knowledge yet in order to judge whether Europe or the Netherlands were relatively expensive in this respect. Hiring chauffeurs instead of driving oneself was ostensibly a habit specific to the Netherlands and possibly other European countries. It is probable that many Americans saved on these costs. See Peter-Eloy Staal, "De diffusie van de auto in Nederland in de periode 1896-1976 vanuit een gebruikersperspectief," (Zutphen: Walburg Pers, 2003). 59-60.

could carry the function of reducing the sense of isolation, relatively low car adoption rates in the Netherlands may very well be expected. A further structural difference between the US and Europe is that European national states tended to conduct transport policies which protected the rail-bound transport modes against the competition from the road. Governments had invested in the building of infrastructure in the form of railways and therefore wished to protect them. This is a further reason why taxes and fees related to automobile ownership and use were higher in Europe than in the US. We may assume that car ownership taxes in the Netherlands were unusually high in the 1930s as a political reaction to the economic crisis and the financial losses of its national railway company.\(^\text{13}\)

1.2.2 Lag and abnormality in Dutch geographical car diffusion

Since scholars in social car history tend to believe that the structural differences between the US and the Netherlands caused their differences in the aggregated diffusion paths, differences between these two countries in respect to their geographical car diffusion may as well be interpreted as caused by these structural differences. We think that this assumption may very well lead us to overemphasize differences in the geographical car diffusion. However, there is in fact little known about geographical car diffusion in Europe. This is in stark contrast to what we know about the geographical car diffusion in the US. Thanks to Jarvis, we have quite a structured overview of geographical car diffusion in the US – at least on the fairly aggregated level of the American states.\(^\text{14}\) Furthermore, car diffusion in rural America has received rather a lot of attention in the American literature.\(^\text{15}\) Jarvis finds that until 1910 the urbanized states were leading in terms of car density in the US. In the period between 1910 and 1920,


the medium urbanized states took over the lead and remained in this position until the end of his observation period in 1969. The upswing of the car before the Second World War was due to its success amongst farmers in the Midwestern United States. The farming communities of the South did not participate in this growth and the proliferation of the car was much less abundant there. This diffusion pattern seems in strong opposition to the Dutch one, where the urban provinces were leading for a much longer period of time, namely until 1976. The empirical evidence for this seems unambiguous and is presented here in figure 1-2 and figure 1-3. The first graph shows the car density levels of five Dutch regions over time.

Fig. 1-2. Car diffusion in five Dutch regions, from 1957 to 1990

Northern provinces: Groningen, Friesland, Drenthe.
Eastern provinces: Gelderland, Overijssel.
Western provinces: Utrecht, Noord-Holland, Zuid-Holland.
South-Western provinces: Zeeland.
Southern provinces: Noord-Brabant, Limburg.

For a map showing the location of the Dutch provinces see figure 7-2 in appendix I.


There is a continual order till 1976. The West, which includes the most urbanized provinces Noord-Holland, Zuid-Holland and Utrecht, clearly held the lead until 1975 (the sudden shift that occurs in the graph in this year is due to registration changes). All other regions, rural or medium urbanized, follow at some distance: the South-Western province Zeeland first, followed by the North and East of the Netherlands. The Southern provinces of Noord-Brabant and Limburg held on unwaveringly to their last position.

This order goes back all the way to the beginning of the twentieth century, with the only deviation being that until 1923 the Southwest of the Netherlands showed lower adoption levels. As visible in figure 1-2 above, this order changed drastically in 1976. The Southern provinces, which had been the prime laggard region, took a leading position together with the South-Western provinces. The urbanized West fell back to the level of the other two remaining regions and subsequently remained there. The same story seems to be told by the next graph, which exemplifies the sudden turn with the average car density of thirty-three small and thirty-three large Dutch municipalities. "Small" municipalities, i.e. municipalities with few inhabitants, stand for rural places, whilst the largest municipalities of the country are representative of urban places. Once again we can see the same marked switch in 1976 from urban to rural dominance.
Fig. 1-3. Car diffusion in 33 small and 33 large Dutch municipalities, from 1928 to 1999


The sample municipalities are chosen on the basis of the number of its inhabitants. Small municipalities are defined as those Dutch municipalities which had but few inhabitants during the entire observation period. The large municipalities were chosen from among those with the most inhabitants in the Netherlands during the entire observation period.

While the interpretation of the American geographical diffusion pattern can be easily supported by theory and is well discussed in the literature, the Dutch so-called lag is puzzling. In this respect, the US can be regarded as the forerunner, or alternatively as the norm. It can be regarded as a stylized fact that consumer goods first diffuse in the vicinity of their production sites. Since production is typically in urban settings, early
diffusion takes place in urban settings as well. The car, however, is more functional in the countryside, where little or no public transport exists and where people adopt the car in order to meet their transport demand. Therefore, the diffusion centre switches from urban to rural places. This is why Peter-Eloy Staal is surprised to see that the switch from urban to rural dominance in car diffusion occurs so late in the Netherlands.\(^\text{18}\) It happened at a time when the traditional dichotomy between rural and urban had de facto vanished. The formerly rural places had been integrated into the urban system. Many of them had acquired new functions as commuter places or had attracted decentralizing industries.

The differences in car diffusion between the two countries can also be interpreted as further evidence that structural differences caused divergent diffusion paths. While in the US farmers can be regarded as the major early user group since around 1906, in the Netherlands farmers never even belonged to the foremost user groups.\(^\text{19}\) If we consider the small municipalities of Fig. 1-3 to stand for agricultural municipalities, it no longer seems surprising that agricultural areas did not belong to the leading areas for so long. The economic situation of American farmers was such that car adoption formed a perfect solution. The American farmers' demand on cars forms a key in understanding why Europe's growth in car ownership was retarded compared to that of the US. In the US, farmers not only formed a huge potential market, but they were also perceived as such by car producers. Henry Ford took the lead in capturing this market. In his comparison between Germany and the US, Flik shows that American farmers could (unlike the German ones) afford cars.\(^\text{20}\) They were relatively prosperous. The car contributed to an impressive rise in productivity of farmers, since its use spared them a lot of time. In the scarcely populated, Western American hinterland, it was crucial to economic success to bring the perishable, agricultural goods to the markets quickly. One could bring the agricultural goods to the nearest train station and from there the


goods were able to be transported further across the entire country and, more importantly, could be exported overseas. The market for agricultural goods was thus greatly enhanced by the interplay between cars and trains. With the introduction of the Ford Model T in 1908, cars could be used for field work just like agricultural tractors. This was made possible through the technical features, i.e. the high axles, of the Model T.

The economic situation of Dutch farmers seems to have been less favourable to car adoption than that of their American counterparts. While the general income level rose after 1940, the predominantly small-scale farmers faced increasing costs and falling prices of their own goods due to worldwide agricultural overproduction.\(^{21}\) Of course, Dutch farmers shared with their American colleagues this interest of transporting perishable goods speedily to the markets.\(^{22}\) There are also instances reported of farmers who used their cars on the farmland.\(^{23}\) However, none of this caused a broad adoption movement. Because farmland was often small in size, much of the traffic related to agricultural production was organized centrally.\(^{24}\) To illustrate, local refining industries possessed their own collection systems, often based on rural steam tramways. Fertilizers and the like could be distributed amongst farmers by a farmers' cooperation. For the regional transportation of goods, well-developed alternative transport modes existed.


The tram served as means for freight transport and in regions with plenty of waterways inland shipping was very important.25

1.3 Methods and structure of this book

In this dissertation, we shall question whether the strong emphasis on the differences between the US and the Netherlands, which is implicit in the research question, "Why is the Netherlands late in car diffusion?"26 is justified if we integrate the figures, which are usually used as proof for this assertion, in a broader quantitative frame. We shall analyze the Dutch diffusion path both on the level of aggregated diffusion curves as well as on the level of disaggregated geographical diffusion patterns. On the aggregated level we shall deal with the issue of whether the lag between the US and the Netherlands really is as impressive as generally accredited when we compare it to the diffusion speed of eighteen other countries and to the diffusion curves of two other modern transport modes, namely that of railways and airways. We shall take these other transport modes into account, because the car diffused into an environment which had already been shaped by the established transport system. The diffusion of transport modes is therefore linked to each other. We shall ascertain whether such a gap between a single forerunner and a group of followers can be observed for the diffusion of railways and airways as well. Furthermore, we shall verify whether there are links between the three diffusion waves, e.g. whether countries which had been late in respect to railways were equally late in their diffusion of cars. In the aggregated part we shall not make use of any other exogenous variables, such as the countries' GDP. The data which we use for this part of the study is mainly taken from international data handbooks and national statistics yearbooks. Chapter 2 will be devoted to the aggregated part.

On the disaggregated, geographical level, we shall take our inspiration from Jarvis’ precursor study on the geographical diffusion in the US between 1910 and 1969. We shall create a parallel study for the situation in the Netherlands until 1980. We shall proceed in two steps. Firstly, we shall interpret and systematize the evidence for the divergent characters of leading areas in comparison with other elements of geographical


diffusion. We shall systematically measure how the geographical variation in adoption levels changed over time as well as to what extent low and high adopting places respectively were clustered around the same areas. From this comprehensive analysis, we are able to make a periodization and interpret the evidence for a Dutch time lag. Secondly, we shall interpret the geographical diffusion patterns of the Netherlands in view of three theories, those of demand theory, theory of social diffusion, and theory of spatial diffusion. To this end, we shall include other variables in the analysis, many of which are not related to other transport modes. We shall take a microeconomic perspective and disregard the structure and agents in the innovation system, in the technical and production changes, as well as in the political processes and measures. The interpretation of the diffusion patterns is drawn from spatial regression analysis for three bench-mark years of the period 1930 to 1980. The data used in the disaggregated part of the analysis stems almost exclusively from that gathered by the Statistics Netherlands.\textsuperscript{27} To illustrate, the figures for cars have been published almost every year since 1928 in the \textit{Statistiek der motorrijtuigen}.\textsuperscript{28} The discussion of the geographical diffusion aspects is dealt with in three chapters: in chapter 3 we shall give a comprehensive description of the Dutch long-run diffusion pattern as compared with Jarvis’ results for the US, in chapter 4 we shall discuss possible interpretations of the two diffusion patterns, and in chapter 5 we shall test for two major periods, with the help of regression analysis, which aspects of the interpretation are so far not to be rejected on empirical grounds. We shall round off by summarizing our conclusions in chapter 6.

\textsuperscript{27} i.e. the Centraal Bureau voor de Statistiek, a department of the Dutch Ministry of Economic Affairs which gathers statistical information about the Netherlands.

\textsuperscript{28} A yearly periodical that includes statistical data on motor vehicles.
2 Is the Netherlands a motorization latecomer? An international comparison drawn from the analysis of three transport modes

2.1 Introduction

"Why so late?" This question has often been asked by historians interested in the social and economic dynamics of the first thirty years of car diffusion in Europe. In view of the high car penetration rate in the US during the Interbellum, many European countries indeed appear hesitant in adopting the car. Up to the 1930s, the Netherlands displayed slightly lower penetration rates than its big European brothers France and Great Britain did.

This chapter deals with the claim that the Netherlands was considerably later than the US in car diffusion and furthermore that it was somewhat delayed compared to the European forerunners Great Britain and France. In the field of social car history, this claim was adopted after a visual inspection of short-run time series for car diffusion in a limited number of countries. This approach does not systematically capture the differences between countries in the long run. It uses a static time frame for the comparison of several diffusion processes, each of which started and finished at different times. To circumvent this one could make sure “that markets [countries] are matched in terms of the time of origin of the within-country diffusion process. This ensures that meaningful comparisons across countries are possible, because ‘time’ reflects the same stage of the within-market diffusion process.”

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Comparing countries on the basis of absolute diffusion levels can be misleading. One can argue that the country-specific point of reference is the saturation level in each country.\(^{32}\) It might well be the case that the US reached mass motorization (i.e. the level of motorization at which, on average, one motor vehicle is owned by each family) a great deal earlier than those countries that followed suit. However, since the number of cars per household continues to be higher in the US than in Europe, the US might actually turn out to be slow in reaching a certain percentage of its saturation level. Moreover, differences in the methods by which the data is gathered pertaining to the different countries can easily lead to overemphasizing the European lag. To illustrate, the American car density numbers are higher than the Dutch figures, partly because vans, personal mini-vans and utility-type vehicles are included in the passenger car registrations.\(^{33}\) Consequently, comparisons between countries seem flawed and the question of how, in the long run, Europe has been different from the US is not yet answered.

In this chapter, we shall systematically test the claim that the Netherlands was considerably later by using long-run data series. We shall employ the empirical methods of quantitative diffusion analyzers, in order to avoid static cross-sectional comparisons of absolute diffusion levels. Quantitative diffusion analyzers distil longitudinal characteristics, such as the concept of fastness, out of aggregated diffusion curves. These characteristics remain related to the curve's peak and time of origin. Quantitative diffusion analyzers assume that diffusion curves tend to be S-shaped and they fit aggregated diffusion curves to an S-shaped mathematical curve such as the simple logistic growth curve.\(^{34}\) They then calculate the longitudinal characteristics of that fitted


\(^{33}\) This was the case until 1985.

\(^{34}\) e.g. Zvi Griliches, "Hybrid Corn. An Exploration in the Economics of Technological Change," Econometrica 1957: 501-22. For a critical view on this methodology see Gijs Mom, "Frozen History.
curve and take those for the true characteristics of the underlying, empirical curve. The idea is that the researcher can then compare a multitude of diffusion curves on the basis of the estimated longitudinal characteristics. We shall introduce a new kind of mathematical curve, with flexible characteristics, which has been termed the "generalized logistic sigmoid growth curve". We shall compare the diffusion speeds of the US and the Netherlands with that of fourteen other European countries and four non-European ones. The comparison is based on nationally aggregated data series for three modern transport diffusion waves, namely that of cars, railways, and airways. Thus we are able to put claims of "relatively late" or "relatively early" into the perspective of a somewhat broader transport performance of countries over the past two centuries. This will eventually lead us to conclude that the Netherlands was indeed considerably later in car diffusion when compared to the US.

2.2 On methodology

Concerning the present analysis, we made a couple of methodological choices: we selected a number of countries for the comparison, we chose railways and airways as additional transport waves and selected suitable measurements, we extracted characteristics such as “late” and “early” from each diffusion curve, and we employed a method called cluster analysis in order to group countries according to their speed characteristics. The following section is devoted to the discussion of these methodological choices.

2.2.1 The research design

A systematic, international comparison on the subject requires that we take into account many more countries than just the US and the Netherlands, so that we can judge


36 Originally we also intended to include the diffusion of waterways in the comparison. However, the data series (carriage capacity of the national float in metric tons) did not lend themselves to the fitting procedure used here. No stable estimates could be calculated and therefore those data entries are omitted. (This shall be discussed in section 2.2.3.)
whether their performances really were remarkably different from each other. We included all sizeable, capitalist European countries in the comparison, so that we can see how the Netherlands performed over a lengthy period of time compared to other European countries. Those European countries selected are Belgium, Denmark, Finland, France, Germany\textsuperscript{37}, Great Britain, Greece, Ireland, Italy, Norway, Portugal, Spain, Sweden and Switzerland. We also included several well-documented, industrialized non-European countries, namely Australia, Canada and Japan.\textsuperscript{38} By doing this, we can see whether Europe can be regarded as an international late-comer. Finally, Argentina was added to those countries that were selected. It forms an exception, because its general economic level is lower than that of the other countries included in the selection. It was added in the analysis, because Argentina, at one time, was an upcoming, prospering country. Specifically, it displayed rather a high car penetration rate during the Interbellum. Altogether the selection encompasses twenty countries, which we deem a sufficient number of cases for a statistical analysis.

We also want to judge whether the perceived drastic lag between the US and Europe was peculiar to car diffusion or whether this divide between leading and following countries is typical for other widely spread transport vehicles as well. Therefore we chose, in addition to cars, two well-documented and widely spread modern transport modes, namely railways, and airways.

For the characterization of countries as “early” or “late”, “fast” or “slow”, we do not wish to depend on one single measurement per transport mode. It was deemed beneficial to measure several aspects of diffusion for each transport mode, such as the number of vehicles, the growth of the infrastructural network and the transport mode performance in terms of kilometers travelled. Applied to the transport mode of cars the following aspects would be of interest: the number of cars per inhabitant, the length of total road and street, and the yearly passenger-kilometers. Of these aspects only the number of cars per inhabitant has long-run data series available for it starting in or originating before the 1920s. For the other two transport modes it was easier to get several indicators per mode. We use the following variables:

Kilometers of railway line open measure the growth of the infrastructural network for rails;

\textsuperscript{37} Between 1949 and 1990 West-Germany.

\textsuperscript{38} Originally we had selected New Zealand and Austria as well, but these countries had to be taken out of the analysis due to incomplete estimates.
Tons transported on railways measure rail transport performance in regard to freight; Passengers transported (trips) on railways measure rail transport performance in regard to passengers; Registered passenger cars measure the diffusion of vehicles; Cargo ton-kilometers in national and international civil aviation (i.e. in flights from/to/within a country by carriers registered in that country) measure airway transport performance in regard to freight; Passenger-kilometers in national and international civil aviation measure airway transport performance in regard to passengers; Airplane-kilometers flown in national and international civil aviation refer to the distance flown by airplanes belonging to carriers registered in a certain country when flying from/to/within that country and is a measurement for the existing transport capacity in airways.

The exact operational definitions of these variables are given in table 2-1 in section 2.2.4. The majority of these time series were compiled in B. R. Mitchell's historical data compendia. We complemented them with data from national statistical yearbooks, work of historians, as well as the statistical yearbook of the United Nations and Euro monitor. In a long-run quantitative analysis, it cannot be avoided that over time changes occur in the exact operational definitions or that they deviate from each other amongst countries. For example, “kilometers of railway line open” may only include the railway system of the national railway co-operation to the exception of other railway systems. Which vehicles are defined as passenger cars according to their dimensions, number of seats, or number of wheels, varies from country to country as well as over time. For the sake of the rest of this dissertation we have assumed that the long-term time dynamics are not severely affected by those variations.

### 2.2.2 The choice of the fitted equation

We allocated scores of "earliness" and "fastness" to each of the time series for each country. In order to produce an estimate for these characteristics, we fitted an S-shaped equation to the empirical diffusion curves. For this procedure we chose to use “a new

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40 See list of sources.
generalized logistic sigmoid growth equation," rather than the more widely used simple logistic growth curve. The chosen equation has the advantage of being able to be adjusted much more flexibly to the empirical curves. In this section we shall compare these two types of equation. Since we have employed the methods used in empirical diffusion analysis, we shall first elaborate slightly on the general characteristics of diffusion curves and their mathematical implications as they are to be found in empirical diffusion analysis.

Visually, long-term diffusion curves take the shape of a stylized "S": after a slow start the adoption rate increases until it reaches its turning-point, after which the diffusion speed gradually looses its impetus and levels off. The logic behind this S-shape is simple. In the early stage only a few people purchase the product in question, making for a relatively flat start to the curve. Then a period follows at which many people acquire said product, which causes the curve to rise dramatically. Finally, a saturation stage is reached at which the rate of adoption declines and the diffusion curve levels off. Thus depicted, diffusion curves usually present themselves in outward appearance as being very similar to certain mathematical equations. Following Zvi Griliches, it has become a tradition to fit diffusion curves to such S-shaped mathematical equations, most notably the simple logistic growth curve. shows what a simple logistic growth curve looks like.

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A simple logistic growth curve is always symmetric by virtue of its equation.\textsuperscript{43} In a symmetric curve, the time at which the slope of the curve is steepest lies at the midpoint of the curve. This is also the inflection point, being the point at which the curve changes from being concave upwards to concave downwards. The curve inflects here when half of the saturation level is reached. The growth pattern on the right side of the inflection point is inversely identical to the growth pattern left of the inflection point. For the generalized logistic growth curve, these two assumptions are deemed relaxed.\textsuperscript{44} These

\textsuperscript{43} The formula of the simple logistic growth curve is:
\[ y(t) = \frac{1}{1 + \left( \frac{y_0}{y} - 1 \right) e^{-rt}} \]
where

- \( y(t) \): A variable representing the penetration rate at a certain time (t);
- \( y_0 \): The initial penetration rate;
- \( e \): A universal constant, the base of the natural logarithm;
- \( r \): The maximum rate of growth at the inflection point.

\[ y(t) = \frac{K}{(1 + T e^{-b(t-M)}) \frac{1}{T}} \]
where

- \( y(t) \): A variable representing the value of a measure of density of a transport mode.

22
assumptions seem unsatisfactory, because the growth rate at any stage of the diffusion process is determined by a complex set of influences and therefore it is not necessarily the case that the fastest growth takes place at the inflection point. Furthermore, it can be the case that the growth patterns on either side of the inflection point differ from each other.

For this study we used the generalized logistic growth curve, since a country like the Netherlands, which has been characterized as a “slow” beginner, might turn out to be slow only during early motorization in its left tail, with the overall growth rate not being particularly low. This idea is inspired by findings that (at least in cars) a pattern of international catch-up exists. Arnulf Grübler, as well as Cesare Marchetti, showed that the later a country had started the spread of the car, the faster its growth. Therefore, those countries which take off early at the same time progress only slowly closer towards their estimated saturation level.

\[ t \quad \text{Year.} \]
\[ K \quad \text{The upper asymptote of} \ y. \]
\[ T \quad \text{An additional parameter in the new generalized, sigmoid equation introduced so that it can define asymmetric curves.} \]
\[ e \quad \text{A universal constant, the base of the natural logarithm.} \]
\[ b \quad \text{The maximum intrinsic rate of increase of} \ y. \]
\[ M \quad \text{The time at which} \ y = \frac{K}{2}. \]

45 Arnulf Grübler, The rise and fall of infrastructures: dynamics of evolution and technological change in transport, Contributions to economics, (Heidelberg: Physica-Verlag, 1990) VIII, 305., pp. 98, 151-153 for cars using the most recent observation as peak. Cesare Marchetti, "The Automobile in a System Context," Technological Forecasting and Social Change 23.(1983): 3-23., pp. 10-12 observes the same pattern of catch-up for cars in nine countries. A. Grübler furthermore discovered that the countries that were quickest off the mark tended to reach a high absolute saturation level, while the reached saturation level dropped with the lateness of the country. Thus catch-up is achieved by virtue of the laggard countries having lower saturation ceilings for their diffusion (Arnulf Grübler, The rise and fall of infrastructures: dynamics of evolution and technological change in transport, Contributions to economics, (Heidelberg: Physica-Verlag, 1990) VIII, 305., pp. 152-153).
Fig. 2-2. Examples of two time series with an asymmetric fit. Car diffusion in Canada and the Netherlands, from 1904 to 1998

Notes: Sources: See list of sources.
The fitted generalized logistic growth curve for Canada has the following characteristics:
Year in which 50% of the estimated saturation level is reached: 1969.
Number of years needed to proceed from 5% to 95% of the estimated saturation level: 81.
Number of years which lie between the half-saturation point and the inflection point: 7 (asymmetric to the left).
Period used for the estimation of the fit: 1904 to 1998.
Likewise, the fitted generalized logistic growth curve for the Netherlands has the following characteristics:
Year in which 50% of the estimated saturation level is reached: 1969.
Number of years needed to proceed from 5% to 95% of the estimated saturation level: 39.
Number of years which lie between the half-saturation point and the inflection point: -2 (asymmetric to the right).
Period used for the estimation of the fit: 1898 to 2001.

We expect that catching-up countries are not (always) symmetric. It seems more likely that the growth rate of such countries is relatively small in the early period of growth and then rapidly accelerates in a later stage of the diffusion process when the actual catch-up sets in. This process is illustrated in Fig. 2-2. The graph in this figure shows the time series for car diffusion in Canada and the Netherlands and the fit of an asymmetric generalized logistic growth curve. The two countries do more than differ in respect to the level of the penetration rate, which has always been higher in Canada than...
in the Netherlands. Canada experienced a strong car boom in the period of 1915 to 1930, when the growth rate was very high. The curve of the Netherlands, on the other hand, remains relatively flat until around 1947 but converges on the Canadian curve in the period of 1965 to 1980. Thus the Netherlands experienced a period of a relatively strong growth much later on than Canada did. In both cases, an asymmetric curve fits better than a symmetric curve. Those fitted asymmetric curves are also shown in the graph. The fitted curve for Canada is asymmetric to the left (right-tailed), while the fitted curve for the Netherlands is asymmetric to the right (left-tailed).

2.2.3 The longitudinal characteristics and the fitting procedure

We calculated three characteristics of the fitted curve in order to judge how early/late and fast/slow the original data series are and whether they are symmetric or not. In this section, we shall give the operational definitions of these longitudinal characteristics and discuss what procedure we used to distil comparable and sensible values.

Traditionally, scholars distil three characteristics from the simple logistic growth curve: "origins, slopes, and ceilings." Each of these variables stands for a particular concept in diffusion studies and they all represent basic features of the given curves: the origin indicates the start of diffusion ("earliness"), the slope shows the overall diffusion rate ("fastness") and the ceiling or upper asymptote signifies the saturation level. For the comparison between the countries, we used the estimated longitudinal characteristics and not the empirical curves as such.

For the characteristics of time series we chose conventional operational definitions. The take-off year shows the beginning of diffusion and is defined as the year in which five per cent of the saturation level has been reached. We term a country with an early take-off year "early" as opposed to "late". The growth time indicates how long the overall process of diffusion takes, and we define it as the time that it takes to move from five to ninety-five per cent of the saturation level. When a country has a short growth time, we term that country "fast" as opposed to "slow". These two characteristics of "earliness" and "fastness" are the basis on which we wish to compare the countries, for this reason we have left out the ceiling or saturation characteristic from the analysis.

The additional symmetry characteristic can further illuminate a country's "earliness"/"fastness". In asymmetric curves, as opposed to symmetric ones, the inflection point shifts away from the half-saturation point and they no longer fall together. In right-tailed curves, where there is a disproportionally extended phase of marginal growth towards the end of the diffusion process, the half-saturation point moves to the left; while in left-tailed curves the half-saturation point is situated to the right of the inflection point when diffusion curves show a prolonged phase of slow growth during the early diffusion stages.

The operational definition of symmetry is the number of years that lie between the half-saturation point and the inflection point. This figure is positive for left-tailed curves and negative for right-tailed ones. When interpreting the symmetry characteristic, one should keep in mind that symmetry is not a feature that stands on its own, it is structurally related to "earliness". Out of two curves, which both start at the same time, the one that is more right-tailed will have reached five per cent of the saturation rate earlier on than the other curve and thus is per definition "earlier". Symmetry is, however, not per definition related to the overall growth time. A left-tailed curve has got "slow" growth in an early period – "slow" means here relative to the same curve's growth rate in a later period and not relative to other curves.

Fitting generalized logistic growth curves to empirical diffusion curves needs to be done with some care. This is so for two reasons. Firstly, any comparison based on this process is flawed if the asymptote of the fitted curve cannot sensibly be regarded as the saturation level. Secondly, there is an additional complication when compared to the fitting to a simple logistic growth curve. For a simple logistic growth curve there exists only a single combination of estimates with the best fit. It is relatively easy to calculate this solution. The estimated curve with the best fit is then selected to represent the original data series. However, for the generalized logistic growth curve it is much more difficult to detect the fitted curve with the best fit. Since the growth rate moves flexibly, several alternative interpretations, which fit almost equally well, exist.

---

We will start by looking at the first reason, that of the saturation level. Fig. 2-3 illustrates how drastically two alternative interpretations of the same curve can deviate from each other. In Fig. 2-3, the open dots stand for the empirical data points of kilometers flown by aeroplanes. The grey and black continuous lines indicate two alternative fits for symmetric logistic growth curves. The empirical data points with their two fitted lines are shown twice, once on a non-logarithmic scale and once on a logarithmic scale.

Fig. 2-3. Two alternative interpretations of a time series. Example: civil aviation from/to/within Norway. 1934-2000

Sources: See list of sources.

The estimated values for both curves are based on the same time period, from 1934 to 2000. The grey line, however, was calculated by transposing the original data onto a
logarithmic scale, while the black line is based on non-logarithmic scale. The reasons for this shall be explained below. Both estimated curves fit very well onto the type of scale, on which they are calculated. The summed difference between the data points of the time series and the ones of the estimated curves is very small, with $r$ squared, a measure of fit, being larger than 0.94. Nevertheless, the two estimated curves differ greatly. The grey line follows the time series until a temporary plateau phase in the early 1980s and takes this period of slow growth as an indication of saturation. Thus ninety-five per cent of the saturation level is estimated to have been reached in 1977. The black line puts more emphasis on the following period of accelerated growth and predicts a much higher saturation level which is to be reached almost a hundred years later, in 2072. Such differences in interpretation do not only occur in ongoing diffusion processes. As a consequence, countries of which the empirical diffusion curves look very similar, can artificially be made to look very different by allocating the higher estimate to one and the lower to the other. Therefore it is important to check whether the calculated estimations make any sense and seem comparable to other time series. In the following paragraph is explained how we did this.

Fitting time series to generalized logistic growth curves requires an iterative procedure. This is because the generalized logistic growth curve has more parameters than the simple logistic growth curve. The researcher first suggests possible values for the major characteristics of the curve, to wit its slope at the inflection point, the time at which it inflects, its saturation level, and its degree of asymmetry. Then the mathematical procedure incrementally approaches the next stable and optimal combination of values with the best fit. If local optima exist, several alternative combinations of values can appear optimal, but only one result is calculated at a time. This calculated result depends on the suggested values which have been entered. Moreover, stable combinations of values with the best fit might not even be discovered. The programme fails to settle at a point where no further improvement of the fit is possible. It continues to switch from one alternative interpretation to the other. In such cases the researcher cannot find any fixed characteristics of the curve and is forced to disregard the underlying time series. We aimed to detect a wide range of alternative solutions. In the second step, the selection of combinations of estimates must be conducted with considerable care, in order to avoid arbitrary and meaningless comparisons.

In order to detect alternative, valuable sets of estimates, the iterative fitting procedure was performed twice. First while using the original version of the generalized logistic growth equation and then while using its logarithmic version. Initially, the programme was run using a time window starting with the first available observation and ending at the statistical maximum point of the figures available. Whenever convergence was not achieved in either run of the original version or its logarithmic version, a third and fourth run was performed while only allowing for symmetric curves. This happened quite frequently. Furthermore, the results for other possible observation periods were explored, e.g. in cases of multiple peaking or when the number of observations was too small between the first available observation and the maximum.
Next we selected feasible combinations of estimates. We generally disregarded combinations of estimates that did not converge at a single optimum or were statistically insignificant. For all other sets of estimates the estimated saturation levels were compared with the true maximum (peak) of the data series. We constructed two groups of estimates: one group contained sets of estimates with saturation levels (partly) much higher than the actual maximum of the time series, the other group contained sets of estimates with saturation levels beneath the actual peak. This way we avoided that a country seemed “early” or “fast,” simply because its saturation level was estimated to be much lower or higher than the ones of the others. Within each group, the set of estimates with the best fit (highest r squared) was selected. Where there was only one stable and significant estimation result that existed, it was used for both data sets, since otherwise the country in question would have been excluded from the analysis, which would mean losing much of the variance in the created data set. Austria and New Zealand were withdrawn from the data sets due to the fact that no sensible, stable estimates could be achieved. Lastly, we checked per data set whether there were any estimates which looked unreasonably higher or lower than all other estimates. The data set with saturation levels below the actual peak contained some outliers, these are observations which are numerically distant from the rest of the data. Because statistics derived from data sets that include outliers may be misleading, we dealt upon continuation exclusively with the data sets with estimates above the actual peak. Eventually, there was one data set. This data set contained twenty-one variables for each of the twenty countries. These twenty-one variables originated from seven time series per country times three longitudinal indicators per time series. Table 2-1 illustrates, how the data set is setup and shows the operational definitions of all variables.
Table 2-1
The Setup of the Data Set and Variable Definitions
For Each Country Seven Variables Were Collected:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Cars Registered</td>
<td>Registered Motor Cars Seating Less than eight Persons, Including Taxis, Jeeps and Station Wagons</td>
</tr>
<tr>
<td>Kilometres of Railway Line Open</td>
<td>State an Private Lines open by the End of the Year</td>
</tr>
<tr>
<td>Metric Tons Transported On Railways</td>
<td>Domestic Revenue Traffic On State And Private Lines. Freight Includes Mail.</td>
</tr>
<tr>
<td>Passengers Transported on Railways</td>
<td></td>
</tr>
<tr>
<td>Total Cargo Ton-kilometers in Civil Aviation</td>
<td>Domestic and International Scheduled Services Operated by Companies Registered in each Country. Scheduled Services Include Supplementary Services Occasioned by Overflow Traffic on Regularly Scheduled Trips and Preparatory Flights for New Scheduled Services. Revenue Traffic Includes Traffic at Reduced Rates. Cargo Means all Goods, except Mail, Carried for Remuneration, Including Excess Baggage. Ton-kilometers Figures are Net.</td>
</tr>
<tr>
<td>Total Passenger-kilometers in Civil Aviation</td>
<td></td>
</tr>
<tr>
<td>Total Kilometers Flown in Civil Aviation</td>
<td></td>
</tr>
</tbody>
</table>

For Each Variable Three Longitudinal Characteristics Were Estimated:

<table>
<thead>
<tr>
<th>Estimated Longitudinal Characteristic</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off Year</td>
<td>Year in which 5% of the Estimated Saturation Level is Reached</td>
</tr>
<tr>
<td>Growth Time</td>
<td>Number of Years Needed to Proceed from 5% to 95% of the Estimated Saturation Level</td>
</tr>
<tr>
<td>Symmetry</td>
<td>Number of Years which Lie between the Half-saturation Point and the Inflection Point</td>
</tr>
</tbody>
</table>
2.2.4 The cluster analysis

We aimed to compare the twenty countries with each other in a systematic fashion, so that we would be able to see whether the Netherlands belongs in a long-run perspective to a group of particularly late or slow countries. We chose to analyse our data with the help of cluster analysis, because this form of analysis is particularly well suited to do this. A cluster analysis groups those countries together that have the most characteristics in common and depart most strongly from the other groups. This way a cluster analysis distils the most apparent differences and similarities between countries out of a large quantity of data. In this section we shall put forth our choices in regard to the cluster analysis provided.

There are various mathematical procedures by which countries can be sorted into groups (clusters). The hierarchical clustering method was used because it is most appropriate for small sample sizes. Hierarchical clustering is a stepwise procedure, by which the most akin countries are clustered together first and then slowly all groups are merged into an ever smaller number of groups until all countries are amalgamated into one single cluster.

With hierarchical clustering the researcher is able to choose the number of clusters. We used a dendrogram in order to determine a feasible number of clusters. A dendrogram visually represents the dissimilarity between clusters, which has to be overcome when merging them. The number of clusters was determined by applying the rule that the largest distance in the merging process should be excluded. The number of clusters which occur before this largest distance has to be bridged, is generally acknowledged as the appropriate one, since it provides some degree of conciseness while at the same time avoiding forcing very multifarious countries into a single group. This procedure resulted in three clusters comprising at least two members each. In the first two columns of table 2-2 one can see to which cluster each country belongs. Argentina, Australia, Canada,
Great Britain, and the US belong to cluster one. Cluster two consists of Denmark, Ireland, Norway, and Sweden. All other countries, including the Netherlands, belong to cluster three.

In which respect do these clusters differ from each other? In order to see which variables were crucial in the grouping of the countries, we used the one-way-ANOVA method. The one-way-ANOVA method is a statistical test, which checks, whether the variance between the means of two clusters contributes significantly to the total variance in these two clusters. If this is not the case, this implies that the variance within the clusters is very large compared to the variance between the cluster means. A variable, the cluster means of which are insignificant in the one-way-ANOVA test, are considered as irrelevant for the grouping of the clusters.

Imagine that cluster one and two are significantly different in respect to the take-off year for cars, how can one see which of the two clusters is “early” and which is “late” in respect to car diffusion? To answer this we can simply look at the means of the two clusters. In this example, the countries of cluster one, on average, reach five per cent of their saturation level in the year 1919, while the average take-off year of cluster two is 1944. Cluster two is thus significantly later when it comes to cars than cluster one.

Columns three to five in table 2-2 show how the clusters are characterized. Only the significant differences between the three groups are shown. The variance amongst cluster members tends to be very high compared to the overall variance in the data set. Put differently, cluster members are rather heterogeneous. Therefore, there are only a few marked differences between the clusters. The groups differ significantly in just eight out of the twenty-one variables. Furthermore, the contrast between groups is often rather weak, so that significant differences only occur laterally between two groups. In these cases, it is not possible to attach an order to the various clusters, telling which of the clusters is fastest, second fastest, and which one trails behind. This, then, can only give a rough indication as to which groups are particularly “fast” or “slow”. In other cases, one group is significantly different from the other two, while the differences between the two other groups remain insignificant, so that at least, for example, the fastest group can be determined, but not the slowest one.

2.3 Late, fast and left-tailed. What the Netherlands distinguishes from the US in the long-run

A systematic, international comparison can clarify the question of whether the lower adoption rates of European countries in the 1930s, in comparison to the ones of the US, are an indication of a systematic, long-run European delay. In this section we shall show that the strong emphasis on the distinction between forerunners and catching-up countries in cars is indeed justified. This is all the more so given the fact that the same differentiation does not come to the fore when we look at railways. The US is, however, not the only leading country. It behaved similarly to the other Anglo-Saxon countries (except for Ireland) and to Argentina. Amongst all catching-up countries, it does not appear that the Netherlands were particularly "late" in respect to car diffusion. However, the Netherlands’ diffusion process is delayed in its first half when set against its second half. In the following discussion we shall refer to table 2-2, which shows the results of the cluster analysis.

When it comes to cars, there exists a clear distinction between countries that lead and those that follow. The leading countries are those of cluster one, whilst clusters two and three contain all follower countries, amongst which the Netherlands. The US belongs to the leading countries, together with Argentina, Australia, Canada, and Great Britain. Cluster two includes the Northern European countries Denmark, Norway, and Sweden, as well as Ireland. Cluster three contains all ten remaining European countries from our selection, and Japan. We shall first describe how the leading countries are different from the catching-up countries in respect to car diffusion and then look at the features of the two catching-up clusters.

If we look at the characteristics of cluster one, we can see that these countries are, highly significantly, distinguished from the members of the two other groups in respect to cars. The Anglo-Saxon countries and Argentina indeed started the diffusion of cars very early. To illustrate by using the earliest estimated country, the US has its estimated take-off year in 1902. Among this forerunner group, Great Britain is estimated to have the most “late” take-off year, to wit 1937. Alternatively, the countries of the two other clusters take off, on average, in the year 1949. At the same time, it takes the members of cluster one very long to proceed to the estimated saturation level. This might appear a contradiction, but is in actual fact the
result of catch-up: the earlier a country begins the diffusion, the longer it takes to reach its estimated saturation level. Our findings confirm this pattern for the diffusion of cars, because Pearson's coefficient of correlation between the estimated take-off years in cars for the countries and their respective growth times is negative and significant.\(^5\) The earliest country, the US, has got the longest growth time. According to this estimation, it will take the US 110 years to approach 95% of its saturation level. Argentina and Great Britain, which take off somewhat later than the US, are also slightly faster; it takes them less than 65 years to approach 95% of their saturation levels. These figures are in clear opposition to the growth times of the countries from clusters two and three. The Netherlands, with its growth time of 39 years, is estimated to be the second fastest country after Denmark—a growth time of 37 years—amongst the countries under investigation. It is followed by "relatively late" follower countries, namely Ireland, Italy, Spain, and Sweden, which have all got a growth time of 45 years.

We can see in table 2-2 that the members of cluster one are characterized as right-tailed when it comes to cars. This difference is especially significant in relation to cluster three, and to a lesser degree in relation to cluster two. In cluster one, only the US and Great Britain are symmetric, while Argentina, Canada, and Australia are right-tailed. Thus they show a period of strong growth in the early years of diffusion, similar to what was illustrated for Canada in Fig. 2-2. The difference between the half-saturation point and the inflection point is more than 6 years for all right-tailed countries belonging to cluster one.

Cluster two also possesses a right-tailed country in Ireland, its figure being -3. The other three countries of cluster two are symmetric. Only two catching-up countries are estimated to be left-tailed. These are Finland and the Netherlands, which both belong to cluster three. The difference between the half-saturation point and the inflection point is somewhat smaller than with the right-tailed countries, the figures being 3 and 2, respectively.

We can deduce two things from these findings. Firstly, they indicate that it is not true that catching-up countries tend to be left-tailed. If anything, the exact opposite is the case, because the "early" countries, as represented in the first cluster, tend to be right-tailed. We should note that this pattern is in accordance with the estimations we made

\(^5\) A correlation indicates the strength and direction of a linear relationship between two variables. Pearson's correlation coefficient is a number between -1 and +1. A positive value for the correlation implies a positive association. A negative value for the correlation implies a negative association. Pearson's correlation coefficient between the estimated take-off years in cars for the countries and their respective growth times: -0.706. Significance (two-sided): 0.001. Number of cases: 19.
specifically for car diffusion. In fact, the only right-tailed curves in the data set are those pertaining to cars.
Secondly, the findings might suggest that it is peculiar to the Netherlands that its growth process is relatively inert in the first half when compared to its second half. The Netherlands and the US are, in any case, quite different in this respect.

Following this, let us turn our attention to other than car-related characteristics of the leading countries found in cluster one. The Anglo-Saxon countries and Argentina are not only "early" for cars, but also for distance flown in civil aviation. On average, the members of cluster one take off in 1933, while the average take-off year for the other two clusters is around 1952. When we compare the US and the Netherlands in this respect, we see that they are rather similar. The US takes off in 1941 and has got a growth time of 80 years, and the Netherlands takes off in 1937 and has a growth time of 50 years.

Consequently, this indicates that the leading countries in cars are not necessarily also the leading countries in airway diffusion. To elucidate, cluster one contains several countries which are not particularly "early" in respect to passenger transport and/or freight transport in civil aviation, whereas when it came to cars it was the decided forerunner group. Of note is that for distance flown in civil aviation, there is no pattern of catch-up to be detected. Therefore, the members of cluster one are only distinguished as "early", and not simultaneously as being "slow". Even though the members of cluster one are quite "slow" for passenger transport in civil aviation, the Northern European countries and Ireland, represented in cluster two, are generally even slower.

None of the measures related to railways appear as being a characteristic of the leading countries. Initially this might be surprising, because the well-accepted leader in terms of railway diffusion—Great Britain—is a member of this cluster. The well-known distinction between this forerunner in rails and its follower countries is lacking in this cluster analysis. It is true that Great Britain is persistently one of the earliest countries in respect to all three indicators for railway diffusion being the length of the network, the amount of freight transport and the amount of passenger transport. However, the variance amongst the clusters in respect to the level of railway diffusion has no systematic relation to the clusters as formed. Only the differences between the countries in respect to car and airway diffusion determined the clustering. The differences in respect to railway diffusion were totally disregarded.
<table>
<thead>
<tr>
<th>Cluster</th>
<th>Members / Countries&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Characterized by</th>
<th>When Contrasted with</th>
<th>Significance&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Variable</td>
<td>Cluster Mean</td>
<td>Group</td>
</tr>
<tr>
<td>1</td>
<td>Argentina, Australia, Canada, Great Britain, US</td>
<td>Earliest for Cars</td>
<td>1919&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slowest for Cars</td>
<td>76&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earliest for Distance Flown in Civil Aviation</td>
<td>1933&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Right-Tailed for Cars</td>
<td>-4&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Denmark, Ireland, Norway, Sweden</td>
<td>Slowest for Distance Flown in Civil Aviation</td>
<td>107&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Early for Freight Transport in Civil Aviation</td>
<td>1957&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Belgium, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, Portugal, Spain, Switzerland</td>
<td>Fast for Passenger Transport in Civil Aviation</td>
<td>50&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetric (Not Left-Tailed) for Passenger Transport in Civil Aviation</td>
<td>1&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1</td>
</tr>
</tbody>
</table>

Sources: See list of sources.

<sup>a</sup>The data set contains sets of estimates with, where applicable, estimated saturation levels above the real-data peaks.

Cluster method: hierarchical clustering of furthest neighbour with squared Euclidian difference. “Furthest neighbour” means the maximum distance between any single case in one cluster and any single case in another, i.e. the distance between the two most distant cases in two separate clusters. “Squared Euclidian difference” is a measure of similarity that represents the sum of the squared differences between the clusters without calculating the square root.

Variables are standardized as Z-scores. The standard score indicates how many standard deviations an observation is above or below the mean.

Comparison of means: One-way-ANOVA, Scheffé coefficient. The Scheffé coefficient is a test, which determines which cluster means differ. It performs simultaneous joint pairwise comparisons for all possible pairwise combinations of means.

<sup>b</sup>Countries excluded from this list: Austria, New Zealand.

<sup>c</sup>Significance level: 10 %.

<sup>d</sup>Take-off year (when 5% of the estimated saturation level is reached).

<sup>e</sup>Growth time expressed as the number of years needed to proceed from 5% to 95% of the estimated saturation level.

<sup>f</sup>Symmetry expressed as the number of years which lie between the half-saturation point and the inflection point. The figure is positive for left-tailed curves and negative for right-tailed ones.
We shall now turn to the characteristics of the two types of catching-up countries. Clusters two and three respectively represent a type of catching-up country. They are distinguished into these two types on the basis of airway diffusion and not on the basis of car diffusion.

The two groups of catching up countries do not systematically differ in terms of take-off year or speed when it comes to cars. In table 2-2, we can see that the take-off year in cars does not appear as a characteristic of either cluster two or three. Thus on the basis of the significant differences, we can identify the leading countries, but not the most laggard ones amongst the catching-up countries. This is because in respect to cars, the members of clusters two and three are rather heterogeneous. Thus we cannot say that cluster three, which contains the Netherlands, comes last in respect to car diffusion. It is true that cluster three is on average ten years later than cluster two: while the countries of cluster two on average take off in the year 1944, the countries of cluster three do so in the year 1954. This is the case, because cluster three contains all really “late” countries with take-off years after 1950, such as Greece (1965), Spain (1960), and Japan (1958). However, it does not exclusively contain all those countries that bring up the rear, so that there is at least some overlap with cluster two, the take-off times of which are between 1939 (Ireland) and 1950 (Norway).

We can detect the differences in performance only by comparing the individual estimations. The Netherlands was one of the countries that took off the latest out of all selected Northern, Western and Central European countries. The Dutch estimated take-off year was 1955. This was later than Ireland (1938), France (1940), Germany (1949), Italy (1953), or even Belgium and Denmark (both 1946). However, the Netherlands did have an earlier take-off year than the Southern European countries: Portugal (1957), Spain (1960), and Greece (1965). Greece is estimated to be latest amongst the countries under investigation. Compared to the only non-European country in cluster three, the Netherlands was also earlier than Japan (1958). These numbers show a tendency and, since they are estimates, should not be taken too rigidly.

The members of cluster two–Denmark, Ireland, Norway, and Sweden–can be regarded as belonging to the catching-up countries which are quite "early" in respect to passenger transport on civil aviation. If we look at the characteristics of cluster two, we can see that these countries are earlier in regard to freight transport in civil aviation than the members of cluster three. The take-off years of cluster two vary from 1955 (Sweden) to 1961 (Ireland). This in contrast to the take-off years of the remaining European countries and Japan, which go up to 1973 (Finland). In relation to cluster one this distinction is not significant, but cluster one has in the US only one particularly "early" country, with a take-off year of 1954. The Netherlands is typical for a "late" country belonging to cluster three. Its take-off year is 1965.

In respect to passenger transport in civil aviation, no single cluster could be identified as having adopted the role of the forerunner. Consequently, this measure does not appear as a characteristic in table 2-2. Nonetheless, cluster two again exclusively contains countries with early take-off years, which go up to 1961.
The Northern European countries and Ireland were slower than all other countries for distance flown in civil aviation. In table 2-2, this has been identified as the second characteristic of cluster two. Its average growth time is 107, which is considerably higher than the average growth time for cluster one and two, their figures being 81 and 64 respectively.

In order to further understand the differences between the two catching-up clusters, we will proceed to the characteristics of cluster three. This cluster is distinguishable from the Anglo-Saxon countries and Argentina in respect to passenger-kilometres in civil aviation. For this characteristic the following rule applies: The slower, the more left-tailed (i.e. the longer the delayed growth rate in the beginning of diffusion). The Anglo-Saxon countries and Argentina are slow and strongly left-tailed in passenger transport in civil aviation, while for the same characteristic the large group of European countries and Japan is in respect to the members of cluster one both faster as well as being symmetric more often. The average growth time of cluster three is 50, whereas the average growth time for cluster one is 91. Apart from Finland and Spain, all members of cluster three are symmetric in passenger transport in civil aviation, while Great Britain, Argentina, and the US of cluster one have all got more than seven years’ difference between their half-saturation point and inflection point.
This means that the US and the Netherlands are distinguished from each other not only in respect to car diffusion, but also in respect to airway diffusion.

2.4 Conclusion
The international literature rightly emphasizes that the US was leading in cars. In our cluster analysis, the distinction between leading countries and follower countries is for no other transport mode as clear as for cars. However, the US is revealed as not being the only leading country when it comes to car diffusion. Australia, Canada, Great Britain, and Argentina are forerunners as well.
The Dutch car diffusion path is distinguished from the American one by three characteristics: a late take-off (relative to the estimated saturation rate), retardation in the first half of the diffusion process, and an overall fast diffusion speed, which has lead to a catch-up situation. We have shown that the international literature rightly assumes the Netherlands to be one of the follower countries.
We have qualified the accepted ideas that the Netherlands was also late within Europe by stressing the conformity between all continental European countries.
However, there is also a national literature on Dutch car diffusion, which seems to suggest—even though in a much more timid voice—that the Netherlands was late in another respect: it possibly repeated the American pattern of geographical diffusion in a strongly retarded manner. While in the US some rural regions exceeded the urban ones as early as 1920 in car density levels, this process possibly did not occur in the Netherlands before 1976. The first step in investigating this is a general overview of the Dutch diffusion process. The following three chapters shall be devoted to this issue.
3 Is there a unique Dutch path of geographical car diffusion? A long-run analysis of geographical dynamics on the level of municipalities

3.1 Introduction

This chapter is about the long-run geographical dynamics in Dutch car diffusion in light of the example set by the US. The US is known as the country in which the Ford Motor Company from 1909 onwards managed to successfully exploit the huge rural market. Jarvis confirms this view in his dissertation from 1972 entitled "The Diffusion of the Automobile in the United States, 1895 - 1969", while simultaneously embedding it in a systematic and multifaceted treatment of the geographical diffusion of cars in the US from 1910 till 1969.51 Within this time span, he distinguishes a pre- and postwar period of accelerated car diffusion and finds that the relatively rural Midwest was leading in respect to car diffusion from at least 1920 onwards.52 Jarvis' analysis is rather elaborate, since he looks at various aspects of patterns of geographical car diffusion. A comparable study which is equally exhaustive does not exist for any other country, follower or otherwise. Therefore, we do not know whether the long-run patterns found by Jarvis are specific to the US, or whether they represent more general patterns of geographical diffusion within the confines of a single country. If such a general pattern exists, do follower countries repeat this pattern in a delayed manner, or do they show a different diffusion path altogether?

Staal observes that the Dutch rural regions in the Southeast of the country took over the lead from the more urbanized Western provinces in 1976.53 In comparison with the US, this seems extraordinary late. Nevertheless, we do not know whether this isolated fact hints at a time-lag or something else. It seems unlikely to Staal that the late switch from


52 Jarvis 141-66 on the periods of diffusion; Jarvis 180-99 on the Midwest as leader in car diffusion.

urban to rural dominance is caused by a similar set of reasons as the massive embrace of the automobile by the Americans in the rural Midwest during the period 1906-45.

In this chapter, we shall aim to create a comparable study to Jarvis' work for the Netherlands as a follower country by using advanced spatial econometrics. Even though individual statistical methods are not identical, we shall use the same frame of analysis as Jarvis. In our choice of the geographical dimensions, along which one can analyse a country's geographical diffusion path, we shall rely on the work of the social geographer Torsten Hägerstrand as found in his *Innovation Diffusion As a Spatial Process*.

As much as possible we will apply geographically small units of analysis to look at the Dutch geographical diffusion dynamics, for these we will use the roughly one thousand Dutch municipalities. The available data allows us to go back as far as 1900. Thus our analysis deals with very small geographical units, while Jarvis dealt with highly agglomerated data on huge areas, namely (groups of) American states. The difference in scale is significant, since a single American state may well exceed the whole of the Netherlands in size.

Therefore, there might be differences between the American and the Dutch geographical pattern of car diffusion, which are not attributable to a Dutch delay as such, but simply to the differences in scale. Because of the discrepancy in scale, we cannot equate an urban respectively rural area in the Netherlands with an urban respectively rural state, or group of states, in the US.

With this in mind, how can we go about determining whether the Netherlands was later than the US or whether it showed an entirely different pattern of geographical diffusion? One should not base one’s judgement solely on the character of the leading and lagging regions. One should instead aim to corroborate the dynamics of spatial diffusion with a host of measurements and approach the issue from several angles, thereby integrating the character of the leading and lagging regions into a larger picture of geographical diffusion patterns.

Hägerstrand’s theory and the multifaceted analysis of Jarvis (the latter being based upon the former), provide examples for exactly such a multifaceted approach to long-term geographical diffusion dynamics.

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We shall distinguish phases of Dutch geographical car diffusion using the same criteria as Jarvis does. We shall determine whether the Dutch geographical path of car diffusion was "late" or different vis-à-vis the US by comparing their phases of diffusion.

This chapter is structured as follows: in section 3.2 we shall summarize the American geographical diffusion path as set forth by Jarvis, in section 3.3 we shall look at various aspects of the Dutch geographical diffusion path and compare it with the American example. We shall see that the Dutch geographical diffusion path was (albeit on a much smaller scale) rather similar to the American one.

### 3.2 *The American geographical diffusion path, from 1900 to 1969—A synopsis drawn from G. K. Jarvis*

We shall give a brief synopsis of Jarvis' findings on the geographical diffusion of the car in the US, so that we can compare them to our own findings on the Netherlands. For this synopsis of Jarvis' results, we have rearranged all his findings and sorted them by phase, which has made it easier for us to compare the Dutch phases with them. We have left Jarvis’ grouping of the American states intact for our synopsis. His division is into four regions: the Northeast, the South, the Midwest and the Far West. The following map of the U.S. (Fig. 3-1) illustrates the meaning of the four regions.
The four regions are comprised of the following states: the Northeast includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and the capital Washington, D.C.; the South consists of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; the Midwest includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; the Far West consists of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Those states excluded form Jarvis’ grouping are Alaska, and Hawaii.
In the early years, till about 1906, cars in the US were predominantly spread over the highly urbanized Northeast, where the early car industry was situated, and the Far West. Jarvis uses this time of urban dominance in car diffusion as a background to his analysis covering the period 1910-69 (See figure 3-2). After 1910, two periods of strong diffusion are roughly discernable. They were punctuated by a time of disruption, spanning from 1930 to 1948. In the time of disruption, the national diffusion speed fluctuated and was even greatly diminished due to the Great Depression and the Second World War. The two periods of strong diffusion were both accompanied by extensive convergence of the regional heterogeneity in adoption levels, even though the convergence was somewhat less in the second period than it had been in the first.

Despite this similarity, the two periods differ greatly in the underlying geographical diffusion dynamics. To gain insight into the changing location of diffusion cores and lagging regions between 1910 and 1920, compare figure 3-2 with figure 3-3. A summary of the developments, in figures, is given in appendix II, table 7-1.

The first period of strong diffusion had three phases. Phase one ran from 1910 to 1920, during which years the old spatial order was replaced by a new one, the latter having a clear distinction between the regions with highly adoptive states and those with lowly adoptive states. The diffusion of the car had started out in the urbanized Northeast of the country, and now the geographical leadership shifted from the urban states of the Northeast and the Far West to the farming states of the Midwest. The year 1920 found the Midwest clearly in the lead in car density figures, the Far West remaining a close second (see figure 3-3 and table 7-1 in appendix II). The Northeast was now lagging behind, as was the agricultural South. This spatial order remained by and large unchanged for approximately three decades thereafter.

55 As to be expected from the fact that consumer goods first diffuse in the vicinity of their production sites (mentioned previously in 1.2.2).
The second phase lasted till 1932, during which the agricultural South continued to have the lowest growth rates and was marked as the major lagging region. The 1920s saw an unprecedented growth rate, particularly in the urban states across all regions of the country. However, even with the agricultural depression of the 1920s, the lead in car
density of the rural parts of the Midwest could not be made undone. After the rapid car density growth of the 1920s, the densest American states in the Northeast of the country started to show a slight loss in growth rates relative to their less crowded neighbours. In phase three, between 1932 and 1945, the overall car density growth was limited, which was in direct relation to the economic crisis and the Second World War. In this phase, the disparity between leading regions and lagging regions, relative to the overall heterogeneity amongst all states, even increased to some extent, so that in 1945 the highest concentration rate of all bench-mark years was reached. This is probably related to the Far West continuing to encroach upon the Midwest. The rural states generally bore the years of disruption with more ease than the urban ones.

The second wave of diffusion consisted of a single, fourth, phase; it spanned from 1945 to 1969 and was characterized by decentralization. After the Second World War, car adoption figures picked up again. Until 1969, growth rates were particularly high in the two lagging regions, especially in that of the South. By 1969, the relative disparity between the leading and the lagging regions was considerably diminished and yet remained remarkable. Eventually, the order of the states in terms of car adoption levels underwent change once more. The Far West took the lead ahead of the Midwest and the highly urbanized Northeast fell back somewhat, still retaining its third place with the South closing the ranks.

What remains unknown is where within each American state the diffusion cores and lagging regions were situated. It is true that the share of farmers amongst all adopters has been impressive since 1910, at which time “0.17 percent of farmers owned 0.50 percent of the registered motor vehicles in the United States; by 1930, 53.1 percent of the rural population owned 50.3 percent of the nation's cars.” Thus it seems likely that rural areas formed a stronghold during the first wave of diffusion in the American diffusion process. Nevertheless, from that supposition we cannot derive clear information on the exact location of diffusion cores and lagging regions. It is possible that at least in some American states the rural counties showed relatively low adoption

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57 Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 156.
rates until well after the Second World War. It is also possible that the cores of diffusion within the states of the Midwest were not only situated in the countryside, but also in the towns and cities. It is possible, too, that the patterns of geographical diffusion differed amongst American regions and states—possibly between rural and urban states in particular.

We cannot derive this information from other studies on car diffusion in the US. Authors writing on rural America, like Joseph Interrante, stress that distance was a great issue in the US: "The automobile significantly changed the lives of farm families by reducing their sense of isolation."\(^58\) This gives the impression that at least in states in which huge rural areas existed, the rural areas, being at a great distance from the agglomeration centers, formed a stronghold of the car adoption process.

In his comparison drawn between the first thirty years of car diffusion in the US and that in Germany, Flik describes the economic situation of farmers in the US.\(^59\) He stresses that the Midwestern farmers used cars to transport their perishable goods quickly to the nearest train station. From there, the goods travelled further to the American population agglomerations and to overseas. This gives the impression that cars would have been particularly popular along the route of the train stations. For cars in America, we have previously argued that the car was particularly functional in the early period to inhabitants of the rural hinterland that were within a 15 kilometre radius of the nearest train connection, because they used cars in combination with the railway services. A similar impression is given by M. Jefferson, who stresses the importance of American railway lines to economic activities.\(^60\) He claims that the economic radius of railway lines was approximately 15 kilometres. Following these lines of argument, we might come to suggest that the size of the rural settlements was possibly less important than the vicinity to a railway station.

\(^{58}\) Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 159.

\(^{59}\) Reiner Flik, "Von Ford lernen?," Automobilbau und Motorisierung in Deutschland bis 1933, (Köln: Böhlau, 2001).

Studies on the appearance of the car in population agglomerations stress the role of the car in the development of suburbs.\textsuperscript{61} Again, we cannot be sure that this means that suburbs formed cores of car adoption, even though this seems likely. Potentially there existed two types of car adoption cores in the US: suburbs in the vicinity of population agglomerations; and large villages, or small towns, in rural areas.

### 3.3 The Dutch geographical diffusion path, from 1900 to 1980

With the American experience as a template, we shall analyse the Dutch long-run geographical diffusion path. In this section we shall describe the Dutch geographical diffusion along the lines of Jarvis' analysis, with Hägerstrand's theory on spatial diffusion patterns as inspiration. We distinguish three elements of geographical diffusion: (1) the convergence of regional heterogeneity of adoption levels, (2) the degree of concentration in the spatial order, and (3) the diffusion cores and lagging regions in car diffusion.

The first element, that of convergence of regional heterogeneity of adoption levels, addresses the questions of how diverse the adoption levels of the geographical units are and how this diversity changes over time.

Element two, the degree of concentration in the spatial order, poses the questions of in which periods the cores and lagging regions were concentrated geographically or whether they were in fact more scattered.

The third and final element, the diffusion cores and lagging regions, addresses the questions of where in the Netherlands the cores and lagging regions were located, or clustered, and how these locations changed over time, as well as of what nature they were, i.e. rural or urban.

We shall tackle these questions one by one in sections 3.3.1 to 3.3.3. In section 3.3.3 we shall also discuss the comparability of the data on car registrations.

3.3.1 The convergence of regional heterogeneity of adoption levels

We start our analysis of the Dutch long-run geographical diffusion path with an initial overview of the convergence process. Following Hägerstrand, it is a well-known stylized fact that the variation between regions of adoption levels of innovations changes over time. The concept is broadly structured as follows: in the beginning of the diffusion process, the innovation is only known of at very few locations in any given country, these are where people start to adopt the innovation. The disparity in adoption levels between these early diffusion centers and the rest of the country increases so long as the innovation is not widely known of yet. As the knowledge about the innovation spreads from the diffusion centers to other places in the country, the innovation itself spreads too. Eventually, the regional heterogeneity in adoption levels diminishes, because the demand in the early diffusion centers has been satisfied and the rest have caught up and reached the same level of adoption. In view of this concept, we set out to learn which long-run changes in the interregional variation of adoption levels the Netherlands experienced and how these relate to the convergence process in the US.

In order to achieve a long-run overview, we approach these questions on a provincial level, since there was a gap in registration figures on the level of municipalities from 1906 to 1927. To establish an initial overview, we show two data series in the graph in figure 3-4. The first concerns car density figures—cars per thousand inhabitants—for the period 1899-2007. This series is representative of the well-known longitudinal change in adoption levels in Dutch car diffusion. The second series shows the coefficient of variation of eleven provinces for the same period, which is indicative of the spatial variation in adoption levels. The same indicator is used by Jarvis. The coefficient of variation is a measure for the dispersion of a distribution. It is defined as the standard deviation divided by the mean. The coefficient can move upwards from zero, with a higher number showing stronger dispersion around the mean. It is often used to show whether the mean of the distribution represents the overall trend of a data-set fairly accurately. This is not the case if a large number of observations is at a considerable distance from the mean.
Fig. 3-4. Diffusion of and convergence in car ownership in the Netherlands, from 1899 to 2007\textsuperscript{62}

![Graph showing car ownership diffusion and convergence]

Sources: See list of sources.

NB: Since 1956 the motor census contains data on the additional, twelfth province: \textit{Flevoland}. This is excluded in the coefficient of variation through to 1990.

Because we display the two time series in a single graph, we can see that the dynamics of the two dimensions change by following a similar sequence. Therefore, from this graph we are able to draw an initial sketch of a periodization. On the basis of this periodization we can then compare the Dutch geographical diffusion dynamics with the

\textsuperscript{62} Credit goes to Peter Staal, who has selected the data, on which this graph is based.
American ones.\textsuperscript{63} A periodization is very helpful, because for the analysis that is to follow we have to confine ourselves to a few bench-mark years, and a periodization can aid in choosing those years which are most appropriate. From figure 3-4 we can identify five periods of car diffusion: (1) early diffusion, (2) the first wave of diffusion and convergence, (3) retardation, (4) the second wave of diffusion and convergence, and (5) saturation.

The first period, that of early diffusion, took place between 1899 and 1905. The heterogeneity in adoption levels, compared to the mean, decreased immediately after 1899 and subsequently increased again. The data points for 1900 to 1905 suggest a divergence occurred. This suggestion stems from the fact that a small number of very small places got to possess one to two cars. Larger places often did not possess more than three cars either, but the car density figures of small places look extremely high in comparison to all other places. Thus the variance in car density grew, while in fact more and more places became acquainted with the new product. The car density figures remained marginal—below 0.3 cars per thousand inhabitants.

Between 1905 and 1908 there is a gap in the data. Thereafter we can observe a second period. The second period constitutes the first wave of diffusion and convergence. Between 1909 and 1924, the coefficient of variation plummeted from 0.61 to 0.20. This indicates that the provinces became more similar in terms of their car density rates. Simultaneously, the overall adoption level increased rapidly.

The third period ran from 1928 to 1954, during which diffusion almost stagnated.\textsuperscript{64} It is therefore called the period of retardation. Until 1954 the dispersion around the mean remained stable, which meant that adoption levels did not further assimilate. It was not before 1954 that the adoption rate showed signs of a substantial rise again.

The fourth period hails the second wave of diffusion and convergence. The diffusion curve for this period, 1955 to 1980, looks very steep: the average adoption level rose drastically. In conjunction with this, the existing regional differences were marginalized, since in 1980 the figure for the coefficient of variation is below 0.05. Its decline, however, had been somewhat less steep this time round.

\textsuperscript{63} For a provisional periodization of early Dutch car diffusion on qualitative grounds see Gijs P. A. Mom and Ruud Filarski, Van transport naar mobiliteit. de mobiliteitsexplosie (1895-2005), (Zutphen: Walburgpers, 2008).63.

\textsuperscript{64} There are no figures available for the years spanning the Second World War.
The fifth period is that of saturation. After 1980, the diffusion curve flattens, indicating a reduced adoption rate in the country as a whole. Possibly, this development is indicative of saturation being achieved. In this period, the spatial variation around the mean marginally increased again, i.e. adoption levels became slightly more heterogeneous once more.

If we compare the pattern of convergence with that of the US, the similarities are evident. In figure 3-5 we depict Jarvis' results on convergence and overall diffusion in the US. Unlike in the graph above for the Netherlands, the graph on diffusion is here not scaled logarithmically.

Fig. 3-5. Diffusion of and convergence in car ownership in the US, from 1910 to 1969
Coefficient of variation on car density through the American states

Notes: Coefficient of variation is on car density through the American states.

Even though the car density figures in the US were at all times considerably higher than in the Netherlands, the basic pattern of diffusion and convergence seems to have been identical: in both countries the speed of convergence was strongly related to the overall diffusion process, in both countries the convergence process had already started by 1910, there were two waves of diffusion and convergence punctuated by the period of economic crisis and the Second World War, the second wave of convergence was somewhat less drastic than the first one, and even the absolute time frame (as opposed to the time frame related to a country's time of origin of the diffusion curve) was similar.
However, there are also differences to be found: the geographical variation in the US started out at a somewhat higher level and did not approach the extraordinarily low Dutch level until 1969, and the retardation phase in the US was shorter than in the Netherlands.

In addition to the three diffusion phases Jarvis distinguishes, we can observe two more phases for the Netherlands. This could very well be due to the lack of data for the US, since Jarvis' analysis does not concern itself with the years prior to 1910 and those following 1969, which is when, for the Netherlands, we can observe the phases of early diffusion and saturation respectively.

We can conclude that, in respect to convergence of interregional differences, the Netherlands thus far does not seem drastically delayed. In 1955, it started its second wave of diffusion and convergence, only nine years after the US had started theirs.

To summarize, the similarity between the US as the leading country and that of the Netherlands as follower country might be taken as evidence of the almost synchronic following of the same geographical pattern. However, as long as we have not investigated the other elements of geographical diffusion which Jarvis uses in his analysis of the American states, this is merely a tentative and preliminary conclusion. We have not yet gained insight into the underlying geographical dynamics which lie at the basis of those agglomerated dynamics sketched here.
3.3.2 The degree of geographical concentration

In this section we shall look at the degree of concentration in the geographical structure of a country. The question here is to what extent places with low and high adoption levels respectively were clustered around one or more areas of the country. In principle, this may well have taken a scattered and unsystematic form. However, when following Hägerstrand, this would seem unlikely in the long-run. People who live in the vicinity of early diffusion centres, get to know about the innovation earlier than people anywhere else in the country. They in turn inform their immediate neighbours. Hence, the innovation will spread in a wave-like fashion outwards from their innovation centres. In addition, the places that become acquainted early on with the innovation show higher adoption levels during most of the diffusion process. These dynamics are expected to express themselves in a certain spatial order of adoption levels. We want to know whether the degree of concentration in the Netherlands followed the same sequence as in the US.

As previously mentioned, Jarvis groups the American states into four regions. He does this according to their location and degree of urbanization. His criterion for concentration is the variation of the adoption levels between the four regions as a percentage of the variation between all separate states. This criterion is called the interregional proportion of variance, and it indicates to what extent places, ranging from highly to lowly adoptive in nature, cluster in one or more of the four regions, which are static by nature.

The interregional proportion of the variance in the US over time is shown in the fourth column of table 3-1. The higher the percentage of interregional variance as part of the variance as a whole, the higher the number of lowly respectively highly adoptive states that cluster in at least some of the four regions. In the US of the year 1910, the states within each of the four regions were rather heterogeneous in terms of adoption levels. The interregional proportion of variance was down to 0.36. This effectively means that the differences within each region when added together were larger than the differences between the regions. The concentration level amongst the regions increased sharply between 1910 and 1932. The percentage of the variance, which can be attributed to the differences between regions, almost doubled in this period. The concentration became further intensified running up to 1945, but at a lesser rate. After that, the clear geographical divide between highly and lowly adoptive regions was to a considerable extent dissolved again. By 1969, the concentration rate was even slightly below the concentration rate of the year 1910, namely 0.32.

Table 3-1
Interregional Variance on Registered Autos Per 100 Population

53
Jarvis' analysis does not include any information on the changing concentration rates within the states. In principle, it is possible that the within-state dynamics followed an entirely different dynamic and/or that they differed between states. For example, it is possible that in 1910, when there was a low interregional concentration level, cars were highly concentrated in urban or rural areas. This within-state heterogeneity is not visible in the car density figure of the states themselves, which is simply the average of all places within this state. Thus, if we find similarities or differences in respect to the American pattern, we still cannot conclude that they behave either similarly or differently on the scale of relative small areas.

Before we compare our own results with those presented by Jarvis, we shall explain why we used a different criterion for the concentration rate than Jarvis did and how this criterion works. Our criterion for concentration is more flexible and allows for more detail than that of Jarvis. In contrast to Jarvis, we capture the changing degree of concentration on the basis of spatial autocorrelation. This way, we avoid superimposing a readily fixed geographical structure on the data. Moreover, we can distinguish between clusters on a local scale and clusters on a regional scale, and investigate whether the clusters were predominantly local or regional in character. We shall go on to explain what spatial autocorrelation means and how it can be measured.

If data points for a number of geographical units are spatially structured, this will usually take the form of a value in a certain place being similar to values of its surrounding places and strikingly dissimilar to that of distant places. The statistical term for this is spatial autocorrelation and it means so much as that the observations of car
densities are in a more or less systematic way ordered by the location of the places. Moran's I is a measure of this spatial autocorrelation and can be used to measure the degree to which lagging areas and diffusion cores are geographically separated. Note that Moran's I does not give any indication as to where, geographically speaking, clusters of highly or lowly adoptive places occur. This will be investigated after we have established the existence as such of these clusters. Moran's I for car density is generated by a bivariate correlation between the car density of a specific location and the car density of its surrounding regions.

Fig. 3-6. Example of a bivariate correlation between car density and spatially weighted car density; car diffusion in Dutch municipalities in 1930.

Sources: See list of sources.

a CARDENS stands for car density, and W-CARDENS for spatially weighted car density.

Spatial weight: Four nearest neighbours.
Number of observations: 1039.

The graph given above in figure 3-6 serves as an illustration for the bivariate correlation. The variable on the horizontal axis is the car density in 1930, the vertical axis features spatially weighted car density for the same year. The dots in the graph represent municipalities. Spatially weighted car density is the car density in the municipalities surrounding a particular place. For the graph, we have opted to include the four municipalities that are nearest to it. We could use other scales, e.g. all municipalities within twenty-five kilometres of Amsterdam, or the ten nearest neighbours (as has been done for table 3-2). If spatial concentration takes place, an upward sloping line is expected to be visible in a graphical representation of the data. An upward sloping line means that municipalities with high (low) car density are also surrounded by municipalities with high (low) car density. The dark grey line
intersecting the points is a regression line. The slope of that line (regression coefficient) is the Moran coefficient for these observations. The value of 0.39 is statistically significant, which means we have significant spatial autocorrelation. This indicates spatial clustering, i.e. concentration of highly and lowly adoptive places.

Let's look at the degree of concentration in the Netherlands. Table 3-2 below shows significant Moran's I values for various spatial weights. For the years 1900 and 1905, the Moran's I values as given in table 3-2 are those on the number of cars rather than on car density. In this period, there were so few cars that the density numbers can be misleading. We shall first give a broad comparison between the US and the Netherlands before going into more detail about the Dutch concentration dynamics. The Netherlands has its basic pattern of concentration and decentralization in common with the US. The first adoptions appear to be rather scattered. Nonetheless, growth was already somewhat ordered towards certain regions, and away from others, in 1905/1910. The first wave of diffusion and convergence served to establish a clear spatial order. This means that while the differences between lowly and highly adoptive places steadily decreased, the predictability of the location of the respective places or states increased correspondingly by virtue of the level of car ownership in the surrounding places. The second wave of diffusion served to weaken the spatial order to quite an extent. Towards the end of the observation period, the locations of highly and lowly adoptive places looks rather haphazard once more. At that point, the differences between highly adoptive places and lowly adoptive places were almost negligible, anyway. There are minor differences in timing between the two countries, and we do not know to what extent they are caused by the use of different methodologies. The Netherlands reached its largest concentration level before the Second World War, while the US did so afterwards.
Table 3-2 Spatial Autocorrelation in Dutch Municipalities, from 1900 to 1980
Significant Moran's I Values at Various Spatial Weights

<table>
<thead>
<tr>
<th>Period</th>
<th>Early Diffusion</th>
<th>1st Diffusion Wave</th>
<th>Retardation</th>
<th>2nd Diffusion Wave</th>
<th>Satu...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Weight</td>
<td>Number of Cars</td>
<td>Car Density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>1900 1905 1900 1928 1930 1938 1950 1965 1980</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearest 4 Neighbours</td>
<td>0.002 0.027 0.006 0.353 0.389 0.374 0.265 0.350 0.101</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearest 10 Neighbours</td>
<td>0.003 0.014 0.006 0.311 0.342 0.309 0.230 0.275 0.084</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearest 16 Neighbours</td>
<td>0.002 0.009 0.001 0.279 0.300 0.267 0.203 0.228 0.066</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearest 22 Neighbours</td>
<td>0.002 0.009 0.004 0.259 0.279 0.245 0.184 0.203 0.050</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 kms Circle</td>
<td>0.004 0.014 0.003 0.315 0.342 0.319 0.242 0.291 0.101</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 kms Circle</td>
<td>0.006 0.012 0.001 0.196 0.213 0.185 0.150 0.137 0.053</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 kms Circle</td>
<td>0.001 0.003 -0.001 0.125 0.143 0.126 0.119 0.069 0.023</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 kms Circle</td>
<td>0.000 0.003 0.001 0.093 0.107 0.095 0.093 0.037 0.007</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: See list of sources.


Aside from the direct comparison with the US, we can also learn from the Dutch case how local and regional concentration in the various periods was related to each other. Even though in the Netherlands the differences in car ownership between lowly and highly adoptive regions were present on both a small scale, that of the four nearest neighbours, as well as for larger distances, the spatial structure was more pronounced for the smaller of the two. The year 1900 forms an exception to this: many of the earliest car adoptions took place in a certain region or regions, yet within those areas these adoptions were rather scattered. Consequently, the Moran's I value in 1900 is
higher for relatively large regions, with a radius of 25 kilometres and beyond, than for the smaller regions. After 1900 the relation between local and regional structure was reversed. Places with high respectively low car ownership levels began clustering tightly into groups of just a few member places. The likelihood existed that such local clusters would in turn cluster on a larger scale in certain regions, but the spatial structure remained somewhat less coherent on the larger scales than on the small ones. On a local scale, many regions were either homogeneously lowly adopting or consistently highly adopting, but most larger regions had mixed adoption levels. Moran's I is therefore highest with narrowly defined neighbourhoods, such as the nearest four neighbours or the ten kilometre radius, with the value of Moran’s I gradually decreasing as we move up the scale from small regions to large ones. In the period in which the spatial structure was the most extended, being the retardation period between 1928 and 1950, the spatial structure on the regional level had equally risen. The value of Moran's I for the larger spatial weights, i.e. 25 to 75 kilometres, changes more drastically in proportion to the value of Moran's I for the smaller spatial weights in the periods 1905-28 and 1950-65. This might indicate that some of the local clusters eventually merged into larger areas during the time of the geographical structure’s highest extension. However, these mergers fell to pieces again quite soon after 1950, so that the spatial structure on the regional level rapidly weakened again.

In summarizing, the two waves of diffusion and convergence seem to have had exactly the same function in the US as in the Netherlands. The spatial patterns, which we have identified here, may well be general in nature and thus possibly hold for follower countries as well as for leading countries. Furthermore, these patterns abstract from the scale of the geographical units. Again, the high degree of synchronicity between the two diffusion paths seems striking. And yet we know from Staal's analysis that the Netherlands was much later in switching from urban to rural dominance than the US had been. If we wish to understand how this aspect plays a role, we should get to know the actual location of diffusion cores and lagging areas in the Netherlands.

### 3.3.3 The diffusion cores and lagging regions

This section is about the Dutch shift in location of diffusion cores and lagging areas on the level of municipalities. Following Hägerstrand’s theory, we would not expect any change in location of the cores to take place at all: the early cores are established in those places in which the first adoptions occur, from then on these early cores retain their lead ahead of the surrounding areas, until the growth in the early cores stops and the surrounding areas catch up. There might be minor deviations from this pattern, in so far as certain places with beyond local economic and administrative functions might develop into secondary diffusion centres.
Richard Morrill did further empirical research on diffusion waves in space and time and fine tuned Hägerstrand's model. He conjectures that during the catch-up process parts of the former periphery might temporarily exceed the early cores in car ownership. This could happen if an area was approached by two different diffusion waves coming from two sides. These two diffusion waves naturally stem from two different early cores, and when they reach the lagging area in question at the same time, the effects of the two diffusion waves may enhance each other, so that the lagging area in question gets a temporal peak in adoption level. In physics this effect is known as the phenomenon of resonance.

As we have seen in chapter 3.2, the order of the regions, which was established towards the end of the first wave of diffusion and convergence, was as follows in the US: Midwest, Far West, Northeast, and South. During the second wave of diffusion and convergence, the Far West overtook the Midwest and the Northeast and South caught up.

The convergence of urbanized and rural states occurred parallel to these processes. Jarvis provides evidence for this, in that he constructs an index for the degree of urbanization of the American states. The index is based on ten size classes of places, and relates to the weighted percentages which exist for each size class. The size classes are: 1 million inhabitants and over; 0.5 million to 99,999 inhabitants; 250,000 to 499,999 inhabitants; 100,000 to 249,999 inhabitants; 50,000 to 99,999 inhabitants; 25,000 to 49,999 inhabitants; 10,000 to 24,999 inhabitants; 2,500 to 9,999 inhabitants; rural non-farm and rural farm. Jarvis uses three categories, namely highly urbanized, medium urbanized, and lowly urbanized states, and analyses their convergence process.

For 1910, we see the remainders of a spatial order, which we can assume to have existed during early diffusion: the highly urbanized states had by far the highest car ownership levels, the medium urbanized states followed them at some distance, and the lowly

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66 For Jarvis' results, see table 7-1 in appendix II.


68 For Jarvis' results, see table 7-2 and table 7-3 in appendix II.
urbanized states again followed the medium ones at some distance. By 1920 the
Midwest had emerged as leading state, and the medium urbanized states overtook the
highly urbanized ones. The highly and lowly urbanized states both had much fewer
adoptions per hundred inhabitants and had an almost equal adoption level.
Between 1920 and 1969 the highly urbanized states caught up close to the leading
medium urbanized states. In fact, they temporarily showed slightly higher car density
levels compared to the medium urbanized states in 1932. The lowly urbanized states
converged closer to the other two categories as well. However, their catch-up was
particularly strong in the years after 1945 and they remained in the position as followers
to 1969. Overall, some degree of heterogeneity between the three categories in the
previous order remained up to 1969.

The changing location of diffusion cores and lagging regions can be analyzed in one of
two ways. The traditional way is to show the regional car density level on maps. We
shall refer to these kinds of maps as diffusion maps. These diffusion maps lend
themselves to a visual inspection, and when conducted on a series of diffusion maps and
their respective time series the leading and lagging regions can be identified. This is the
approach both Jarvis and Staal use. One disadvantage of this approach is that the
number of regions must necessarily be limited to a manageable number. It is difficult to
systematically summarize the changes over time when dealing with a multitude of
spatial units, such as with municipalities. This is why Jarvis and Staal work with
relatively aggregated spatial units. Nevertheless, we shall use simple diffusion maps,
too, but mainly to make the differences between cores and lagging regions as concrete
as possible.
A second method is to calculate diffusion cores and lagging regions on the basis of
spatial autocorrelation as was explained in section 3.3.2. The resulting maps of this
process are concentration maps. Using concentration maps, we avoid superimposing
static geographical units on the large number of municipalities. With the previous
chapter in mind, we can come to understand the local as well as the regional clustering.

If we use maps in order to judge, to what degree the American and Dutch diffusion
cores and lagging regions were rural or urban in character, we should be aware of a
possible bias, which may be present in the figures that we use. In the US, personal
minivans and utility type vehicles were included in passenger car registrations until
1985, while in the Netherlands this was not the case.\textsuperscript{69} This could bias the American spatial pattern towards states that showed an unusually high demand for the additional vehicle types. However, the variation between the states in the US was so high that it is unlikely that the leading position of the Midwest can be explained mainly on a regional demand for minivans and utility type vehicles.

In the Netherlands between 1928 and 1956, cars and other vehicles were registered at the place where the vehicle was stored, and not at the place of principal residence of the owner as was commonplace in America. We may assume that this creates a bias towards places with a large interregional traffic function or high economic activity, where people, and particularly firms, alien to these places may be prone to store their vehicles there. We compared maps of the period shortly before 1956 and shortly after it and are able to see ample continuity, notwithstanding the switch in registration method. Thus we are confident that the bias, if it exists, remains with both registration methods. This would mean that such a bias exists in either country and the differences in location of leading places cannot be attributed to it.

Let's look at some more technical details concerning the different maps which shall be presented in the course of this book. For each of the years 1900, 1905, 1928, 1930, 1938, 1950, 1965, and 1980 we shall show diffusion maps of the original car density data. The scale of the maps is chosen to highlight low and high values.

In addition, we created concentration maps which are based on Moran’s I. The concentration maps show those areas that are most responsible for the patterns of spatial autocorrelation. Thus one can clearly identify at which locations highly respectively lowly adoptive places cluster together. Hereby, we gain an immediate overview of the spatial structure present in the diffusion process.

Concentrations are statistically defined as those areas that are present well into the upper-right, or lower-left quadrant of figure 3-6 on the bivariate correlation between car density and spatially weighted car density. These are the areas that have high car density and are surrounded by high car density areas (right upper corner) or have low car density and are surrounded by low car density areas (lower left corner). The maps on the pages to follow display these areas. The dark red areas correspond to the upper right corner in the graph in figure 3-6, the dark blue areas correspond to the lower left corner. Concentrations with high values we shall call maximum concentrations, likewise those

\textsuperscript{69} In both countries taxis and passenger vans (with up to eight or nine seats) were included in the registrations and publicly owned vehicles and pickup were excluded.
with low values minimum concentrations. The maps also show light blue and light red areas. These are the municipalities that go against the grain of spatial concentration: high car density enclaves surrounded by low car density, or vice versa (the upper left and lower right quadrants).

We show here two series of maps, one for the 50 kilometres’ radius and the other for the four nearest neighbours. These two spatial weights were chosen, because they generally show higher Moran's I values than the other spatial weights tried in the previous section. The first series of maps uses a spatial weight of fifty kilometres, which makes the opposition between regional cores and lagging areas visible. The maps with the spatial weight of the four nearest neighbours show whether the maximum concentrations were typically in the form of towns and whether the exact location of the major concentrations was stable.\(^70\)

We shall describe the Dutch diffusion dynamics per period, as described in section 3.3.1, and then summarize the diffusion patterns which the Netherlands and the US have in common. However, we leave out period five (saturation), because we cannot make any definite statements on this ongoing process. During the description, we shall refer to "rural" and "urban" areas. These generalizations stem from background knowledge of Dutch economic history and can also be traced back on figure 3-9 in the section 3.3.3.2 on period two below, which gives the Dutch occupational structure in 1930. Our detailed analysis of the spatial dynamics on the level of municipalities ends with the year 1980.

3.3.3.1 Period one: Early diffusion
The early diffusion years are an important period to understand. They can illuminate some theoretical discussions, for which there is data lacking on many other countries. The knowledge we have so far is sporadic and ambiguous. On the one hand, we know from the US and other countries that early diffusion was a predominantly urban phenomenon. This assertion is often underpinned by economic reasoning.\(^71\) After all,

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\(^70\) For those unfamiliar with the geographical make-up of the Netherlands: Appendix I contains maps showing the location of all Dutch provinces as well as the major cities.

\(^71\) For more details on theory see chapter 4.
the earliest distribution centres lie in urban regions, and the infrastructural provisions are better there.

On the other hand, the evidence and reasoning for the scattered, almost coincidental appearance of adoptions is equally valid. The rich elite everywhere took an immediate interest in this "plaything for the rich," and the streets in any case were not prepared for the use of these motorized four-wheelers.

We cover the period of early diffusion with the help of the two benchmark years 1900 and 1905.

When looking at the data used here for the period 1900-05, it should be kept in mind that the data does not only reflect the locations of the users, but also that of the dealers and manufacturers, because it includes their fleet. Car owners were obliged to attach a vehicle registration plate to their vehicles between April 1899 and the close of 1905. The data on this subject was gathered and published by Ariejan Bos et al. At the time, the fleets of dealers and manufacturers did not encompass more than roughly four cars. Yet since the entire number of cars per municipality was so small, this can distort the picture of individual municipalities considerably. Therefore, we avoid deriving our conclusions from the behaviour of individual municipalities.

Already from the very beginning of the diffusion process, there was a greater likelihood of adoptions in a radius of approximately 40 kilometres around the location of car dealers and car producers than anywhere else. We can obtain this information from the diffusion map in figure 3-7 and concentration map in figure 3-8 respectively. Car importers of that time were situated in Amsterdam, Arnhem, Nijmegen, 's-Gravenhage, and Utrecht. Car producers were situated in the same places and additionally in

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72 Ariejan Bos, Hans van Groningen, Gijs Mom, and Vincent van der Vinne, Het Paardloze Voertuig: de auto in Nederland een eeuw geleden, (Deventer: Kluwer, 1996). The use of this data source caused some problems, because data was lacking or ambiguous. The place of residence of the owner was not mentioned for a total of nine cars, and these cars were therefore left out of this analysis. Furthermore, the place name was not always identical with the official municipality name. With the help of recent maps, these official names could in many cases be retraced. However, for 17 cars this proved impossible, and their data was not incorporated in the present analysis. The benchmark date was set to end of year.


Amersfoort, Deventer, and 's-Hertogenbosch. Therefore, especially the provinces Gelderland, Noord-Holland, Overijssel, Utrecht, and Zuid-Holland were systematically more endowed with cars than other provinces.

Within these regions, the spread was almost as scattered as everywhere else in the country. By far the most places that had one or two adoptions were not adjacent to other adopting places. The direct neighbourhoods of the "car cities" Nijmegen/Arnhem, Utrecht, and 's-Gravenhage formed an exception to that. They sported more than two adjacent places with car adoptions. Two of these regions are also marked as dark red, maximum concentrations on the local scale version of the concentration map in figure 3-8: Renkum (close to Arnhem) and 's-Gravenhage with surroundings.

Large cities within the areas around the car industry were particularly favoured. The most cars were located in the "car cities" Amsterdam (54 cars), Nijmegen (18), Arnhem (17), and Utrecht (7). These are impressive numbers if we consider that most places had just one or two cars. The fact that fleets of car dealers and manufacturers are included does not take away the impression that the first within-municipality clusters of adoptions appeared in towns.

If we thought that there was ever a period in which exclusively city dwellers adopted the car, this was wrong. If we thought that there was ever a period, before the construction of cores, in which the diffusion of cars was completely scattered, this appears to be wrong, too. Instead, an order, albeit weak, favouring the regions around the major car manufacturers, and the surrounding towns in particular, was present from the very beginning of diffusion.
Fig. 3-7. Car diffusion in the Netherlands, 1900 and 1905

Cars per thsd. inh. | Percentages of municipalities | Cars per thsd. inh. | Percentages of municipalities
--- | --- | --- | ---
Top 1% | Top 5% | Remaining 95% | Top 1% | Top 5% | Top 10% | Top 16% | Remaining 84%
0.59 to 2 | 0.01 to 0.59 | 0 to 0 | 1.87 to 8.89 | 0.63 to 1.87 | 0.31 to 0.63 | 0.01 to 0.31 | 0 to 0

Number of cars

Sources: See list of sources.
These categories are based on Moran's I values of car density. "Four nearest neighbours" and "fifty kilometres circle" refer to the spatial weights used for the value of Moran’s I. Moran's I is here based on the number of cars (and not car density).

Sources: See list of sources.
During early diffusion up to and including 1905, the overall character of the spatial order described above remained. Like before, it was more likely that people adopted the car in the regions around the car industry, no matter what the size of their own place of residence was, than anywhere else in the country. For example, by 1905 up to 28% of all places in the provinces Gelderland and Overijssel already showed car adoptions. In addition, the first local maximum concentrations emerged. The earliest local clusters of highly adoptive places were situated in those urbanized areas close to the car industry. This judgement is based solely on the number of cars in a number of different places, and is therefore not influenced by the fact that car fleets of car traders or manufactures are included in the data set. The early clusters of highly adoptive places consisted of both the large urban location and the very small places adjacent to it. In fact, the divergence process visible for the first diffusion phase (see figure 3-4) is caused by these little suburbs, which form outliers.

The road for the rapid convergence of the subsequent period was paved by the car being spread to all corners of the country during early diffusion. We will illustrate this with the use of some figures. In the year 1900, 258 cars were registered in 56 different places. No single province was left entirely untouched by the car. Between 1900 and 1905 the total number of cars in the Netherlands increased from 258 to 1444. In the same time, the number of municipalities that showed signs of car adoption increased from 56 to 178.

We can see from the diffusion map in figure 3-7 that non-local spread was very common and continued to reach all provinces. This development was largely acted out by local centres of a substantial size, since they attracted the most cars. For the purpose of illustration, table 3-3 lists those towns which by the end of 1905 had more than 16 car registrations.
Table 3-3
Municipalities With 16 Cars or More, 31 December 1905

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Provincea</th>
<th>Population</th>
<th>Cars</th>
<th>Cars per thsd. inh.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilburg</td>
<td>NB.</td>
<td>46517</td>
<td>16</td>
<td>0.344</td>
</tr>
<tr>
<td>Leiden</td>
<td>ZH.</td>
<td>56724</td>
<td>19</td>
<td>0.335</td>
</tr>
<tr>
<td>’s-Hertogenbosch</td>
<td>NB.</td>
<td>34093</td>
<td>19</td>
<td>0.557</td>
</tr>
<tr>
<td>Haarlem</td>
<td>NH.</td>
<td>68997</td>
<td>24</td>
<td>0.348</td>
</tr>
<tr>
<td>Hilversum</td>
<td>NH.</td>
<td>26417</td>
<td>24</td>
<td>0.909</td>
</tr>
<tr>
<td>Baarn</td>
<td>U.</td>
<td>8280</td>
<td>37</td>
<td>4.469</td>
</tr>
<tr>
<td>Utrecht</td>
<td>U.</td>
<td>114321</td>
<td>50</td>
<td>0.437</td>
</tr>
<tr>
<td>Nijmegen</td>
<td>Gdl.</td>
<td>50684</td>
<td>56</td>
<td>1.105</td>
</tr>
<tr>
<td>Arnhem</td>
<td>Gdl.</td>
<td>61515</td>
<td>66</td>
<td>1.073</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>ZH.</td>
<td>379017</td>
<td>77</td>
<td>0.203</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>NH.</td>
<td>557614</td>
<td>173</td>
<td>0.310</td>
</tr>
<tr>
<td>’s-Gravenhage</td>
<td>NH.</td>
<td>242054</td>
<td>192</td>
<td>0.793</td>
</tr>
</tbody>
</table>

Sources: See list of sources.
a Gdl. = Gelderland; NB. = Noord-Brabant; NH. = Noord-Holland; ZH. = Zuid-Holland; U. = Utrecht (province).

The increase in the number of cars was particularly high in the large cities within the region that extends from Noord-Holland in the West to Gelderland in the East: Amsterdam, Haarlem, and Hilversum, Noord-Holland; Rotterdam and Leiden, Zuid-Holland; Utrecht, Utrecht; Nijmegen and Arnhem, Gelderland. This region was already quite susceptible to the acceptance of cars in 1900. In addition, two places in Noord-Brabant, namely Tilburg and ’s-Hertogenbosch, also showed high car adoption figures. Rotterdam and Tilburg, two cities that ranked among the nineteen largest in 1900, had formerly shown no adoptions, but showed a considerable number of car registrations in 1905.

At the same time, the rural regions, which had few places with more than 10,000 inhabitants, systematically showed the fewest number of cars. These are identifiable as the dark blue areas on the regional concentration map in figure 3-8: Groningen and Friesland, as well as parts of Zeeland and its surrounding areas. These provinces had just fourteen municipalities between them that listed car registrations by 1905. Noord-Brabant, on the other hand, even though it was a rural province did not belong to the regional minimum concentrations due to its possessing a couple of larger cities.

If we compare the Dutch dynamics with that of the US, we see that the basic features of early diffusion look the same provided we leave the differences in scale out of consideration. In both countries, the earliest diffusion cores lay in the neighbouring regions to the sites of the major, early car manufacturers. For both countries that pertains to urbanized areas. For the Netherlands we can go even further and state that in the year 1900 car ownership was both a predominantly urban phenomenon as well as
highly scattered. We cannot compare this last statement with the US, because we do not know how scattered early car diffusion was on a local scale in the US.

3.3.3.2 Period two: The first wave of diffusion and convergence
We describe the developments in the second period of diffusion by comparing the maps of 1905 with those of 1928.\textsuperscript{74} There is a significant gap between these two years if we consider how drastically the Dutch people adopted the car and how speedily the interregional variation diminished in the meantime. However, this gap is unavoidable due to lack of data on the municipal level between 1906 and 1927. The source of all data on car registration since 1928 is the Statistiek der motorrijtuigen published by Statistics Netherlands.\textsuperscript{75}

During the first wave of diffusion and convergence, a new spatial order and a clear regional divide between leading and lagging areas was established. This is visible in the regional concentration map in figure 3.11, where large parts of the country are coloured dark and thus belong to either minimum or maximum concentrations. The location of the, in any case marginalized, national car industry apparently had little to do with this new spatial order.\textsuperscript{76} The new spatial order was much more condensed than the spatial

\textsuperscript{74} The concentration maps of 1905 are not directly comparable with the ones of 1928 and after. This is because the concentration maps are based on the spatial autocorrelation of car density and not of the number of cars. Since 1928, the registration date for cars was 1 August, while that for number of inhabitants was 31 December. In order to calculate car density, these two figures need to be matched, and this matching can be somewhat imprecise. In the time between the two registration dates, multiple small and large adjustments of the area of municipalities would take place. In the extreme case of a merger, the resolved municipality would not show up on the population list anymore and could therefore not be considered. In all other major or minor cases of change, the figures for cars would refer to a different area situation than the population figures and therefore the resulting figures are flawed. Some level of distortion is present for all municipalities, due to the growth of population between August and December. It is no wonder then that the calculated data sets for every year since 1928 show some form of distortion or have cases missing.

\textsuperscript{75} See 1.3.

order that had existed during early diffusion: it encompassed more, as well as somewhat larger, local clusters.
The core of the new Car Belt was highly urban by nature. The local maximum concentrations in the immediate neighbourhoods of the four cities Amsterdam, Haarlem, 's-Gravenhage, and Utrecht formed the core of the new Car Belt along the Western coast. This metropolitan area is called the Randstad.\(^7\) On the regional level, the area of the Randstad is the most coherent area within the maximum concentration with relatively few minimum enclaves. However, the Car Belt did not exist exclusively out of urban areas. Rural areas such as Zeeland belonged to the Car Belt as well.

\(^7\) The Randstad (“Rim City”) is a conurbation in the Netherlands. Currently, its densely populated area consists of a cluster of the four largest cities in the country, which are Amsterdam, Rotterdam, ‘s-Gravenhage, and Utrecht, and several smaller cities, towns and urbanized villages in the surrounding areas. The cities that make up the Randstad more or less form a crescent or chain, which is the origin of its name (rand means “rim” or “edge” and stad means “city” or “town”). The area that is semi-enclosed by the larger cities is called the Groene Hart (“Green Heart”), because of the towns in it being much greener than the cities that envelop them. As of 2009, the Randstad is home to 7.5 million people, which make up almost half of the population of the Netherlands. When other conurbations connected to the area are also taken into consideration, it would have a population of a little over 10 million, almost 2/3rds of the entire Dutch population.


Fig. 3-9. The location of urban and rural places in the Netherlands, 1930

<table>
<thead>
<tr>
<th>Number of inhabitants</th>
<th>Percentages of municipalities</th>
<th>Inhabitants per square kilometre</th>
<th>Percentages of municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>78.234 to 757.386</td>
<td>Top 1%</td>
<td>4.477 to 10.443</td>
<td>Top 1%</td>
</tr>
<tr>
<td>7.105 to 78.234</td>
<td>5(^{th}) quintile without top 1%</td>
<td>283 to 4.477</td>
<td>5(^{th}) quintile without top 1%</td>
</tr>
<tr>
<td>3.828 to 7.105</td>
<td>4(^{th}) quintile</td>
<td>153 to 283</td>
<td>4(^{th}) quintile</td>
</tr>
<tr>
<td>2.306 to 3.828</td>
<td>3(^{rd}) quintile</td>
<td>102 to 153</td>
<td>3(^{rd}) quintile</td>
</tr>
<tr>
<td>1.314 to 2.306</td>
<td>2(^{nd}) quintile</td>
<td>78 to 102</td>
<td>2(^{nd}) quintile</td>
</tr>
<tr>
<td>206 to 1.314</td>
<td>1(^{st}) / bottom quintile</td>
<td>8 to 78</td>
<td>1(^{st}) / bottom quintile</td>
</tr>
</tbody>
</table>

Percentage of agricultural employment out of entire employment

Sources: See list of sources.
The lagging regions were mainly located in certain relatively expanded rural regions, as well as in regions with mixed employment structure. On the map in figure 3-9 one can see that the Netherlands did not possess large, exclusively rural regions in 1930. *Drenthe* and *Noord-Brabant* were, particularly in terms of employment structure, rural provinces. They formed part of two regional minimum concentrations in 1928. The Southwest became the part of the country with the least adoptions per thousand inhabitants. The entire provinces of *Noord-Brabant* and *Limburg* are marked on the regional concentration map in figure 3-11 as minimum concentrations – astonishingly interconnected with only a few maximum enclaves. Their adoption levels appear low on the diffusion map in figure 3-10, too. To illustrate, 12 out of the 32 municipalities that were without adoptions were located in *Limburg*. *Limburg*, which possessed more industrial places than *Noord-Brabant*, shows the most incoherency in this minimum concentration. A second, somewhat smaller minimum concentration on regional scale was situated around Southern *Drenthe*.

Fig. 3-10. Car diffusion in the Netherlands, 1928

| 1928 | Sources: See list of sources. |
Fig. 3-11. Geographical clusters and enclaves in Dutch car diffusion, 1928

These categories are based on Moran's I values of car density. "Four nearest neighbours" and "fifty kilometres circle" refer to the spatial weights used for the value of Moran's I.

Sources: See list of sources.
High car adoption growth remained directed towards large places everywhere in the country and their immediate, sometimes small, neighbours. As a result, there was quite a bit of variation in adoption levels along the Western coast in 1928. This is expressed on the local concentration map in figure 3-11 in the fact that the various clusters are separate from each other. In the regional concentration map in the same figure, the fact is expressed as numerous minimum enclaves dispersed among the maximum concentrations. In the lagging region of Noord-Brabant immediate neighbours of the towns Tilburg, 's-Hertogenbosch and Eindhoven form maximum enclaves. The large Western city Rotterdam formed an exception to the rule: Large places first. On the local concentration map, Maasland, a place next to Rotterdam, formed the centre of a very small minimum concentration. This is likely to have been related to the low income level in Rotterdam, which was due to the amount of labourers in this harbour city.

The regional variation between the, mainly urban, diffusion cores and the, mainly rural, lagging regions was small, because the periphery (in the sense of a conjunct area without any adoptions) had vanished during this second period of diffusion. If we compare the diffusion maps of 1900 and 1905 with the diffusion maps of 1928, we can immediately see that the latter is much more "green". Since in the maps for the years 1900-38 the brownish colour is reserved for places without adoptions, we can conclude that much more places showed adoptions in 1928 than in 1905. One can see that in 1928, only 5% of all municipalities had not yet accepted the car, as opposed to 84% in 1905.

As in the US, the leading and lagging regions emerged during the first wave of diffusion and convergence. In both countries the distinction between rural and urban areas played an important role in determining the leading and the lagging areas: in the Netherlands, the most urban places and their direct surroundings attracted the most cars; in the US, the medium urbanized Midwest did that. We shall investigate in chapter 5 which elements of urbanization and related elements might have caused the character of the Dutch diffusion cores and lagging regions.

3.3.3.3 Period three: Retardation
For the characterization of the retardation phase we use the maps for 1930 and 1950. The economic crisis of the 1930s and the Second World War contributed to a merely marginal growth in the Netherlands. The disruptive effect of these two events was spread relatively equally amongst all regions in the Netherlands. Therefore, the heterogeneity in adoption levels retained its status quo. The divide between the West, with its large number of places exceeding 10,000 inhabitants, and the East remained as well. Thus it is not true that either urban or rural areas were particularly affected by the disruptions of this period. The few minor changes which we observe in the spatial order would not allow for this conclusion. An example of a relatively small region which was greatly affected lay to the East of Arnhem, in the province of Gelderland. This region with both rural places and places of mixed economic structure continued to drop in
relative car density levels, so that this region in fact became part of the lagging region (see the regional concentration map pertaining to 1950 in figure 3-13). At the same time, a number of places with high car density levels in the direct neighbourhood of this region persisted, they show up as light red maximum enclaves on the regional concentration map in figure 3-13. The dense, and often agricultural, places in the Groene Hart were relatively more affected than the agricultural, dense little places of Noord-Brabant. These places are shown as enclaves in their respective regional clusters on the regional concentration map for 1950, in figure 3-13. They worked against the dominant spatial order and therefore contributed to the weakening of the coherency of the spatial structure (see Moran's I values in table 3-2).

Fig.3-12. Car diffusion in the Netherlands, 1930 and 1950

Sources: See list of sources.
Fig. 3-13. Geographical clusters and enclaves in Dutch car diffusion, 1930 and 1950

These categories are based on Moran's I values of car density. "Four nearest neighbours" and "fifty kilometres circle" refer to the spatial weights used for the value of Moran's I.

Sources: See list of sources.
In rough comparison to the US we can again see some similarity: in both countries the spatial order did not change significantly during the period of disruption, which is unsurprising given the poor increase in car ownership levels. Jarvis gives us to understand that, in the US, the rural states generally kept a higher car density level than the urban ones. In the case of the Netherlands, albeit on a much smaller scale, we cannot make such a generalization.

3.3.3.4 Period four: The second wave of diffusion and convergence

We use the maps for 1965 and 1980 in order to describe the dynamics of the second diffusion wave. With the choice of these bench-mark years, there is always a fifteen year interval between each bench-mark year since 1950. During the second wave of diffusion and convergence, a new spatial order was once more created. As car density figures climbed to heights far above the levels seen before the Second World War, the “car escape” out of the extremely dense population agglomerations of both Noord-Holland and Zuid-Holland took place. This effectively meant that the regions within the traditional diffusion core stopped their extensive growth. The highest car density levels of the country were redirected towards somewhat less dense areas in the formerly lagging regions. ‘s-Gravenhage, Haarlem, and Utrecht—those cities which had formed the core of the Car Belt since at least 1928 remained unaffected by these developments until 1965. These three cities and their direct neighbours remained the axes of a regional maximum concentration. This would appear to be the main reason why autocorrelation on a regional level was not weakened until 1965. However, locations around this stronghold had been disintegrating. Zeeland, the Groene Hart and northern Noord-Holland almost entirely vanished as local maxima on the local concentration map in figure 3-15.

As the regional variation continued to decline after 1965, the dichotomy between rural and urban areas lost much of its importance. In many Dutch areas, including almost the entire West coast, places with "high" and places with "low" car adoption levels were now located next to each other without any clearly identifiable spatial structure. These areas are coloured white on the concentration map for 1980 in figure 3-15.
Fig. 3-14. Car diffusion in the Netherlands, 1965 and 1980

Sources: See list of sources.
Fig. 3-15. Geographical clusters and enclaves in Dutch car diffusion, 1965 and 1980

These categories are based on Moran's I values of car density. "Four nearest neighbours" and "fifty kilometres circle" refer to the spatial weights used for the value of Moran's I.

Sources: See list of sources.
During the second wave of diffusion and convergence, the formerly lagging areas caught up. This seems to have occurred much like a wave that moved from north to south, or from the somewhat prosperous areas to the least prosperous areas. As the regions in the East one by one drew level, they attracted (at least temporarily) a more than average number of cars. It is possible that Morrill's idea of temporal peaks applies here. Until 1965, the mid- and northeastern areas caught up most. Only the poorest part of the country, the Southwest, persisted as a lagging region in 1965, as is visible on the regional concentration map in figure 3-15. This region became less and less coherent, a result of a few places within Noord-Brabant catching up as well. In 1980, the whole of Noord-Brabant and Limburg had caught up.

The late "switch" from urban to rural dominance that took place in the Netherlands was in this perspective not late, but possibly unique. By contrast, the US did not experience the major lagging region catching up, and even exceeding the diffusion cores in terms of car density, even though only temporarily, until 1969–though it is possible that the US experienced this only after 1969. Neither did the US experience the complete dissolution of the former cores: the overall interregional variation remained too high for that to happen. For the US, the South was the lagging region; in the Netherlands it was the East, particularly the Southeast. In the US, the Far West eventually exchanged its secondary position with the Midwest and took over the lead. We do not know, whether this hints at the US and the Netherlands sharing the same sequence of events, i.e. that the lagging areas caught up in the same order, with the least lagging areas being the first to do so.

Staal appears to have been right to be sceptical about equating the Dutch late switch from urban to rural with the American rise of the Midwest. According to our analysis, these two dynamics should not be equated, because they belong to different diffusion periods. However, this last period of diffusion features striking similarities between the US and the Netherlands as well: the function of the second wave of diffusion and convergence was the same for both countries in that the regions which previously had the lowest car density now managed to catch up, and in both countries these regions were rural in character.

78 As described at the start of this section 3.3.3.
3.4 Conclusion

The switch from urban to rural dominance indeed occurred between 1965 and 1980 in the Netherlands. However, this does not mean that it is structurally late in its geographical diffusion path, to conclude this would be faulty for two reasons. Firstly, because it would wrongly equate the catch-up of the Dutch Southwest with the rise of the American Midwest as diffusion core in an earlier diffusion period. In fact, both countries show the same pattern of geographical diffusion in a similar timeslot. Secondly, because it would assume that in the US the diffusion cores on the level of counties or municipalities were exclusively rural, which is something we cannot find support for.

We shall corroborate these conclusions by summarizing the basic pattern of geographical diffusion. In both countries, we see two waves of rapid diffusion interjected by a period of retardation. After early diffusion, until around 1905-08, the convergence of regional heterogeneity seems to be a function of the diffusion rate, and time. Therefore, the two diffusion waves are both accompanied by a wave of convergence, with the second wave being somewhat less pronounced than the first wave. During the first wave of convergence a stable spatial order was established with a clear spatial divide between diffusion cores and lagging areas. In the US, the medium urbanized Midwest took the lead. In the Netherlands, the provinces along the Western coastline constituted the diffusion cores. This area saw large, urbanized places existing side by side with very small, yet often densely populated places. The core area encompassed sections of the provinces Zuid-Holland, Noord-Holland, and Utrecht, which amongst the three of them hosted the largest cities of the country. After the Second World War, the lagging regions caught up, which resulted in decentralization. The catch-up process might well have occurred in spatial waves, but we cannot be sure of that. In accordance with this interpretation, the catching-up process looked as follows: as the wave of diffusion swept through the two countries, the formerly lagging regions in turns even exceeded the former cores in car density, the least lagging of the regions always being the first to do so. Eventually, we can observe for the Netherlands that high car density levels were reached in the Southwest, the region which had been the prime laggard. The time framing of these diffusion dynamics is not remarkably different for the two countries, notwithstanding their considerable differences in take-off year of the aggregated diffusion curves.

Even with the large difference in scale, we can observe certain similarities in the way in which diffusion cores both appear and alter. In both countries, the initial dominance of urban areas during the phase of early diffusion was compromised soon after the turn of the 20th century. The diffusion cores were not exactly identical to the original urban growth centres at the fin de siècle, but none of the original growth centres ever turned into a prime laggard region. The prime laggard region constituted a traditionally poor, rural area. In the US, this was the South; in the Netherlands, it was the Southwest.
spatial order thus established was retained until after the Second World War in both countries. Thereafter, the lagging regions caught up.
4 How can one interpret the Dutch geographical diffusion path? On theory and historical background

4.1 Introduction
This chapter concerns possible interpretations of the Dutch geographical diffusion path as described in the previous chapter. The possible interpretations are derived from theory also employed to understand the American geographical diffusion path. The car owed its popularity in the American hinterland to the reduction of the sense of isolation it gave the rural population. This idea figures prominently in the American literature on car diffusion. In a small country like the Netherlands, such a sense of isolation could hardly take hold, because the country does not include a vast hinterland and because at the beginning of the 20th century the Netherlands already possessed an extensive public transportation system: both the train and tram network were quite pervasive. The lack of isolation in the Netherlands might be one of the main reasons that the Dutch diffusion cores were mainly urban, and not rural, in character. Since we wish to understand the Dutch geographical diffusion path, we shall consult various theoretical approaches in this chapter to see what may further our understanding of it. We shall consider three bodies of literature, namely social diffusion (following Everett M. Rogers), the theory of contagious diffusion, and microeconomic demand theory. Jarvis builds his explanatory model on the latter two of these three and he seems to take on concepts of the social diffusion theory as well, even though somewhat more implicitly. Furthermore, we shall describe how the theoretical rules may be expected to have operated given the economic and social situation of the Netherlands. Thus, we shall take the economic and social history of the Netherlands into account. In order to do justice to the specific, local circumstances, we shall distinguish between those parts of the Car Belt which were urban in character and those that were rural in character. We shall go on to argue that it is unlikely that isolation was as important a consideration in the Netherlands as it was in the US.

4.2 Overview of three theoretical perspectives
In this section we shall discuss the theoretical grounds for the expectation that rural areas quickly supersede urban areas in car density levels, as well as alternative expectations. For each string of theory, we shall first introduce the basic ideas and concepts and then discuss the implications of the expectations related to rural car adoption. We shall find that on theoretical grounds we cannot extrapolate the American experience and are unable to claim a general rule that suggests early dominance of rural places in the car diffusion process.
4.2.1 The contagious diffusion model

Hägerstrand’s theory of contagious diffusion has motivated Jarvis' book and is because of this associated with the idea that rural areas "naturally" supersede urban areas relatively early in the car diffusion process. In our view, this interpretation of Hägerstrand's theory is wrong. We can use this theory, coming to quite different insights regarding the spatial diffusion process.

The theory of contagious diffusion dates back to Hägerstrand's *Innovation Diffusion as a Spatial Process*. It is Hägerstrand's belief that innovations spread in space and time by virtue of the "telling" to non-adopters by adopters. The assumption here is that diffusion of information is at the core of diffusion of innovations. People are connected with each other in social networks. Within these networks they exchange information about the innovation. The decision of an individual to buy or adopt a good is, then, in part a function of the frequency with which this person is exposed to the innovation by friends and colleagues.

According to Hägerstrand, social networks are local in character, i.e. by far the most social connections lie within five kilometres of a person's residence. Additionally, the contacts which lie in this area are the most frequently sought out. This is the reason why the concept of space matters to the diffusion of innovations. It is clear from various statements by Hägerstrand that the term “information” should not be taken in a narrow sense, which would mean that no more than the sheer information about the existence of the innovation and its objective characteristics is being exchanged in social networks. That is why he uses phrases such as “influence process”. If non-adopters would accept the innovation immediately after the first contact with it, then the innovation would spread at the speed of a rumour. Evidently, this is not the case. Social influence works only with repetitive instances of communication. Therefore, the rate of adoption depends on two factors: firstly, on the frequency with which one is exposed to instances of social influence in one's social network. If a non-adopter is surrounded by many

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79 The five-kilometre radius is drawn from the empirical analysis of data on migration in the period 1935-39, as well as from data on telephone traffic in the year 1950. Torsten Hägerstrand, Innovation diffusion as a spatial process, (Chicago [etc.]: The University of Chicago Press, 1967). 167-234.

adopters with whom there is frequent exchange, one is likely to adopt quicker. Secondly, the rate of adoption depends on the degree of "resistance", i.e. how many instances of social influence are necessary before one makes the decision to adopt. "Resistance" is a term for a person's willingness and opportunity to accept innovations. Hägerstrand elucidates: "In reality, extremely few people can be expected to accept an innovation upon initial contact with it. The barriers may be many, all the way from rational economic considerations to a more unreasoned aversion to change."\textsuperscript{81} In principle, everyone will eventually take the decision to adopt.

With the aid of this theory, Hägerstrand is able to explain why innovations spread wave-like outwards from early diffusion centres. As a stylized fact, he observes three stages in diffusion waves. In the first stage, the early cores develop. This means that in the beginning of diffusion, early adopters agglomerate in a few spots, namely where the first acceptances have taken place. These spots are called the diffusion cores. All other places, where no acceptances have taken place, are called periphery.

During the next stage, "Radial dissemination outward from the initial agglomerations is accompanied by the rise of secondary agglomerations, while those original centres simultaneously continue to condense."\textsuperscript{82} This can in large parts be understood through the neighbourhood-effect: since information is spread locally, those parts of the periphery that are closest to the cores will be first to show new acceptances. Because of this, the cores slowly increase in size. The waves spread rather symmetrically around the first adoption agglomerations, since "a person's private information field generally surrounds him almost uniformly in all directions."\textsuperscript{83} Simultaneously, the information about the innovation is spread further within the cores themselves and thus the number of acceptances there rises continuously.

In the third stage, the growth ceases. There is nobody left who has not yet adopted. Growth ceases first in the cores, since they show the highest adoption level. Adoption

\textsuperscript{81} Torsten Hägerstrand, Innovation diffusion as a spatial process, (Chicago [etc.]: The University of Chicago Press, 1967). 263-64.

\textsuperscript{82} Torsten Hägerstrand, Innovation diffusion as a spatial process, (Chicago [etc.]: The University of Chicago Press, 1967). 134.

\textsuperscript{83} Torsten Hägerstrand, Innovation diffusion as a spatial process, (Chicago [etc.]: The University of Chicago Press, 1967). 237.
levels between cores and periphery will align. Thus Hägerstrand is also able to explain spatial convergence of adoption levels with this model. The reason for convergence is simply that everybody is a potential adopter, i.e. everybody is assumed to adopt.\footnote{Morrill starts from the assumption that resistance levels are systematically higher in the periphery than in the cores of diffusion, since “the diffusion waves usually reach into less appropriate and responsive territory” (262) and he comes to expect that saturation levels remain lower in the outer periphery than in the cores.}

One element remains unexplained in Hägerstrand’s stages of spatial diffusion. In stage two, when cores continue to develop and the diffusion wave unfolds, secondary cores are established. The establishment of secondary cores could simply be the result of spatial variation in resistance.\footnote{Compare Torsten Hägerstrand, Innovation diffusion as a spatial process, (Chicago [etc.]: The University of Chicago Press, 1967). 148.} Still, we would like to introduce another mechanism here, which is brought up by J. C. Hudson, as well as others, and which is called the hierarchy effect.\footnote{J. C. Hudson, "Diffusion in a Central Place System," 1 ed. 1969) 45-58.} He starts with a focus on non-local contacts in private information fields. It is true that the bulk of the contacts in the private information fields are exerted locally, yet non-local, private contacts exist. Morrill, in a collaborative publication, presents the character of distant contacts in comparison with local contacts as follows: “[T]he likelihood of interaction is directly related to size of place and inversely related to distance between the point of interaction and the place. The resulting trade-off between place size and distance may result in a nearby medium-size city [to] have a probability of contact equal to a much larger distant city.”\footnote{Richard Morrill, Gary L. Gaile, and Grant Ian Thrall, Spatial Diffusion, (Newbury Park: Sage, 1988).48.} It is this assumption that lays the foundation for the idea of diffusion along the hierarchy of places. People in larger places are more likely to come in contact with adopters. This might be the case in particular for places that fulfil economic and administrative functions for a larger region surrounding it. Hence, these places develop into secondary cores, from which diffusion waves are generated and progress outwards. In addition to the wave-like diffusion, there is a hierarchical effect. Within a system of places, the hierarchy of the places can be determined through the number of their functions and size of their hinterlands. The
hierarchical effect causes the innovation to spread downwards along the hierarchy of places.

Hägerstrand's theory is sometimes interpreted as if laying the groundwork for the generalization that urban car diffusion centres are superseded naturally by rural areas. In this view, the urban centres are merely necessary predecessors of the "true" rural cores. Cars first spread in the urban vicinity of both car production and distribution sites. Soon they find their way to rural areas, which become the early car cores by virtue of the larger need that exists there, originating out of a lack of availability of public transportation.

We do not agree with this interpretation. In our view, Hägerstrand did not intend to give a general rule concerning this subject matter. The theory as described here does not even deal with the question of which character the early cores possess. It simply starts with the observation that early cores exist, and is an answer to the question of how innovations diffuse spatially from there. In regard to cars in the part of Sweden which Hägerstrand analyses, he observes an opposite development: "[A]t a very early date acceptances were relatively well scattered throughout the entire study area. However, the very first of these were not located in population agglomerations, which is perfectly logical, since the automobile was introduced by estate owners and officers. But by the end of 1920 the automobile had appeared in all presently existing population agglomerations . . ." (emphasis added).

4.2.2 Microeconomic demand theory

In this section we shall show that microeconomic demand theory provides us with concepts and ideas that can contribute to our understanding of an early or late switch from urban to rural dominance. However, this theory does not provide grounds for a single, simplistic rule in this matter. Rather, it can be used as an analytical tool for analyzing the specific economic circumstances under which cars diffused in various countries and places.

Microeconomic demand theory has a long tradition and has developed multiple subschools of thought, each with their own variation in assumptions. This overview does not aim to show the variations between the subschools, but serves purely to sketch the implications of this theory for our expectations regarding geographical car diffusion.

Microeconomic demand theory deals with the purchase of innovations which are for sale. The basic idea in economic theory is that individuals set off the costs of the good against the advantages. This calculation is based on expectations in regard to potential future use. A decision to adopt, which is in this case identical to a decision to purchase, is positive when the possession of the good pays off. Economists abstract from the individual's situation, and they generalize and rationalize adopters' considerations related to costs and benefits. Microeconomic demand theory can be read as an elaboration on Hägerstrand's notion of "resistance". After all, resistance can come in the form of limited economic opportunity. However, there are a few crucial differences in assumptions and perspective, which we shall describe here.

In Hägerstrand's reasoning, social influence is the main factor that leads individuals to the decision to adopt. Economic circumstances can have only a retarding effect. In economics, individuals are considered to be making their buying decision on the basis of rational, economic considerations. This calculation can to some extent be seen as influenced by social elements. The crucial difference between the two schools of thought is not that economists tend to play down the social benefits. On the contrary, in certain schools of economic thought the social implications of the decision to buy or to refuse a good are regarded as a crucial component of the payoff between costs and benefits.

89 We set the decision to purchase here equal to the decision to adopt, because a quantitative possession of cars is easily measured, but not so for the actual use of them.


Economic demand theory has often been applied to locally varying car demand. For example Janine Morice, "La demande d'automobiles en France," Théorie - Histoire - Répartition géographique - Prévisions, (Paris: Librairie Armand Colin, 1957).

The crucial difference between the two schools of thought lies in that in economics the individual eventually makes up his or her own cost-benefit calculation, uninfluenced by social interaction, with as the result that once the payoff appears to be negative, no further social pressure can change this decision over time. Another way of tallying up the differences between Hägerstrand's approach and economic reasoning is to say that for Hägerstrand the saturation level is static and inclusive of the whole population, while for economists the saturation level depends on the economic cost-benefit ratio and is therefore in flux both through time and space. The difference in assumptions practically means that not everybody is a potential adopter, e.g. people who cannot afford a car are not potential adopters at that time. The cost-benefit ratio might be influenced by spatially varying economic and social circumstances. If benefits and/or costs vary spatially, this can explain persistent spatial heterogeneity in adoption levels. Regions in which the cost-benefit ratio is often considered as favourable will show high adoption levels. We shall provide examples of arguments drawn from the economic demand theory in favour of or against a dominance of rural areas early on in the car diffusion process.

As far as the cost side is concerned, the most obvious economic obstacle is the combination of lack of money on the side of the consumers, and high prices for the good. In the case of cars, the initial costs already form a strong barrier: the car has always been a luxury good and its purchase price has been consistently high. However, its running costs are also considerable and form a further economic barrier. Fuel, taxes, costs for parking space, and reparation costs are all examples of running costs. Furthermore, income is of importance as well, because it is not the absolute costs which matter, but the ratio between income and costs. This ratio determines whether a good can be afforded or not. Income, initial costs, and running costs vary in space, e.g. parking is more expensive in cities than in villages. There are areas where a lot of poor respectively rich people live. Thus, we cannot derive a general rule such as "rural areas supersede urban ones" from these notions. Rather, we have to take into account the costs and income levels of various regions. If an urban region, for example, is more prosperous than a rural region, and all other conditions are equal, we can expect more cars in the urban region. Over time, the economic situations of the two regions might reverse, and the car density level can be expected to adjust itself accordingly.
As far as the benefit side is concerned, an individual can be assumed to buy a good, if
the envisaged purpose(s) outweighs its costs. For a multipurpose tool like the car, for
which one can determine the precise aim of each individual ride separately, economists
usually abstract from specific purposes by considering the general technical features of
the good. There are two major features of cars that are often brought forward: speed,
and flexibility. To a lesser extent, comfort is also mentioned.92
Since we wish to explain spatial variation in adoption levels, we shall focus on those
aspects of these qualities, which can vary in space. We therefore introduce the terms
"real speed" and "real flexibility," which indicate how the car actually performed under
certain geographic circumstances rather than its technical optimum without any real-
world restrictions.93
The role of infrastructure is crucial to the concept of real speed. Infrastructural
provisions that matter to the real speed of the car are, for instance, pump stations, sign
posts, and streets. If streets are of poor quality and narrow, real speed can be expected to
be very low, notwithstanding that the true capacity of the car used might be much
higher.
Spatial variation in “speed” can also come to the fore, when the technical characteristics
of the fleet vary from area to area. For instance, the car fleet in wealthy areas might be
of a higher technical standard than the one in poor areas.
Like real speed, real flexibility is also dependent on infrastructural provisions. These
can be captured in the term “connectivity.” Connectivity stands for the ease with which
a place can be accessed from various directions and how it in turn provides easy access
to various directions. The structure of streets can serve as an indication for connectivity.
Comfort is often described in negative terms as the loss of comfort under certain
conditions. This can also be referred to as utilization costs, which is a broader concept
than running costs. Utilization costs are not only expressed in money, but also include
both the effort, and time employed to use the good, as well as the discomfort
experienced while using the good. They can show spatial variation, since the ease with

92 See the discussion on time constraints and infrastructure as present in Arnulf Grübler, The rise and fall
of infrastructures : dynamics of evolution and technological change in transport, Contributions to
93 e.g. Nebojsa Nakicenovic, "The Automobile Road to Technological Change. Diffusion of the
Automobile as a Process of Technological Substitution," Technological Forecasting and Social
which a good is used can depend on infrastructural provisions. Utilization costs rise in places with a lot of car use due to spatial externalities. Spatial externalities are disadvantages and losses, which accompany the use of a good and do not merely strike the user, but rather the people surrounding the user. Spatial externalities can be considered to rise exponentially with the number of users. Noise, danger, congestion, and the lack of parking space—all examples of historically relevant spatial externalities of cars. When spatial externalities effect co-users, this translates into higher utilization costs.

It is often assumed that spatial externalities are larger in crowded population agglomerations than in scarcely populated places. In two places with an identical degree of car use per person, people in the more crowded place will be faced by more accidents caused by the use of cars than people in the scarcely populated place.

The perception of benefits can be shaped by the existence of related technologies. In the case of the car this is important, because the car diffused into an environment where a lot of other transport modes were already in existence. The quality of a good is compared with that of its alternatives. Because benefit estimations are based on expectations, they have a lot to do with customs, social norms, and belief systems. Expectations can be formed through the experience with other transport modes. Therefore, benefits are shaped by the possibility to use and try alternative transport modes. This can both be stimulating or retarding for the innovation in question. For instance, people might be used to the comfort found in trains and find that in comparison with this the dusty car travel is annoying.

The "necessity" argument probably has its roots in this type of reasoning. In areas in which public transport services are limited, the purchase of a car might be found to be worthwhile. On the other hand, in regions with good public transport services a car might appear unnecessary and too expensive. If one assumes that rural areas are less endowed with access to public transportation than urban areas, a higher car density level is expected in the rural areas—with other conditions being equal.

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Another type of reasoning focuses on infrastructural provisions which were laid down for other transport modes. Benefits can be influenced by them, e.g. bicyclists and car drivers alike could use paved roads and hotels. Infrastructural provisions, however, also have a more systemic influence. At the arrival of the car, the structure of the economy had already adjusted to the possibility of long-distance travel, by increasing transport speeds and decreasing transport costs. These structural adjustments created more demand for transport, e.g. the introduction of non-local trams stimulated suburbanization. The car built upon the transport demand fuelled by suburbanization. Thus one may argue that transport demand, and by extension demand for cars, is higher in places where other transport modes, such as train and tram, are well-established. Because the access to alternative transport modes varies in space, so might the benefit functions and the resulting adoption levels.

In his overview of the theories pertaining to this matter, Geels shows how complex inter-artefact relations can be. Here we wish to exemplify how alternative transport modes can stimulate or dampen car diffusion. We shall give examples of two famous inter-artefact relationships, namely substitution and complementation. Substitution means that two goods have one or more functions in common and can therefore replace each other. Horses, trams, bicycles, mopeds, and motorcycles all had in part substitutive relationships towards the car. These vehicles carried part of the functions which the car carried as well. For people who could not afford cars, they served as a precursor to it. Technological complements support each other. For cars in America, we have previously argued that the car was particularly functional in the early period to inhabitants of the rural hinterland that were within a 15 kilometre radius of the nearest train connection, because they used cars in combination with the railway services.

We can see that one can make quite fixed assumptions as to how benefits differ in urban areas from rural areas. These fixed assumptions then guide one's expectations towards

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98 e.g. see H. M. Cameron and J. S. Metcalfe, "On the Economics of Technological Substitution," 32 ed. 1987) 147-62.
the car density levels in areas with certain characteristics, such as urban/rural, densely populated/scarcely populated, good/little or no access to public transport, etcetera. A rather common assumption is that infrastructural provisions for public transport modes are less developed in rural areas than in their urban counterparts, and that this fact has an enhancing effect on the perception of villagers as to the benefits of the car. With these assumptions in mind, the idea has been proposed that car density levels should be higher in rural areas than in urban areas as soon as restrictions in supply no longer keep the adoption level in towns and cities "artificially" high.

We have showed that this argumentation covers only one aspect of the complex issue denoted by "benefit." Ultimately, any such assumptions are subject to empirical investigation. Therefore, microeconomic demand theory does not as such lend itself to derive clear expectations from it of how the car density levels of rural and urban areas, with or without access to public transport, change over time. Even if it was generally true that cars were perceived as being necessary in isolated places, one cannot make the generalization that isolated places will show a high car density. Instead, one should take into account other aspects of benefits, as well as the ratio between costs and income, e.g. if villagers cannot afford a car, the infrastructural provisions in said village may not matter to its car density level.

4.2.3 Social diffusion and functional fields

The theory on social diffusion and functional fields is only related in passing to issues of isolation and rural dominance. It does draw our attention to the importance of the location of user groups.

The classic book on social diffusion theory is Everett M. Rogers' *Diffusion of Innovations*. Rogers develops a model for social diffusion of innovations. He claims that the diffusion of innovations proceeds in phases, starting with the rich elites and continuing down the social ladder. The shape of the aggregated diffusion curve resembles these stages. In the first stage, only a very privileged few become acquainted with the innovation. They have enough resources to risk its adoption. Next, the "early majority" adopts. This user group is still characterized by social and economic welfare, but it is already quite a large group. The "late majority" is again a large number of people. They are, however, ordinary in respect to their economic and social resources. Lastly, only the socially isolated and disadvantaged groups are left to adopt.

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Alongside with the user group, the functional field of a technological innovation might change or widen in the long run. A famous example of this is that the car was mainly a touring and sporting vehicle until around 1906. In 1908, Henry Ford's Ford Motor Company designed stable cars with high axles, which were suitable for the transport of agricultural goods and travel on unpaved roads. This technical change made the car attractive to American farmers. The functional field changed, because farmers did not use the car as a sporting vehicle any more, but rather as a transport and agricultural vehicle.

Rogers did not apply his theory to spatial dynamics of innovation diffusion. Nevertheless, we see implications for the geographical diffusion process of innovations. If we imagine that labourers belonged to the "late majority" or to the last users in car diffusion, then we can expect that during the first two phases of car diffusion there were relatively few car adoptions in places or regions with a large percentage of labourers in its population, e.g. in harbour cities or mining communities. In places with a large percentage of wealthy and educated people, e.g. cities with universities or important administrative functions, we can expect an outstandingly high car adoption level. If the main user group is clustered in certain areas, so will the innovation. The location of the leading and lagging areas may change as the group of adopters widens. It also changes when the percentage of people in the population who are resistant to innovation changes.

The emphasis on functional fields can illuminate changing spatial dynamics as well. The example of the Ford Model T used above shows how local demand in the US was influenced by a change in functional fields.

There is a third element in Rogers’ diffusion theory: the role of public information in the diffusion process. Potential user groups are approached by diffusion agencies, i.e. interest organizations and business organizations, which support the diffusion of an innovation. Examples for such organizations in relation to car adoption are automobile clubs and car industry representatives. This aspect of the theory has implications for geographical diffusion as well. If diffusion agencies are particularly active in certain regions, we may expect the adoption level to increase more in these regions than in others. We shall not, however, continue to develop this reasoning in our further

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treatment of the material, because it is difficult to integrate in a quantitative, long-run analysis.

The theory of social diffusion redirects our attention to the following questions: which were the major user groups in the Netherlands at the time when the diffusion cores developed; were they locally clustered, and if so, where? If we were able to answer these questions, they might contribute to our understanding of the location of the diffusion cores and lagging regions.

Staal's book on Dutch car history sketches the change over time in major user groups and in functional fields of cars in the Netherlands. However, he does not give any information as to where in the Netherlands the major user groups were located. In the second part of this chapter we shall use his book as a background for our hypotheses on the Dutch geographical diffusion path.

4.3 Embedding the theory in the Dutch historical context

In this section, we shall apply the theoretical framework to the Dutch case and create hypotheses as to how one may interpret the Dutch car diffusion path. We shall focus on explaining the turning points in the dynamics of geographical car diffusion. From the overview of the three theoretical perspectives, we may conclude that convergence of adoption levels does not require detailed clarification in the case of cars. Geographical convergence seems directly related to the fact that cars diffused pervasively and had a general transport function. If a good is acknowledged as being essentially worthwhile, and its functioning is not specific to certain geographical or economic circumstances, it almost automatically spreads in space. This automatic reaction can be described in terms of the neighbourhood effect. What needs to be explained then is the way in which the neighbourhood effect is shaped in the Netherlands: the direction of growth, and the extent to which geographical convergence of adoption levels occurred. In order to emphasize the similarities and differences with the American case as depicted by Jarvis, and others, we shall first summarize the literature on the US.

4.3.1 The US, Jarvis' regression results and the issue of isolation

Given the theoretical framework laid out in the section above, which economic and social circumstances contributed to the rise of the Midwest as the leading region in American car diffusion during the first wave of diffusion and convergence? In this section, we shall present the answers to this question as given in the literature. This will help us to derive our hypotheses pertaining to the Dutch case and compare systematically our own findings on the Dutch situation with the American example. We shall consider Jarvis' regression results, as well as Flik's "Von Ford lernen?" and Interrante's study "You Can’t Go to Town in a Bathtub: Automobile Movement and the Reorganization of Rural American Space, 1900-1930." The latter serves as one example of the literature on the diffusion of cars in the rural Midwest.

Flik compares Germany’s car market with that of the US until 1930 using both qualitative and quantitative material. He connects the nationally high car density level of the US in these early years of car diffusion with the success of the car amongst its farmers. He analyses the situation of the farmers in the American Midwest in terms of costs and benefits.

According to Flik, the farmers of the Midwest experienced strong benefits, because they were at a considerable distance from the international transport centres which served to transport their goods to the international markets. The car contributed to an impressive rise in the productivity of farmers, since it saved them a lot of time. In the scarcely populated, Western American hinterland, bringing the perishable agricultural goods to the markets quickly was crucial to economic success. One was able to bring the agricultural goods to the next train station, from where the goods traveled further into the country and, more importantly, could be exported overseas. The market for agricultural goods thus saw great improvement due to the interplay between cars and trains. We may say that a complementary inter-artefactual relationship existed between cars and trains.

Flik shows that American farmers, unlike the German ones, could afford cars; they were relatively prosperous. At the same time, both the initial and the running costs of cars were relatively low all through the US. Compared to Germany, taxes on car ownership and use were low. Thus, on the cost side, the ratio income to costs was favourable. The combination of strong benefits with a favourable ratio between income and costs created the strong demand amongst the Midwestern farmers. Isolation as such does not
matter in this argumentation. Rather, it is an indication for how markets could be greatly enhanced by the use of the car.

Flik's interpretation of the Midwestern demand for cars focuses on the utilitarian character of the car. This is to say, he stresses that the car was used for commercial purposes by farmers. However, it seems likely that the functional field of the car at the time was not limited to use related to commercial purposes. When Interrante speaks about "sense of isolation" in rural areas, it concerns a social quality which the car carried, and which cannot be set equal to an economic isolation in the sense of distance to large markets. He stresses that especially the women on the farms suffered from isolation. Already in the 1920s the women of the farm became important users of the car. The car could be used to meet people. It is quite possible that the desire to reduce the sense of isolation was a strong motivation to purchase a car and was perceived as part of the benefits of the car.

Moreover, Interrante claims that the emergence of consumerism changed the spatial structure of rural life in such a way that "the automobile itself changed from a farm convenience into a farm necessity." James J. Flink describes how the coming of the car to the US altered almost every aspect of social life, such as shopping, cooking, and having vacation, in an incredibly short period of time, namely roughly in the two decades between 1910 and 1930. To illustrate, these decades saw the introduction of supermarkets and refrigerators. Elements of a modern lifestyle and consumerism diffused rapidly in the US. As early as the first decade of the twentieth century, the diffusion of a modern lifestyle and consumerism was certainly not limited to towns and cities, but also grew strongly in the Midwest. A modern lifestyle created a dependency on the car, e.g. once the household's economy was orientated towards food obtained

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102 Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 159.

103 Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 159-61.

104 Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 156.

from the supermarket rather than towards homegrown and self-made food, it appeared to be a necessity to possess a car for travel to the next supermarket. In the Midwest, many activities related to the farmers’ everyday life became more centralized. One had to travel to the next town or larger village for services involving education, health care, the postal services, general stores, or gas stations. As a result of these structural changes, “the car was [for Midwestern farmers] a means of consumption, of buying household commodities and enjoying recreational activities.”

We are dealing here with a functional field of the car, which we shall denote the "family car." One feature of this type of car use is that it does not solely reside in men, women also use the car in this capacity, namely for all the activities just mentioned. We see that the functional field of the car was no longer confined to utilitarian well before the onset of the Second World War. The strong demand of the Midwestern farmers can be understood on the basis of the benefits drawn from social, "family car" use of the car.

Jarvis explains the long-run American geographical diffusion pattern with the help of cross sectional multiple regressions, where the dependent variable is in turns either the car density of the states, or the rate of change per state within each period. As benchmark years he uses 1910, 1920, 1932, 1945, and 1969. We show Jarvis regression results in table 7-4 and 7-5 in appendix II.

We shall first give an overview of the variables which Jarvis uses and introduce which theoretical concepts these variables are supposed to represent. The theory which Jarvis uses has two roots, namely the theory of contagious diffusion, and microeconomic demand theory. Therefore, his model is made up of three components: it includes a distance component, which captures Hägerstrand's concept of contagious diffusion; an

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106 Joseph Interrante, "You Can't Go to Town in a Bathtub. Automobile Movement and the Reorganization of Rural American Space, 1900-1930," 1979) 151-68. 156-158.


economic opportunity or costs component; and a benefit component. The latter two concepts of "economic opportunity" and "benefit" are introduced to test the theory of economic demand. Jarvis did not explicitly use measurements that represent the concepts of the social diffusion theory, since Rogers' book was not yet published at that time. Nonetheless, Jarvis uses indicators for social diffusion and we shall treat them as part of the economic reasoning.

Jarvis uses two measures for the distance component. The first is an index for access to automobile production, which stands for the neighbourhood effect. This index is calculated as the sum of all distances from a state to all states with automobile plants. Each distance is weighted by the number of automobile plants in the plant's state. The assumption is that diffusion started in the vicinity of the car production sites and spread from there. In addition, this variable captures costs, because cars are more expensive at greater distances from the production units because of additional transportation costs. The second measure for the distance component is the urbanization index. The index is based on ten size classes of places, as outlined in section 3.3.3. The urbanization index is used, in order to measure the hierarchy effect.

There are four measures which capture economic opportunity. The first measure is personal per capita income, which is a general measure for economic opportunity. Jarvis adds two measures to the mix to reflect farmers' wealth, namely the average value of land and buildings per farm and the percentage of farms operated by tenants. The assumption is that tenants tend to be relatively poor, have smaller farms, and lack the economic ambitions of independent farmers. Thus the percentage of farms operated by tenants should be negatively associated with car ownership levels. The fourth and last measure related to economic opportunity is the share of African-Americans in the entire population. This variable does not only represent the effects of poverty, but also of a socially isolated group.

There are two measures for the benefit component. "%Congestion" is the percentage of people living in extremely densely populated areas. This variable stands for restricted car use, inconvenience and/or additional expenses of car use in densely populated areas. The idea is that in large and dense cities, traffic jams are common, and parking space is both limited and expensive. Therefore Jarvis expects that the congestion variable is

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109 Percentage of a state's population living in central cities of 100,000 inhabitants or over and more than 7,000 inhabitants per square mile. G. K. Jarvis, The Diffusion of the Automobile in the United States. 1895 - 1969, The University of Michigan (unpublished dissertation), 1972). 216.
negatively correlated with car adoption choices. For the 1969 regression, Jarvis enters an additional variable for the access to public transport, this is the percentage of people who commute to work while using public transportation. This is the only variable in Jarvis’ analysis that is related to the isolation argument: the relative advantage of cars should decrease with the increase of the accessibility of public transport, so that we expect a negative relationship here, too.

Next we shall summarize Jarvis' understanding of the geographical diffusion dynamics of the two American diffusion periods using the analytical model just described. Jarvis does not explicitly link his interpretation of his regression results to the diffusion phases. We do so in our summary of Jarvis' results, for it to be easier to compare his results with the Netherlands’.

When looking at the first wave of diffusion and convergence (see tables 7-4 and 7-5 in appendix II), the variables that were significant in this period were those related to farmers' wealth and that of share of African-Americans in the population. Thus the emergence of the rural Midwest during the first wave of diffusion and convergence was strongly related to the wealth of the farmers there.\textsuperscript{110} This is a confirmation of qualitative findings that farmers were one of the major user groups in the Midwest. How can we then affirm that the rural South showed the lowest adoption level out of all American regions? An answer might lie in that the South had, at that time, the highest percentage of African-Americans living there. Seemingly, this group did not demand cars very much. The overall demand of the South was clearly affected by the sizable presence of this poor, socially isolated group.

During the period of disruption, additional considerations came in. The general income level gained importance, while the wealth and economic independence of the farmers continued to remain important. After the years of massive spread of the car, the benefits of cars in crowded areas diminished in 1932. For all these years after 1910, the two distance measures were not significant. It is unlikely, however, that neither the neighbourhood effect nor the hierarchy effect existed. Rather, it is proof of something which we already know to be true: during the first wave of diffusion and convergence the spatial order did not follow the conventional rules reflected in these measures any more, and car diffusion became independent from the location of car plants.

\textsuperscript{110} Measured as value of land and building per farm. Personal income per capita is insignificant during the first period.
During the second wave of diffusion and convergence, the logic of American car diffusion changed again. After the Second World War, the discomfort or additional expenses of using a car in congested areas, as well as the general income level, became increasingly important in explaining the remaining variance in car adoption levels amongst the states.\footnote{111} With the increasing importance of the general income level, farmers' wealth became less important in relation to it, and the leading role of the Midwest dissolved. We would suggest that this means that the importance of farmers as the major user group disappeared. The car being more and more common amongst a broader range of user groups had consequences: the importance of farmers' wealth lost ground to the general income level, and the African-Americans variable became insignificant. Jarvis interprets this as follows: the catch-up of particularly the South was made possible by the migration of African-Americans from the South. Additionally, we consider it plausible that this socially disfavoured group began adopting cars to such an extent that their presence no longer had a negative effect on the overall car adoption level. Their impact was integrated into the general income level. For the 1969 regression, Jarvis includes an additional variable, to wit the access to public transport, this is the percentage of people who commute to work while using public transportation. This variable is negatively significant, indicating that people in areas with good access to public transport found the purchase of a car less worthwhile.

With his choice of variables, Jarvis cannot get a grip on how important the element of isolation was for the geographical diffusion pattern present in the first wave of diffusion and convergence. Since this is pre-1969 regression, Jarvis' analysis lacks a variable which indicates access to public transport. Furthermore, his urbanization index does not reveal how isolated or distant from the urban centers the rural areas in each state were. However, what does become clear from Jarvis’ analysis is that the farmers in the Midwest indeed played an important role in the pattern of car diffusion during the first wave of diffusion and convergence. In terms of theory, we might conclude that we are able to regard the wealthy farmers as one of the major user groups of the time. Furthermore, Jarvis' study emphasizes that wealthy farmers alone, whether isolated or not, demanded cars in this period. Thus, the isolation argument can only be valid on the further condition that there is sufficient economic opportunity in the region in question.

\footnote{111} The importance of the discomfort or additional expenses of using a car in congested areas can be deducted from the significance of the congestion variable.
Sufficient economic opportunity, location of the major user group, distance to markets, access to trains, and a sense of isolation—a combination of these elements presumably contributed to the rise of the Midwest as the major leading area in the US during the first wave of diffusion. All of these elements should probably be understood in the context of a demand structure, which carried both economic as well as social elements. If we wish to compare the Netherlands with this situation, we should look at the Dutch economic and social circumstances and create hypotheses as to which of these conditions existed in certain regions in the Netherlands as well.

4.3.2 The Netherlands

In this section we shall describe the economic situation in the Netherlands and highlight some results of previous studies on car diffusion, in so far as this evidence can contribute to our understanding of the Dutch geographical car diffusion pattern. This information will be used to give a hypothetical interpretation of the Dutch diffusion path. The hypotheses shall cover all issues that were previously addressed in our discussion of the American Midwest—economic opportunity, location of the major user group, distance to markets, access to trains, and a sense of isolation. We shall furthermore bring in the role of spatial externalities, as discussed in section 4.2.2, as well as issues relating to contagious diffusion, as we believe that they were important in shaping the Dutch diffusion path.

We shall not hypothesize about the period of early diffusion. Lack of data prevents us from dealing with this period in our empirical analysis, which shall be put forth in the next chapter. For the same reason, we shall not propose hypotheses about the relationship between car-related infrastructure and car density either.\(^{112}\)

4.3.2.1 The historical background

In section 4.2.2, we showed that economists approach spatial diffusion in terms of spatially varying cost-benefit ratios. Furthermore, when discussing the US, we saw that economic benefits derived from the use of the car seem to have been important to the American farmers. In this section we shall highlight a few dynamics in Dutch economic history, so that we can derive hypotheses related to economic opportunity from it. We


Van Zanden characterizes the economic system in the Netherlands and points out two kinds of structural difference between its East and West:

The variations in economic structure [between the East and the West] had at least two dimensions. There existed large differences in occupational structures. These remained essentially unchanged throughout the twentieth century, but the sharp contrasts were somewhat diminished. The international services - the source of the highest incomes - and capital intensive industries were concentrated in Holland. The inland provinces, on the other hand, were generally more agricultural and their industries tended to be more labor intensive as a consequence of their proto-agricultural origins. . . . The regional variations in wages and prices, on the other hand, almost disappeared during the twentieth century.113

We may add a third structural difference which seems important for car diffusion, namely the degree of urbanization. It is true that large places existed in both the East and the West. However, the metropolitan area of the Randstad is characteristic of the two Holland provinces in the West of the Netherlands. For an illustration of urban and rural places in the Netherlands we refer to figure 3-9 in section 3.3.3.2.

The West-East divide in regard to income, which Van Zanden talks of in the quotation provided above, is illustrated by figure 4-1 below. It shows the regional variation in income, and that in wealth, in 1930. When we look at the data for income, we can observe a similar West-East divide as we do for cars, with Gelderland and Overijssel holding a middle position between the Randstad and the less wealthy Northeast and Southeast. The income level of all occupations, including farmers, was generally higher in the West than in the East.114 This was due to the strong demand for educated labour in this region. We can see that in the West, e.g. in Zeeland and northern Noord-Holland, the rural population on average did not trail far behind the population of the Randstad when it came to their level of wealth.

The West-East divide was strengthened by the distribution of wealth, which was very similar to the distribution of income. Noteworthy is that the prime laggard region of the

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Southeast was the poorest Dutch region, both in terms of income level as well as in terms of wealth.

Fig. 4-1. Income and Wealth after Tax in the Netherlands, 1930

Following microeconomic theory, we expect the car density level to have been positively related to the level of economic opportunity. The latter can be measured as income after tax, or wealth. So we derive from this hypothesis 1a: The degree of economic opportunity was at all times positively related to car density levels.
The differences in economic opportunity between the East and West were to a large extent resolved during the twentieth century.\footnote{Jan L. van Zanden, een klein land in de 20e eeuw. Economische geschiedenis van Nederland 1914-1995, (Zeist: Het Spectrum, 1997). 39-41.} Van Zanden compares the salary and income levels of the Dutch provinces. He concludes that "[b]etween 1938 and 1950 . . . a very drastic reduction of differences in salaries takes place; the assimilation within these twelve years is equal to that within the one and a half century preceding it. After 1950 the pattern of regional differences hardly changes any more."\footnote{Jan L. van Zanden, een klein land in de 20e eeuw. Economische geschiedenis van Nederland 1914-1995, (Zeist: Het Spectrum, 1997). 44. Translated by H. M. Wolf.} When looking at the differences in income, the largest assimilation occurred in a similar period to that for salaries, namely between 1930 and 1950. After which the assimilation of income levels continued once more at a much lower rate. This description seems to mesh well with the empirical evidence that car density levels between the East and West assimilated as well.

However, we shall argue below that economic opportunity gradually became less important as determinant of car adoption levels. This is related to a further development in income levels which Van Zanden describes: after the Second World War income levels rose quite spectacularly. In fact, we have reason to believe that the ratio between costs and income shifted to where adoption became much more favourable. It is typical for any pervasively diffusing good that its initial costs fall over time.\footnote{When pertaining to the car in the Netherlands, however, the empirical evidence on this process is very fragmented. See Gijs P. A. Mom and Ruud Filarski, Van transport naar mobiliteit. de mobiliteitsexplosie (1895-2005), (Zutphen: Walburgpers, 2008). 273.} Initial costs of cars fell relative to income levels. Together the two dynamics enhanced each other, so that cars became much more affordable in a short amount of time. This meant that the car became less and less of a luxury good. This helps explain why the lagging areas in the Netherlands caught up after the Second World War. Our next hypothesis is hypothesis 1b: The effect of economic opportunity declined after the Second World War.

Next we shall give a summary of Staal's account on social diffusion in the Netherlands. His work applies social diffusion theory to the case of the Netherlands. His findings can
aid in creating hypotheses for the Netherlands which are related to the theory of social diffusion.

Staal distinguishes four waves of diffusion for the car in the Netherlands between 1902 and 1975. Each of the waves are mirrored in the national diffusion curve and are related to technical changes to the automobile, new user groups, and new functional fields of the innovation. It is assumed that changes in technical and design features of innovations are neatly interwoven with changes in user groups.

The first Dutch car diffusion wave lasted from 1902 to 1907 and encompassed the spread of the car amongst the rich elite in its capacity as a luxury good. Rich landlords, heads of businesses, high ranking officials, and rich tradesmen belonged to this user group. Nota bene, many of these occupations were probably more prolific in cities and towns than in the country. This might go some way to explain why up to 1905 cars were more frequent in cities and towns than in the countryside. Van der Vinne makes an addition to this list of occupations when he states that many of the earliest users were technicians who worked in the car, bicycle, or wagon industry and thus showed sufficient knowledge about and affinity to this product. This might contribute to our understanding as to why the regions in the vicinity of the car industry were so prone to adopt cars.

The second and the third wave were characterized by a move of the car out of its niche as an adventure and touring vehicle for the rich to what is termed "utilitarian use," i.e. a flexible transport vehicle used for commercial purposes by the middle classes. This


happened in two steps: firstly, in the period 1908 to 1923 the upper middle class gained access to the light car, i.e. the car, which lent many technical features from the bicycles and not from the heavy carriages. Secondly, in the period 1923 to 1935 the somewhat less wealthy middle class started to adopt cars as well, making use of cheap American cars like the Ford Model T, which by this time had become readily available in the Netherlands. With this the car became a flexible means of transport for the middle classes for numerous commercial purposes; it served to distribute goods, and it allowed people to travel who had to travel extensively by virtue of their occupation. Various kinds of businessmen, such as shop keepers, local salesmen, doctors, and veterinarians, belonged to this newly adopting user group. Officials such as mayors were also in demand of cars.

From Staal's description it becomes obvious that farmers were not in the least as central to car diffusion in the Netherlands as they had been in the US. On the contrary, the share of people who adopted cars and worked in agriculture seems marginal right up to the Second World War. Therefore, hypothesis 2a is as follows: Farmers generally did not belong to the major user group of cars till after the Second World War; the share of people working in agriculture was therefore negatively associated with car ownership levels until the end of the retardation phase.

After 1958 a new user group gained importance in the diffusion process, namely that of private households. This entails the rise of the "family car," i.e. a vehicle used by private households for commuting, shopping, and leisure trips:

As the democratization of car ownership accelerated, the use of the car changed. While commercial traffic at first continued to dominate, as of 1970 commuting increased. The so-called social/recreational traffic also increased rapidly. While in 1963 40% of the car fleet was privately owned, in 1991 this percentage had risen to 81% . . . during the 1970s the growth of car ownership amongst women was particularly noteworthy. . . . If the new user group is not locally clustered, a lateral growth of the market leads to the convergence of adoption levels. Private households are apparently not locally clustered and thus this development contributed to the convergence of regional adoption levels.

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The conclusion is, therefore, hypothesis 2b: During the second wave of diffusion and convergence, the influence of the location of the major user group on car density levels vanished.

4.3.2.2 "Distance to markets" and "necessity" in the Netherlands

In this section we shall discuss which implications we might elicit from the literature which we described above in relation to the case of the American Midwest. As has been shown in section 4.3.1, these arguments correlate with distance to markets, necessity, and a sense of isolation. As we did for the American case, we shall distinguish here between the utilitarian use of the car and the use of the car as family vehicle.

Let us first look at the issues related to the utilitarian use of the car. We saw for the US that the Midwestern farmers were able to reap business-related benefits from their possessing a car. The crux was that the car helped to increase their market by bridging long distances between them and (potential) buyers. In respect to the Netherlands, we saw that the utilitarian use of the car was commonplace at the time when the divide between the diffusion cores and lagging regions was established, which reflects the situation in the US. Also like in the US, the car was used to distribute goods during the first wave of diffusion and convergence. We may therefore assume that a key benefit from the use of the car was to distribute one's goods or services quickly to as many clients as possible. Put differently, the focus is once more on increasing one's market.

Therefore, "distance to markets" may apply to the Netherlands as well. Staal suggests, on the basis of articles published in the magazine of the national car club, that cars were mainly attractive to "country dwellers, doctors, notaries, factory managers, landlords, dealers in agricultural equipment, et cetera. In areas where one could make only limited use of train and steam tram, these people were potential buyers of a reliable car, because they had to cover long distances."\textsuperscript{124} This is clearly a phrasing of the "distance to markets" argument, which we discussed in connection to the US in section 4.3.1. The difference being that the adopters are rather middle class country dwellers than farmers. There are two issues which deserve special attention. Firstly, there is no way to definitively empirically determine, for a small and dense country like the Netherlands, where the members of these diverse occupations had to cover long distances. Secondly, Staal’s argument is in essence different to what we have encountered to be the case with

the American experience. When considering the first issue, there is obviously no account of the exact locations, or of any other specifications of the markets which were to be served. This is why we shall assume, for the sake of argument, that business people had to cover larger distances in places with low population density. In those places it takes more time to serve the same number of destinations or clients than in places with a high level of population density. We therefore arrive at hypothesis 3: Approximately since 1908, people who operated their cars in some "distance to markets" had a larger economic benefit from car adoption than people elsewhere—population density was therefore negatively related to car density levels.

The second issue which deserves attention is that the argument which Staal puts forward is essentially different from the American experience as laid out before. We stressed in section 4.3.1 that it was the combined effect of "distance to markets" and "access to public transport" that contributed to the high car demand in the American Midwest. Staal's argument, on the other hand, is based on the combination of "distance to markets" with a relative lack of public transport. It appears to assume that members of the aforementioned occupations would have taken the tram and train for their business-related travel and not merely a horse and/or carriage, or motorized two-wheelers, if public transportation had been readily available. This would be substitution between artefacts. While this assumption on the whole is questionable, we may back it up with some background information on the character of trams and railways in the Netherlands. Notably, first of all, is that both the train as well as the tram network was rather dense until the Second World War. Forty per cent of the municipalities in our data set for 1930 possessed a train station and forty-five per cent had an interlocal tramline. The tram was designed and built as an overland vehicle which did not cater exclusively for large places, so that with it one could reach diverse destinations relatively easily. Furthermore, one should be aware of the fact that trams were not only used for travel, but also for the transportation of goods. Trains were mainly used for the transportation of bulk goods in large quantities. This means that, in principle, it is possible that the middle classes transported their goods via the tramway in particular, because trams were suitable for the transportation of goods utilized by small and middle-sized enterprises. Our hypothesis regarding the access to public transport is therefore in opposition to the American experience in that hypothesis 4 reads: People who operated their cars in areas which were scarcely pervaded with public transport had a larger economic benefit from

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125 See for an illustration drawn from our own data appendix III.
car adoption than people elsewhere. Therefore, good access to rail-bound modes of transport was negatively associated with car density levels.

In order to give more concrete substance to this hypothesis, we produce figure 4-2 and figure 4-3. Figure 4-2 shows the interlocal tramline system as it was present in the year 1930. The map in figure 4-3 shows the number of train departures per municipality per working-day in the summer of 1930. The map in this latter figure contains implicitly information on the location of operational train stations, because each coloured section is indicative of the presence of one or more train stations.

Fig. 4-2. Interlocal Tramlines in 1930

Sources: See list of sources.
Date: 31 December 1930.
We see a rather large absence of networks for rail and tram in the area of the Randstad called the Groene Hart. The Groene Hart, together with some places in Noord-Limburg and Gelderland/Overijssel, formed an exception to the rule that the Netherlands was also well invested with access to rail-bound transport services outside of the cities. From the map on train departures in figure 4-3, we can see that the South was generally less invested with well-frequented train stations than the North. Particularly Zeeland and parts of the Groene Hart lack train stations. It is feasible that the "distance to markets" argument applies to these areas.

We shall now move on to the social, or family-related, use of the car. In the case of the US, the term "necessity" was associated with the car use of private households. We showed for the US that farmers already demanded cars prior to the First World War in order to satisfy their social benefits and make household-related trips. This was apparently different in the Netherlands. According to Staal, the diffusion of cars amongst private households did not take off until the end of the 1950s. We may say that, in respect to the US, the diffusion of cars in their capacity as family car was delayed. This would mean that in the Netherlands during the first wave of diffusion and convergence the motivation of country dwellers to buy a car was solely based on an economic reasoning on their part and not accompanied by the consideration of the
benefit of reducing one's social isolation. We argue that the "necessity" argument did not apply to the Netherlands as it was during the first wave of diffusion and convergence.

There is a second reason why the "necessity" argument did not hold for the Netherlands in this early period, which is related to the spread of modern lifestyle and consumerism. We argued for the American case that the adjustment of private households to a modern lifestyle and consumerism created dependencies on the car or so-called necessities. In the Netherlands, the diffusion of a modern lifestyle and consumerism took off after the Second World War, e.g. the first Dutch self-service store was not founded until 1947. In comparison to the US, the Netherlands was also delayed in this respect. The diffusion of a modern lifestyle and consumerism took particularly long in the country, e.g. self-made food went hand in hand here with industrially produced and packaged food obtained from stores for a long time.\textsuperscript{126}

However, for the Netherlands as it manifested itself during the second wave of diffusion and convergence, we shall argue that the "necessity" argument did apply, as this was when the diffusion of the car amongst private households set in. Staal writes about this period, "[P]eople, who live in isolated regions, will purchase a car for purposes such as daily, cultural, and recreational travel, but also in order to reach churches, health institutions, et cetera. The necessity to travel will be more common amongst households in which more people are engaged in employment" (emphasis added).\textsuperscript{127} Clearly, this argumentation runs parallel to the "necessity" argument as we encountered it with the American case. However, it lacks the fierceness with which probably only people in extremely scarcely populated areas, like the American hinterland, suffer from social isolation. For the purpose of our regression analysis, therefore, we assume that a sense of isolation as such did not play a role in the Dutch diffusion process, though we cannot test this.

Suburbanization created dependencies on the car as well. Suburbanization had taken place in the Netherlands long before the year 1950. Initially, it dominated in the Randstad. The emergence of the tram had made the escape from crowded cities


possible. People now had a choice through having the ability to commute being made available to them. However, it was not until after the Second World War, in 1950, that a massive exodus from the densely populated cities took place. Those who migrated were in particular people who were rich enough to be able to afford their own family home. Their destinations were the polders as well as places in the east and north of the country where the quality of life was high. The suburbanization movement remained most pronounced in the Randstad. Once a family had moved outside the perimeter of a city, their transport demand automatically rose and the car became a "necessity" to them. Therefore we expect hypothesis 5: The negative relationship between population density and car density increased after the Second World War as a result of suburbanization, change of lifestyle, and the diffusion of cars amongst private households.

We wish to complete this list of hypotheses, which have all been related to the balance between rural and urban areas, with two hypotheses related to spatial externalities. We saw for the US that spatial externalities in the most crowded areas became important after the first wave of diffusion and convergence. We expect the same effect, which is based on microeconomic theorizing, for the Netherlands. Furthermore, we assume that the running costs and/or living costs in towns were higher than in rural areas. We add hypothesis 6a: In the most densely populated places, spatial externalities and additional costs of housing and car use held down the car density figures. Thus the negative relationship between population density and car density, as hypothesized in hypothesis 3, transforms into a positive relationship when taking the most densely populated places into consideration.

As the level of car density grew, the discomfort of living in crowded places was aggravated by the massive use of the car. Moreover, the utilization costs in crowded places can be assumed to have grown relatively more than those in places with a low level of population density. To illustrate, consider that people in crowded cities might

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have suffered from car congestion, increasing parking costs, and increasing difficulties to obtain parking space directly in front of the house. It would appear that the discomfort of living in crowded places caused a further spread of suburbanization. Around 1970, the location of one’s work was increasingly detached from the location of one’s home. Wealthy families especially were willing to commute across long distances, if only they could live in a quiet village with a high quality of life. Good access to a town provided by public transport did not necessarily matter any longer to the choice of living place. "Subsequently, the newly vacated city dwellings are occupied by young, non-Dutch immigrants and other, primarily less wealthy, small households." In the long run, cities became the new social problem areas of the country. This does not only entail that income variation was reintroduced. It also means that the difference in quality of life between the cities and their suburbs was increasing, and that people used their car as a means to escape the cities. We infer hypothesis 6b: The effect of spatial externalities increased over time.

4.3.2.3 Contagious diffusion
To complete our hypothetical interpretation of the Dutch diffusion path, we shall cover here the expectations we have in regard to the neighbourhood effect and the hierarchy effect (see section 4.2.1). In short, we expect that the theory of contagious diffusion holds true. Thus we find the following three hypotheses: hypothesis 7: The neighbourhood effect was at work during the entire diffusion process; hypothesis 8: The hierarchy effect was at work during the entire diffusion process; hypothesis 9: During initial diffusion, the number of municipalities with adoptions fell as their distance to car producers and dealers grew. This last hypothesis serves as a background, but is not tested.

4.4 Conclusion
We have introduced three strings of theory in this chapter. With the help of the central concepts of these theories we may grasp the main similarities and differences between the geographical diffusion logic of the US and that of the Netherlands.

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The literature on American car diffusion suggests that the rise of the Midwest as leading American area was due to its farmers, who benefited from the car in ways both related to their business as well as to their social, and family life. The farmers were wealthy enough to afford cars, and they had a strong sense of isolation, which was greatly reduced by the coming of the car. There was a complementary relationship between the car and the train in those regions that were at a distance from population agglomerations.

After considering the literature, we reason that the situation in the Netherlands during the first wave of diffusion and convergence was slightly different. Not surprisingly, the sense of isolation, as felt by the American Midwestern farmers, is not recorded in the literature on the Netherlands. Social benefits did not play a role in the Netherlands during the first wave of diffusion and convergence, since the diffusion of cars amongst private households had not yet taken hold. The major user group did not consist of farmers, but rather of the middle classes. Also, we found support for a substitutional relationship between trains and/or trams and cars, as opposed to the complementary counterpart in the US. In all other respects, the same rules apply for the Netherlands as for the US, albeit on a much smaller scale.

We do not know yet whether our hypotheses regarding the Dutch geographical car diffusion path can stand up to scientific scrutiny. In what follows, we shall see which of our hypotheses is corroborated by regression analysis.
5 Is there a common logic in the geographical car diffusion of the US and the Netherlands? A spatial regression analysis for the Netherlands

5.1 Introduction

This chapter focuses on the empirical evidence related to the hypotheses concerning Dutch car diffusion as stated in the previous chapter.\textsuperscript{132}

We have shown in the previous chapter that we already possess an interpretation of the American diffusion pattern, which has largely been verified. However, we do not know whether a similar interpretation would also be plausible for the Netherlands.

If we wish to know whether the benefits of so-called isolated places played a role in shaping the location of leading and lagging areas in either the first or the second wave of diffusion and convergence, we have to verify that empirically against the background of alternative interpretations. Therefore we shall use regression analysis in this chapter in order to see which of our hypotheses seems plausible. A regression analysis is a statistical method which is often used to test hypotheses such as the ones posited in the previous chapter. It shows the link between one variable which is to be examined (in our case: car density) and a multitude of other variables, which may or may not contribute to the understanding of changes in the first, dependent, variable.

We shall take roughly the same theoretical basis as Jarvis, namely the theory of contagious diffusion, and microeconomic demand theory, and add to it the theory of social diffusion proposed by Rogers. We shall take the years 1930, 1950, and 1980 as bench-mark years for the regression analysis, so that we can draw conclusions concerning the two waves of diffusion and convergence. We shall use types of spatial regression analysis rather than the more commonly used ordinary least squares method, in order to do justice to the spatial structure incorporated in the data.

\textsuperscript{132} Credit goes to the Young Scientists Summer School at the International Institute for Applied Systems Analysis (IIASA) and my supervisor there, Arnulf Grübler. The theoretical frame for the analysis found in this chapter, parts of the data collection, and the first trial runs for the regression analysis were conceived and executed there.
5.2 On methodology

For the present analysis we selected a number of variables and created data sets. We investigated whether spatial econometrics models were necessary. This section of the chapter is devoted to the choices we made in methodology.

5.2.1 The measurement choices

If one wishes to test empirically a number of general rules, one is required to transpose abstract concepts into concrete measures. To illustrate, the concrete measure “income after tax” would be chosen to be representative of the abstract concept “economic opportunity.” These measures need to be selected with care, the danger lying in that a chosen measure might not accurately represent the theoretical abstract concept for which it is intended to stand. Alternatively, the choice might be too broad in scope and thus capture unforeseen components in addition to the original concept. In this section, we shall give an overview of the concepts which we wish to measure and then discuss, in some depth, the individual measures one by one.

The dependent variable is car density in 1930, 1950, and 1980.\textsuperscript{133} The basic concepts of the explanatory model are identical to the model Jarvis uses. It encompasses contagious diffusion, economic opportunity, costs, and benefits. Jarvis also mixes in social variables related to the economic situation of farmers, as well as the share of African-Americans in the population. He seems intent on capturing the social circumstances specific to the American diffusion process. For our analysis of the Dutch diffusion process, we add a measure for social diffusion and several measures which capture the role played by rail-bound transport modes. Our intention is to better distinguish between "distance to markets" and "access to public transport modes." We therefore also take into account recent literature which emphasizes the importance of various kinds of interplay between several transport modes within a single transport system.

We selected variables on the basis of their theoretical relevance and availability. In table 5-1 we give an overview of the measures used per theoretical concept; the figures in column four indicate for which of the three bench-mark years they were used. If the

\textsuperscript{133} To be more precise, the logarithm of car density is taken as the dependent variable. See section 5.2.3 below. The data is drawn from the national car census, the comparability of which with the US we discussed in section 3.3.3.
year in which the data for the measure was collected is not identical to the bench-mark year, this is indicated parenthetically. One measure, i.e. squared population density, was used only in the trial runs and later disregarded. This one is in smaller print.

Table 5-1 Measures Used in the Regression Analysis

<table>
<thead>
<tr>
<th>Contagious Diffusion</th>
<th>Hierarchy Effect</th>
<th>Number of Inhabitants (Indicating Size of Place)</th>
<th>1930, 1950, 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>Wealth after Tax per Capita</td>
<td>1930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Train Departures on a Working Day</td>
<td>1930, 1950, 1980</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Existence of a Train Station (Dummy)</td>
<td>1930, 1950, 1980</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Existence of Interlocal Tramline (Dummy)</td>
<td>1930</td>
<td></td>
</tr>
<tr>
<td>Social Diffusion</td>
<td>Social Groups</td>
<td>1930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Agriculture in the Employment</td>
<td>1930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Manufacturing in the Employment</td>
<td>1930</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% Agricultural Workers in Population</td>
<td>1980</td>
<td></td>
</tr>
<tr>
<td>Correction for Longitudinal Autocorrelation</td>
<td>Car Density of a Previous Period</td>
<td>1930 (1928), 1950 (1938), 1980 (1975)</td>
<td></td>
</tr>
</tbody>
</table>

The choice of these variables will be the topic of discussion for the rest of this section. The two major concepts which we aim to reflect in the measurement for contagious diffusion are the neighbourhood effect and the hierarchy effect. The neighbourhood effect is best measured as the autocorrelation of the dependent variable. This autocorrelation is reflected in the values of Moran's I and is already accounted for in spatial regression models. Thus we do not need any further measure for that.

134 For the definition of spatial autocorrelation see section 3.3.2.
We used "number of inhabitants" as a measure for the hierarchy effect, thereby positing that larger places are more receptive to change than smaller ones are. The "number of inhabitants" measure is a direct equivalent to Jarvis’ urbanization index. We chose not to use an index, because we do not deal with an area composed of multiple places, but consider separately each place in the analysis, thereby forfeiting the need for an index such as Jarvis saw fit to use. “Number of inhabitants” is the only distance measure which we included. Unlike Jarvis, we did not enter any measure to capture distance to car production sites, since we believe that this influence had vanished by 1930. For the Netherlands, there are three indices available which are designed to reflect the importance of locations within the urban system. These indices are "administrative centres," "regional economic centres," and "cultural centres."\(^{135}\) None of these indices is collected repeatedly and during several periods. Since the role of locations is likely to have undergone considerable changes over the significant time span inherent in the choice of bench-mark years, we disregarded the distance measures relating to locations. “Number of inhabitants,” indicating the size of a place, is expected to be in positive relation to the car density level.

The interpretable meaning of any measure used for the hierarchy effect remains ambiguous. All measures chosen to represent the hierarchy effect can equally be interpreted as a general indicator for the benefits related to a well-developed infrastructure. We argued earlier that driving a car might have been more attractive in towns and cities in possession of a well-developed infrastructure. Thus well-developed infrastructure should be positively correlated with car density levels. By taking into account both possible interpretations, we strive to deal adequately with the ambiguity inherent in this statement.

Economic opportunity is the ratio between costs and income. Thus ideally, when choosing measures to represent economic opportunity, both the components that


The source for “administrative centres” and “cultural centres” is also W. Voster, De cultureel-geografische indeling van Nederland. Een beredeneerde hierarchie van culturele gebieden en centra, (Rotterdam: Universitaire Pers Rotterdam, 1967).
contribute to the ratio should be taken into account. In our case, data on spatially varying initial costs and on running costs do not exist. On the income side, it would be desirable to include both the average income after tax and its distribution per municipality.

How the income was distributed is important to our analysis. If two municipalities have the same average income, and in the first municipality the majority of the wealth is in the hands of a small minority, whereas in the second municipality the variation around the mean is negligibly small, the latter will more likely have a greater number of cars, because in the former the only people in possession of a car are those belonging to the small percentage that make up the rich elite. Due to time constraints, we nevertheless limited ourselves to the “average income after tax” as a measure for the concept of economic opportunity.136 Previously, Jarvis limited himself to that same measure to represent this concept. For our analysis, the measure “average wealth after tax” was included for the regression analysis with benchmark year 1930, because the data present in our sources allowed for this.

For the interpretation of these measures we should be aware that they abstract from the reality of spatially varying fixed costs per household. To illustrate, housing might be more expensive in cities than in villages, this would lead to the reality of city dwellers being in need of a higher income level relative to those living in villages for them to be in a position where they are able to afford a car. Since we measure urbanization separately, these effects should show up in the respective variables, if they are indeed significant that is.

For the benefit component of the model we use two types of measures. Firstly, we use the conventional measure "population density." Secondly, we integrate into the model the availability of rail-bound modes of transport. By introducing variables on public transport, we may be able to separate the effects of connectivity from those resulting from other characteristics inherent to crowded places. Regarding benefits, we dismiss entirely the aspect of infrastructural provisions; we were not able to conceive of any measure which would not have been relatively cumbersome to bare. For example, it would be possible, yet very time-consuming, to derive the length of street from the

yearly records of the provincial governmental agencies for construction. A connectivity analysis would be equally time-consuming. The "population density" measure is rather a collective term for several concepts. It can convey many meanings, which makes its interpretation very fragile. The intention was to use it simultaneously for two different concepts: "distance to markets" and spatial externalities. However, it might also capture increased running or living costs in crowded places. It might even don the aspect of "isolation" for the social necessity argument.

The ambiguity of this measure is far from ideal, because if it proves to be significant we will not be able to tell which of our hypotheses posited relating to population density is affirmed. We could have chosen to include a measure which indicates the distance to population agglomerations to represent "distance to markets." However, this does not seem wholly appropriate, since people like country doctors and shopkeepers most likely did not serve neighbouring population agglomerations, but rather confined their services to the inhabitants of the little dense area in which they resided. Thus, through the lack of an acceptable alternative, we opted for simply considering all possible interpretations of this single measure.

There are further reasons why we have to be extremely careful with any interpretation of the measure “population density”. “Population density” has sometimes been used as an indicator of access to public transport. The assumption then is that access to public transport is better in densely populated places than elsewhere. The matter of these two aspects being linked positively causes further complications. This is why we introduced variables which concern the access to rail-bound transport modes. Through these we intend to separate the effect of access to public transport from the other meanings which “population density” is capable of carrying. Even with this scope, “population density” might still be burdened with the inclusion of other kinds of public transport, such as busses or metro, which are not integrated in this analysis.


Finally, “population density” can also convey meanings related to urbanization and the hierarchy effect. Generally, we expect infrastructural provisions to be better in densely populated places, and therefore the benefits of car use to be greater.

We have expressed an expectance of a negative relationship between population density and car density, which culminated with hypothesis 3 and contributed to hypothesis 5 and 6a.139 However, one could argue that the relationship between population density and car density is not linear, but takes the form of an inverted "U" (hump-shaped). Such a relationship is a non-linear relationship in which both ends of the distribution spectrum, i.e. places with a rather low and places with a particularly high population density, show low car density levels. The highest car density level lies somewhere between the two extremes in distribution. The relationship with the form of an inverted "U" would indeed be the case, if the "distance to markets" argument shows only marginal results in comparison with the other effects discussed here. For extremely dense places, negative externalities prevail and car density is therefore expected to be relatively low there. For medium dense places, elements which work in favour of high car density dominate. All things considered, population density is an indicator for urbanization: people in dense places may be quick to adopt due to the hierarchy effect; only the medium urbanized places may have been both central places within the system of places and not too crowded, with as a result that the medium urbanized places led in the diffusion process.

We tested, whether the relationship between population density and car density took the form of an inverted "U", by entering the quadratic form of the variable "population density" into the regressions. If this variable had constituted a significant part of the regression equations, this would have indicated that the relationship between population density and car density took the form of an inverted "U". However, the "population density" variable in its quadratic form never proved significant in the trial runs, and therefore was eventually left out.

Let us move on to the measurement for the availability of public transport. We use measures constituting both the availability of trams (in the regression analysis for 1930) and railways. Ideally, we would like to capture the ease, i.e. flexibility and speed, with which travelers can reach a certain range of places starting from the municipality in question. This can be gained by a combination of complex measurements which take into account: 1. the existence of stations or stops; 2. the frequency of public transport.

139 See section 4.3.1.2.
connections; 3. the range, as exhibited by such variables as the number of lines, the furthest direct destination et cetera; and 4. the travel time. We refrained from opting for such a complex connectivity analysis and instead chose measures which were relatively simple to obtain. Due to time considerations, we limited ourselves to sources which were already nationally standardized, and yet reflected at least one aspect of those that were mentioned above.

The connectivity of places by use of the tram was measured through the existence of an interconnected tram network in a given municipality by the end of 1930. By the start of the Second World War, the nationwide tram network was speedily disrupted. Many pieces which had been destroyed during the Second World War were not rebuilt. Trams were therefore perceived as being relevant to the first regression analysis, that of 1930, but not to the ones for the other benchmark years. The data on the existence of trams in a given municipality was taken from the maps in "Overzicht van de Nederlandsche Spoor- en Tramwegbedrijven." It is presupposed that there are stops in municipalities through which a tramway was lain. The measure is a dummy one, i.e. places with a tramway have the number 1 attached to them and places without a tramway have the number 0. Tram networks that were only located within a single municipality and thus without a connection to other places were disregarded. These municipalities were allotted a 0, because connectivity is about the possibility to travel to other places, i.e. beyond the boundaries of the place of origin.

The connectivity through trains was measured in two ways, namely with the help of the location of railway stations and the number of departures on a working day, i.e. Monday. The sources for both measures are the summer train schedules of the years 1930, 1950, and 1980-81. The existence of a railway station is again a dummy, thus the number of railway stations in large places like Amsterdam is not reflected as such. Since the number of departures and arrivals is equal in both directions of a line, it was deemed sufficient to count only a single direction.

We considered entering further kinds of alternative transport modes for which data is available. For instance, figures on busses are in principle available. We nevertheless disregarded these figures, because ownership data for busses does not exactly capture "connectivity": we do not know where these vehicles were used and whether it concerned private or public transport. Moreover, a more appropriate measurement is not

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straightforwardly available on a national scale. It would entail tracking down the reports of all individual bus companies and creating a comparable measurement out of these sources. This procedure seemed entirely too time-consuming. Ownership data also exists on the most akin transport modes to cars, namely motorcycles and three-wheelers, and the adoption of these alternative, private transport modes can also be expressive of benefits. We nevertheless disregarded these variables, because exactly the same factors which worked upon car density, worked simultaneously on its most akin transport modes. Thus, entering these variables would be similar to entering car density on both sides of the equation.

Variables representing social diffusion were available in the guise of two different measures related to the agricultural employment in the years 1930 and 1980. An equivalent measure is missing for 1950. We were able to use data on the percentage of each of three economic sectors, i.e. agriculture, manufacturing, and services in the employment statistics for 1930, but this was at the same time the only year for which these were available.\(^{141}\) For the characterization of places, it is sufficient to utilize two out of the three percentages, namely "percentage of agriculture" and "percentage of manufacturing," because the percentage of the last section is implicit in the sum of the other two. For 1930, we expect a negative relationship between the share of agriculture in employment and car density, because farmers did not belong to the main user group in 1930. As said above, 1950 will not play a part in our analysis when it comes to social diffusion. For 1980, we used the measure "agricultural workers as a percentage of the entire population."\(^{142}\) We expect that there is no longer any correlation between farmers and car density, because cars have diffused among the entire population.

As opposed to Jarvis' social measure "percentage of African-Americans," our measures for social diffusion are not tailored exclusively to particularities of a certain country and thus lend themselves to international comparison. The disadvantage of this choice is that the social groups are distinguished in rather broad terms.

Finally, "car density of a previous period" is entered into the regressions for all benchmark years. In regression analysis, all possible influences on the dependent variables

\(^{141}\) Source: Historische databank Nederlandse gemeenten, in: "Nederland in Verandering,"

should be entered, in order for the equation to be complete. This makes it possible to utter statements such as, "With all other influences remaining the same, we can say that income has the strongest impact." Of course, car density figures are not only autocorrelated in space, but also in time. Since the growth of the adoption level is always building on the levels reached previously, it appears as if the earlier, and later, values influence the level of car ownership in any year under investigation. To illustrate, if there are two municipalities which have the same economic and social conditions at the time of a regression analysis, the municipality that exhibited low car density prior to this analysis is expected to have a continuation of this trend, even though its conditions are now identical to that of the other municipality which previously had a high car density level. Thus, the influence of the social and economic conditions is relative to the previous car density level. Therefore, we added “car density of the previous period.”

The second reason for entering this variable in the equation is the following: when the social and economic conditions which are summarized in our variables change, it takes some time before the car density level adjusts to these new conditions. To illustrate, an individual who receives a rise in salary will not instantaneously implement all conceivable adjustments to his or her lifestyle, such as the purchase of a car. On the contrary, it will take some time to get used to the new situation and adjust his or her consumer behaviour accordingly. On the agglomerated level, there is such a time lag between the settling of the economic and social conditions and the adoption of the car as well.

If there was no time lag between the change in conditions and the change in adoption levels, all municipalities with identical social and economic conditions would invariably have the same adoption level. Evidently, this is not the case. If we revisit the example of the two municipalities, they both have a theoretical value of car density, which can be calculated if we leave the previous car density level out of the equation. The municipality with the low car density level has a real car density level much below that theoretical value. For this municipality, it takes more time for the car density level to rise, as would theoretically be appropriate according to its new conditions. Over time, however, its real car density level will converge on the theoretical level. This is called conditional convergence.

The question is then how long it takes for the real level to merge with the theoretical level. If we know this, we get an idea of how strong the short-term impact of the sum of all social and economic conditions actually was. After all, it is possible for the social and economic conditions to appear to be fairly uninfluential in the short-term. In order to determine the speed of adjustment, we calculated a homonymous coefficient, which shall be discussed in section 5.3.1.

Unlike Jarvis, we opted for short intervals between the regression year and the previous period. In the Netherlands, changes in the areal scope of municipalities were quite frequent. Municipalities merged with, or transferred parts of their area to neighbouring municipalities. Comparisons of the figures for a municipality before and after an areal change are futile, because there are no longer identical units available for the analysis. We opted for short intervals between the regression year and the previous period, in
order to keep the data disruptions due to areal changes in municipalities small. The earliest available figure for a period preceding 1930 is 1928. For 1950, the previous period fell to 1938, there being no possible figures for after 1945 and this being the latest available year before the onset of the Second World War. For 1980, the previous period was determined to be five years earlier, namely 1975. Places which vanished in the period between the "previous period" and the regression year, were taken out of the data set. The figures for the municipality which now incorporated one or more other places thus refer to different areas and consequently to a different number of inhabitants. Nevertheless, these municipalities were left in the data set, in order to maintain as many cases as possible. Any other adjustments in the size of areas were not corrected either.

5.2.2 Choices for spatial multiple regression models

In this section, we shall explain why we chose certain spatial multiple regression models. We first tested whether the most commonly used multiple regression method, namely that of ordinary least squares (OLS), was appropriate to our data sets. We arrived at the conclusion that it would not be appropriate for the bench-mark years 1930 and 1950. To support these findings, we shall explain how multiple regression works, why it was deemed inappropriate for our use, and what would be alternatives to it.

Multiple regression analysis generally serves to reach an understanding of how a single dependent variable is linked to multiple other variables. The name of its most commonly used method is ordinary least square, and it refers to the procedure by which a straight line is chosen which goes through as many dimensions as there are variables. The operation is designed to maximize this line’s best fit with all the data points of the variables. The sum of all deviations from the real data points to the estimated straight line is captured in the so-called error term. One of the underlying assumptions in OLS is that the error term in all measurements is randomly and normally distributed. However, this is not the case if one or more of the variables are spatially ordered. On the contrary, when this occurs, the error term becomes spatially ordered as well, which constitutes spatial disturbance. The OLS model is therefore not appropriate to most spatial data and certainly data concerning diffusion processes.

For each benchmark year, we ran several OLS models, in order to specify the degree of spatial disturbance. We can determine that from the value of significant Moran's I statistics for residuals. This Moran's I measures spatial autocorrelation, much like the Moran's I which we used earlier. The only difference is that it measures the spatial autocorrelation in the residuals of the entire model rather than the spatial autocorrelation in a single variable. The OLS models and their respective Moran's I statistics are shown in the regression tables (table 5-3, table 5-4 and table 5-5). Clearly, the Moran's I statistics are significant and above 3 for 1930 and 1950. This is indicative of quite a lot of spatial disturbance, for which there would need to be corrections. For 1980, the figure is not significant any more. Thus, only for the years 1930 and 1950 is the use of spatial econometrics models suitable.

We went on to compare several types of spatial regression models, in order to separate the sources of the spatial disturbance in our models. In principle, spatial disturbance as found in the error term may be caused by one or more of the following: 1. the dependent variable is spatially autocorrelated, this autocorrelation can be intrinsic to the type of measurement, or can be caused purely by measurement error; 2. one or more of the independent variables are spatially autocorrelated; 3. the spatial structure lies in the very mechanisms of the diffusion logic, so that the diffusion logic varies across space in a systematic way—this is called spatial heterogeneity; 4. an independent variable, which is not included in the model and is nevertheless part of the car diffusion logic, is spatially autocorrelated.

From a theoretical perspective, which of these sources of spatial disturbance are likely to occur in our regression analysis? We already know that the dependent variable “car density” is spatially autocorrelated (see section 3.3.2). We interpret this as the neighbourhood effect in contagious diffusion. It is likely that some of the independent variables are spatially autocorrelated as well. Spatial autocorrelation in some of the independent variables can be due to diffusion effects, or else to hierarchy effects, or spillover, e.g.: highly dense places often cluster in one region; public transport is also subject to diffusion processes, and it reflects spatial hierarchy as well. Spatial autocorrelation in the independent variables can equally indicate measurement imprecision between administrative units, e.g. a train station might be placed on the

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border between two municipalities—it’s existence may influence both border municipalities and yet is counted for only one of them. Spatial heterogeneity is also likely to occur. Elements of the diffusion logic, which play a role under certain economic and geographical conditions, matter less or not at all in different settings. If below a certain minimum threshold, differences in income do not play a role, because no-one is able to afford a car. Likewise, in cities where the cost of living is high, and where most of the personal budget is allotted to housing, income elasticity might be different to places with generally lower costs of living. On theoretical grounds, we do not see a reason to believe that we left out a crucial independent variable. Therefore we disregard the possibility that an independent variable, which is not included in the model and is nevertheless part of the diffusion logic, is spatially autocorrelated. To summarize, there are several interpretations of the spatial disturbance in our models, all equally likely and possible.

In order to deal with the fact that there are a few sources of spatial disturbance possible, we opted for two alternative spatial multiple regression models. Each of the two models offers a different technical solution to the integration of spatial disturbance. In the first one, which is referred to as a mixed autoregressive-regressive model (SAR), only the spatial autocorrelation of the dependent variable is taken into account. In the second one, the error model (SEM), the entire spatial disturbance is subsumed. The error term, in its function as the agglomeration of all unconsidered variables, measurement problems, and nonlinear spatial effects, is treated as if it was a single spatially-correlated variable. As such, it does not actually elucidate the source of the spatial disturbances in the data, which is precisely because the error term is the sum of all unexplained parts. Not at the least, a spatially-correlated error term could be an expression of what is called spatial heterogeneity: the very nature of the impulses and mechanisms, which create certain geographical patterns, vary across space.145

In SAR, the spatial autocorrelation of the dependent variable is incorporated into the regression, as if the average value of the neighbouring regions codetermined the value in question. The average value of the neighbouring regions is established on the basis of a binary neighbourhood matrix and then entered into the equation as an additional

independent variable.\textsuperscript{146} In SEM, the entire (spatially autocorrelated) error term is entered in the same fashion, that is as if it concerned a further independent variable. The indicator for the additional variable in SAR is called Rho; in SEM it is called Lambda.

5.2.3 Further technical choices

This section shall be used to describe certain further technical choices which we made, as well as how to read the regression tables which are to be found in the next section. We desired to be able to check the coherence in the results. What follows is an explanation of how we arrived at the final models, which we shall use as the base for the subsequent discussion. We first ran regressions for each regression type, these included all variables—except for one—in the data set. Train stops and train stations are by definition related to each other, since trains can only stop in places where train stations exist. Therefore, we entered either of these in each complete model. Thus, we started out with two complete models per regression type: one with train stations and one with train stops. Next, we discarded the insignificant variables one by one, starting with the least significant. This way we were able to compare how the significance of the independent variables changed accordingly. The cases in which the significance fluctuated a lot will be discussed in the sections 5.3.2 and 5.3.3. For reasons of clarity, however, only the significant variables of the reduced models are presented in the result tables.

A further way to look for stability of results is to compare the results of the three regression types, OLS, SEM, and SAR, with each other. In this respect, most elements of the models appeared to behave consistently. Lastly, we ran regressions employing various distance weights, in order to see how stable the results are when distance measures vary. Much like with simple spatial autocorrelation, the size of the neighbourhood has to be defined for the distance matrix. We chose distances ranging from “four nearest neighbours” to a 125 kilometre radius. In principle, the choice of the radius for the distance circle can influence the results in the spatial regression models. In our case, however, the results are surprisingly stable. In the regression tables presented in the next section, we show the results for the “four nearest neighbours” distance weight. The “four nearest neighbours” distance was chosen as the main point of reference, because autocorrelation in car density is strongest

\textsuperscript{146} In a binary neighbourhood matrix, municipalities defined as neighbours are assigned a 1, and all other places are marked as 0. If spatial autocorrelation in the dependent variable was the only source of spatial disturbance, then the error term should be normally distributed (and not spatially autocorrelated).
there. Thus the systematic differences between locally clustered lagging and leading regions should come to the fore most pronouncedly on this level.

The dependent variable in the regression analysis is not "car density," but the logarithm of car density. This was done, because the distribution of car density figures is skewed. Regression models cannot deal adequately with that, because one of the underlying assumptions in regression analysis is that the data are normally distributed. The normal distribution is not skewed. By using the logarithm, the car density figures become more aligned. This decision had the additional consequence that the independent variables would also have to be in logarithmic form, so that one can see instantly to which degree the variables influence the car density level. The disadvantage to this procedure is that we lost all cases where the figure was 0. The logarithm of 0 does not exist and cannot be calculated. The variable "train stops" was not transfigured into logarithmic form, because each place without a train station shows a 0. The variables "percentage of agriculture," "percentage of manufacturing," and "percentage agricultural workers" were not transposed, because this would have led to a considerable loss in cases. The dummy variables were not transformed into its logarithm either, for the same reason. The adjusted R-squared is the measure of fit for the model as a whole. It shows how much of the entire variance in the dependent variable is explained by the model as a whole. An R-squared value of 1.0 indicates a perfect fit. Which threshold of an R-squared is still acceptable is very debatable. Still, in economics, a minimum threshold of 0.3 is often employed. The regressions of the years 1930 and 1950 show a reasonable fit, with the adjusted R-squared value being higher than 0.5. Thus all regression models of 1930 and 1950 explain a considerable percentage of the entire variation of the car ownership levels throughout the Dutch municipalities. There are only minor variations in fit between the various models. However, the adjusted R-squared of the OLS regression for 1980 is below the 0.3 threshold. Thus only a very small percentage of the entire variation in the dependent variable is explained by the use of this model.

The regression tables show a list of all variables used in the complete model. In the subsequent column, the β-coefficient of each significant variable is given. The β-coefficient shows the degree to which this factor influences the car density level, as well as the direction of influence. The variables that contribute to the explanation are the so-called significant variables. The significance test implies that the distribution of the data is tested against the so-called null hypothesis, which states that the variable does not have any influence on the dependent variable. The variable is called significant, if it seems unlikely that the data appear as it is, if it had no influence on the dependent variable. In the regression tables, the significant variables were assigned 1-3 stars to their β-coefficients. The significance level of a variable shows how likely it is that the null hypothesis in fact holds true. E.g. a significance level of 10% indicates that there is 10% chance that the data points of this variable did not influence the dependent variable. Therefore, the lower the significance level, the more trustworthy the interpretation of the data as an influencing factor.
5.3 The diffusion logic in the Netherlands in view of the American example

In this section we shall demonstrate which interpretations of the Dutch geographical diffusion path cannot be rejected in view of the present material. We shall first consider how quickly car density levels adjusted to the sum of all conditions integrated in each regression model. For the remainder of this section, we shall structure the material chronologically and look at the first and the second wave of diffusion and convergence. We shall use the bench-mark year of 1930 to see how the geographical diffusion pattern came about for the end of the first wave of diffusion and convergence. We shall use 1950 and 1980 to indicate the changes in the diffusion path during the second wave of diffusion and convergence.

5.3.1 The speed of adjustment to the conditions

This section shall be devoted to the comparison of the speed of adjustment in conditional convergence over time. We thereby gain an idea as to how strong the short-term impact was of the sum of all conditions expressed in the independent variables. Table 5-2 shows the coefficients of adjustment for various regression models, as discussed in section 5.2.2. They are an indication for the time lag which occurs between the settling of the combination of all significant impact variables and the actual adjustment of the car ownership levels to these conditions. A low value resembles a long time lag. The coefficient is based on the β-coefficients of the car density in the previous period. The calculation of this additional coefficient was deemed necessary, because the window of time between the years of the dependent variable, e.g. 1930, and the year for the previous timeslot, e.g. 1928, is investigated differently for the three time periods, i.e. 1930, 1950, and 1980. Therefore one cannot compare the β-coefficients of a bench-mark year directly with the β-coefficients for car density in the previous period which are shown in the regression tables in sections 5.3.2 and 5.3.3.
# Table 5-2 The Adjustment Speed in Conditional Convergence

<table>
<thead>
<tr>
<th>Model</th>
<th>Period 1928 to 1930</th>
<th>Period 1938 to 1950</th>
<th>Period 1975 to 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>0.22</td>
<td>0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>SEM</td>
<td>0.23</td>
<td>0.05</td>
<td>X</td>
</tr>
<tr>
<td>SAR</td>
<td>0.24</td>
<td>0.05</td>
<td>X</td>
</tr>
</tbody>
</table>

Sources: See list of sources.

The coefficients of adjustment speed are between 0 and 1 for all three periods, which means that convergence to the theoretical adoption level is taking place. The coefficients of adjustment are—much as the coefficients of the underlying variable "car density of the previous period"—rather stable across the various types of regression models.

By far, car density levels adjusted the quickest during the earliest period, i.e. 1928 to 1930. We do not know the reasons for the fast adjustment in this particular period, but we propose the following: firstly, the compound annual growth rate in car density levels was 20% between 1928 and 1930, which is extremely high. Since relatively many people adopted cars in quite a short period of time, the car adoption level quickly adjusted to the change in conditions. Secondly, the purchase of a car was probably given a high priority amongst several possible ways to spend money. Therefore, soon after a car became affordable to an individual, their purchase would tend to follow.

The longest time lag in the adjustment to conditions occurred in the period 1938 to 1950. The corresponding figure being 0.05. 1950 seems to be an exceptional case due to the disruptive effects of the Second World War. We might speculate that the political, social, and economic instability around the time of the Second World War caused strong hesitations among the general public to invest and consume.

In 1980, the adjustment speed was up once more, to 0.11. The compound annual growth rate in car density levels between 1975 and 1980 was very low at 6%, and the adjustments to the changes in conditions were relatively tardy. The reason for that could be that the economic prospects of the time were not bright, so that people and organizations might have been hesitant with larger investments.

Overall, we see that the changes in conditions had quite immediate effects in 1930, while the short-range effects in the years 1950 and 1980 were limited.
5.3.2 The first wave of diffusion and convergence

This section will see the discussion of the results of the regressions for 1930, as presented in table 5-3. We shall discuss the results in the order of the hypotheses stated in section 4.3.2. For 1930, we cannot make a decision on statistical grounds of which of the two spatial regression models we ought to prefer. The R-squared of the SAR and of the SEM model are both around 0.79 and differ only in the third decimal after the comma. The two models differ mainly in respect to two variables: “share of agriculture” and “population density” are both significant in the SAR model, but not in the SEM model. Since we cannot decide which model is more appropriate, we are equally unable to decide which interpretation of these two variables is right.

Let us first consider economic opportunity as measured by the variables “income” and “wealth.” Both variables “income” and “wealth” are highly significant to all types of regression models. Their $\beta$-coefficients are very high. Only “car density level of 1928”, has a higher $\beta$-coefficient. Therefore it seems plausible that economic opportunity formed a crucial consideration in the geographically varying adoption behaviour of the time. We cannot reject hypothesis 1a for this period, which read: The degree of economic opportunity was at all times positively related to car density levels. The value of the $\beta$-coefficient for “income” is higher than the $\beta$-coefficient for “wealth.” This indicates that a change in the level of income had an even greater impact on the level of car adoption than an equally strong change in the level of wealth did. In a hypothetical situation based on these figures, the car density of a municipality would rise by approximately 1%, if the average income of that municipality saw a rise of 6% and all other conditions remained constant.
Table 5-3 Summary Regression Results 1930

Number of cases = 1011  Dependent Variable: ln \(^a\) (Car Density 1930)
Row-Standardized Distance Circle: Four Nearest Neighbours

<table>
<thead>
<tr>
<th>Model</th>
<th>OLS</th>
<th>SEM</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.529</td>
<td>**c</td>
<td>-0.568</td>
</tr>
<tr>
<td>ln (Car Density 1928)</td>
<td>0.649</td>
<td>***e</td>
<td>0.632</td>
</tr>
<tr>
<td>ln (Population)</td>
<td>-0.026</td>
<td>**</td>
<td>-0.029</td>
</tr>
<tr>
<td>ln (Population Density)</td>
<td>-0.028</td>
<td>*d</td>
<td>-0.027</td>
</tr>
<tr>
<td>Train Stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Stops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln (Income per Capita)</td>
<td>0.192</td>
<td>***</td>
<td>0.200</td>
</tr>
<tr>
<td>ln (Wealth per Capita)</td>
<td>0.118</td>
<td>***</td>
<td>0.122</td>
</tr>
<tr>
<td>% Agriculture</td>
<td>-0.001</td>
<td></td>
<td>-0.001</td>
</tr>
<tr>
<td>% Manufacturing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R-squared
(Adjusted) 0.787  0.790  0.792
Moran's I 3.273  ***
Lambda 0.126  ***
Rho 0.119  ***

Coefficient of Adjustment Speede 0.22  0.23  0.24

Sources: See list of sources.

a "Ln" stands for logarithm to 10.
b *** significant on the 1% level.
c ** significant on the 5% level.
d * significant on the 10% level.
e The coefficient of adjustment speed (\(\alpha\)) is calculated as in the following equation:
\(\alpha = -\ln (\beta\)-coefficient for car density of the previous period divided by interval in years between the previous period and the regression year).
In this equation "ln" stands for logarithm to 10.

Moving on to social diffusion, we shall discuss the measures "share of agriculture" and "share of manufacturing" in the occupational structure. In the Netherlands, these two measures pertaining to economic structure are generally not significant. An exception to this is formed by the SAR model. The \(\beta\)-coefficient here is significant on the 10% level and extremely small. This means that if we allow for corrections to that part of the total spatial disturbance only, namely the part that stems from the autocorrelation in the dependent variable, the share of agriculture would seem to have been negatively associated with car diffusion. If we correct for the entire spatial disturbance present in the model, the share of agriculture does not appear to have influenced spatially varying adoption levels. It is not significant. If we consider other distance weights, the
The variable "share of manufacturing" is clearly not significant. We are inclined to think that the Randstad lead in the diffusion process at the time, since international services and capital intensive industries were concentrated there. In fact, it is impossible to define the major user group along the broad lines of the three economic sectors, to wit agriculture, manufacturing, and services. People working in any one of the three economic sectors apparently adopted cars in certain regions.

We learned earlier that the economic West-East divide in the Netherlands had at least two dimensions, the first being of an occupational structure and the second being in income variation. If we combine our findings on economic opportunity with our findings on social structure, we conclude that the crucial difference between the West and the East did not lie in the East being more rural, but rather in the East being less prosperous.

Which rural regions showed relatively high adoption levels, and which did not, is not information derivable from this regression analysis. Therefore, it is left to future research to determine whether the following was true: Those parts of the Western Car Belt which were simultaneously rural and prosperous could contribute in the exceptional car growth of the West by virtue of their population being prosperous and thus being able to afford a car; the poorer Southeast, whether industrial or rural, was lagging in car adoption.

"Distance to markets" will be discussed with the help of the variable "population density.”

Shown in table 5-3, the “population density” variable is negative and significant on the 10% level in the reduced SAR model, as well as in the OLS model. It is, on the other hand, insignificant in the SEM model. Thus, if we correct for the entire spatial disturbance in the model, it is not significant any longer. Note, however, that population density remains significant for a broad array of trial runs that incorporate other distant
weights. The sign of the variable is negative, as was hypothesized in hypothesis 3 and 5, which respectively read: Approximately since 1908, people who operated their cars in some "distance to markets" had a larger economic benefit from car adoption than people elsewhere—population density was therefore negatively related to car density levels; The negative relationship between population density and car density increased after the Second World War as a result of suburbanization, change of lifestyle, and the diffusion of cars amongst private households.\textsuperscript{147}

As we saw previously, the variable “population density” conveys several meanings. The first interpretation is related to the concept of "distance to markets." The second interpretation is related to negative spatial externalities and/or additional expenses in crowded places. We cannot tell to which extent either meaning is feasible. “Population density,” if significant, may indicate the influence of either concept, or of a combination of both. In this paragraph we will assume that its meaning is related to "distance to markets."

Since the evidence, as relayed by the regression analysis, is not consistent, we must consider that the economic benefits from the car were generally not perceived as being higher in areas with dispersed markets than in other areas. Thus hypothesis 3, as reproduced above, may actually not hold. There was no, or only a minimal, systematic additional benefit from the purchase of a car in places with a low level of population density in which the markets were dispersed.

Note, however, that this interpretation is subject to an impediment inherent in the measure: the dispersion of the market is typically a characteristic of an area, and not just of a single place. People in a small, dense place in the direct vicinity of many dense places, which might also potentially be large, can be expected not to suffer from "distance to markets" in the sense of dispersed markets a lot.

If we look at the real figures, we see that there is a large variance in car density for similar values in population density. The large variance in car density level in relation to population density suggests that there is a third factor, which determines which of the places with a low, respectively high population density possess many or few cars. We shall later on suggest a new hypothesis concerning this quandary.

\textsuperscript{147} Squared population density is never significant. Squared population density is supposed to be indicative of a well-developed car-related infrastructure and/or of the hierarchy effect. If this variable is insignificant, this either means that we do not measure the concepts "well-developed infrastructure" or "hierarchy effect" with it, or it means that neither effect mattered.
The negative correlation between “population density” and “car density” appears to be significant in the SAR model. Therefore, we must also consider that there might have been some effects on “car density” originating from “population density.” It would appear that, at least for a certain subpopulation amongst all Dutch municipalities, it did matter whether a place was highly densely populated or not. If we assume that “population density” is an indicator for "distance to markets," we cannot reject the hypothesis that people places with low population density expected a larger benefit from the car, because they had to cover larger distances in order to serve a dispersed market. We should, however, consider that this hypothesis may not apply to all Dutch municipalities.

The effects of “population density” on “car density” are statistically quite limited in our regression analysis, since the value of the $\beta$-coefficient of “population density” is very low. Theoretically, a place would ceteris paribus have to reduce its population density level with 36%, in order to achieve a 1% increase in car density level. As we have seen earlier, people living in the West of the country were more likely to be able to afford a car than people in the East. There existed relatively few areas with low population density in the West, i.e. the Groene Hart, Zeeland, the northern edge of Noord-Holland, and the northern branches of the Car Belt in Friesland. These areas might, at least in part, have become sections of the Western diffusion core, because they combined “wealth” with “distance to markets.”

Note that this interpretation only holds under the assumption that “population density” stands for "distance to markets." Though we cannot be sure that the negative relationship between “population density” and “car density” is not, at least partly, a reflection of concerns related to the "necessity" argument.

Let us look at the variables related to public transport. The “tramline” variable is highly significant and has a positive value. In fact, “tramline” is the only variable which is designed to measure an aspect of benefits and which is clearly significant. At the same time, neither “railway” variable ever enters as significant in any of the models shown above or for any other distance weight. It was clearly not the case that benefits increased as a result of "lack of public transport." Therefore, we can reject hypothesis 4, which read: People who operated their cars in areas which were scarcely pervaded with public transport had a larger economic benefit from car adoption than people elsewhere. Therefore, good access to rail-bound modes of transport was negatively associated with car density levels.

We shall speculate a bit on how we can interpret the positive relationship between “tramline” and car density levels. As we have mentioned earlier, the tram was designed as an overland vehicle which did not cater exclusively for large places. It served for transport of people, as well as for transport of goods. It is possible that it served economic distribution centres of regional importance in which transport demand was high. The high car density level in these places thus built upon a tradition of high transport demand. This transport demand possibly did not only concern travel, but the transport of goods as well.
Furthermore, the existence of trams in a place might have created further transport demand in said place. As we saw earlier, the building of tramlines invited suburbanization, thereby creating dependencies on new modes of transport. This would in turn mean that "necessities" shaped spatially varying car demand as early as by the end of the first wave of diffusion and convergence, which is against our previous expectations. It seems as if people were prepared to purchase a car as a consequence of their emigration from the city centres. If we look at the data set, which are the places with car density levels far above 10 cars per 1,000 inhabitants, and with tramlines? A lot of them are places in Zuid-Holland, Noord-Holland, and Utrecht, which have until now been known in the Netherlands as typical suburbs and commuter places, e.g. Wassenaar, close to ’s-Gravenhage; Driebergen, and De Bilt, close to Utrecht, to mention but a few. This constitutes further support for the idea that the positive relationship between tramlines and car density reflects the importance of trams in serving and creating commuter places. As we have said earlier, the Randstad was leading in the suburbanization process. Therefore, we propose that the Randstad became the core of the leading region in car diffusion because of, amongst other things, its relatively high degree of suburbanization, and the "necessity" for, or at least the benefit from, the car, which go along with that.

To illustrate the possible influence of the “tramline” variable on the geographical diffusion pattern, we once more refer to the map in figure 4-2, which shows the tramlines as they were present in the Netherlands in 1930. In the western region where cars were most affordable, tramlines were frequent in Friesland, Zeeland, and in the coastal regions of Noord- and Zuid-Holland.

To illustrate the effects of tramlines on the car density, we shall give a hypothetical example: if a municipality were to gain a tramline, and all other conditions remained equal, the car density level of that municipality would rise with 0.05%; provided that this municipality initially had a car density of 7, then its car density level would now rise to 7.35.

The access to railways neither weakened nor strengthened the perception of benefits. The location of railway stations and their implied connectivity had nothing whatsoever to do with car adoption. Unlike in the US, the arrival of the long-distance train did not increase the benefit derived from car adoption. This suggests that cars were not bought predominantly in order to make long-distance economic transfers easier or faster. Moreover, trains were a phenomenon which was strongly associated in the spatial structure of the Netherlands in the year 1930 with the degree of urbanization: train stations—and particularly the busy ones—were at that time likely to be located in large and densely populated places. The fact that “trains” have no systematic effect on “car density” shows us that the relationship between urbanization and car density is more complex than a simple positive or negative correlation. We shall develop the issue further when looking at the remaining variables.

We turn now to the issue of negative spatial externalities and/or additional expenses in crowded places as measured by “population density.” As detailed in the paragraph on
"distance to markets," “population density” is not always significant and has a negative value. We cannot reject hypothesis 6a, which states that negative spatial externalities and/or additional expenses in crowded places already had a systematic effect on car adoption choices in 1930. In the most densely populated places, spatial externalities and additional costs of housing and car use held down the car density figures. Thus the negative relationship between population density and car density, as hypothesized in hypothesis 3, has a different origin when taking the most densely populated places into consideration. However, the support for this hypothesis is not strong.

Again, it is possible that negative spatial externalities were perceived as a feature of a cluster of places instead of a single, separate place. Imagine an individual living in an extremely densely populated place, which is surrounded by somewhat less densely populated places. Such an individual might not perceive negative spatial externalities to any troublesome degree. Such a situation was not unusual in the Netherlands of the 1930s. As you can see in the map in figure 3-9, the Randstad saw extremely densely populated places existing side by side with somewhat less densely populated places.

So far, we have not commented on the “population” variable, which is supposed to stand for the hierarchy effect. The “population” variable is significant and shows a negative value, indicating that small places tended to have high car density levels in 1930. The negative relationship with car density levels goes against our expectations as expressed in hypothesis 8: The hierarchy effect was at work during the entire diffusion process. We expected a positive value as an indication for the hierarchy effect. Here, we shall give some suggestions for the interpretation of this relationship.

Quite a few small places were suburbs. In these cases, it is likely that the small places showed high adoption levels by virtue of their function as suburbs. Thus the negative relationship between “population” and “car density” corroborates the earlier statement that people in suburbs already orientated their adoption behaviour towards “necessities.” However, these “necessities” were not so much stimulated by tendencies of consumerism, as did the habit of suburbanization create these dependencies on cars.

More generally, quite a few small places were situated rather close to towns and cities. Therefore we suggest here a somewhat broader interpretation of the “population” variable, namely that these small places in the neighbourhood of towns and cities had intense economic exchange of various kinds with those towns and cities. Since the villagers gained access to the markets of the population agglomerations by using the car, the benefits for car use might have been generally high in places which were close to
towns and cities and which maintained economic exchanges with their respective population agglomeration.

To take the argument even further, we propose that in places in which the local agricultural population serviced the neighbouring population agglomerations, and where they were simultaneously able to afford the car, the agricultural population may have adopted the car quite quickly. Of course, many very small places were also rural in character. E.g. those places which had fewer than 1350 inhabitants in 1930 and which at the same time had very low population densities (with 78 inhabitants per squared kilometre or below), they had an average share of agriculture in their employment of 76%. When farmers lived in places which served the population agglomerations, they had a strong economic incentive to buy a car. After all, they had to cover a certain "distance to large markets". The car density level was consequently rather high in these small places. Note that direct consumption was not the main motive for production of most Dutch farmers. A large percentage of agricultural products was delivered to the processing industry, which, as an aside, was often located in the regions of production and often had their own, central delivery system as well.

In view of this interpretation, the strong variance in car density levels amongst places with similar population density can be understood. For places with intense economic exchange with other places, there was not a lot of influence by their own population density on the benefit obtained from cars.

In order to illustrate the intensity of the effects of "population" on car density levels, another hypothetical example will suffice. The β-coefficient for "population" is 0.029 in the SEM model. This means that the population of a place has to drop by approximately 34% in order to increase the car density level by only 1%. A place with 10,000 inhabitants and a car density level of 7 cars per 1,000 inhabitants would have to rid itself of around 1,500 inhabitants, everything else remaining unaltered, for its car density level to move up to 8.

There is, however, a limitation to the aforementioned interpretations: the negative value of the variable "population" might in some respects be related to car adoption behaviour in certain rural parts of the Car Belt. In Friesland and Zeeland, small places tended to show higher car density levels in 1930 than their larger neighbours. In these regions, both relatively large as well as small places were rural in character. At the same time,

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148 Note, however, that this only holds for the smallest places. In a large range of places, the variance in “share of agriculture” with similar values for “number of inhabitants” is very large. This is to say, there are relatively large places with a lot of agriculture and small places with very little agriculture.
smaller places were likely to have higher income and wealth levels, so that we might as well be dealing with a superficial relationship.

Does this entail that the hierarchy effect did not exist? This is in principle possible, but rather unlikely. The hierarchy effect perhaps no longer, if it at some point had done so in the first place, followed the conventional pattern "large places first." Maybe it would be appropriate to include in the measurement the places that are direct neighbours to the large places. To us it seems probable that the measurement for the hierarchy effect as used here is not suitable.

To summarize, there is strong support for the idea that variation in income, and in wealth, was crucial in determining the location of the leading and lagging areas in the Netherlands during the first wave of diffusion and convergence.

On the benefit side of the ratio between costs and benefits, the results of the regression analysis are much more obscure. For a start, it is possible that there were already incentives to buy a car, which were not exclusively related to the utilitarian use of the car. It appears that in 1930 suburbanization already exerted influence on the car diffusion pattern. This being a deduction from the fact that the variables "tramline" and "population" are significantly associated with car density levels.

If, however, we adhere to the assumption that cars were mainly important for business-related journeys and the distribution of goods during the first wave of diffusion and convergence, it appears that we have to differentiate slightly more between our ideas on "distance to markets." Through the choice of the relatively small scale of the analysis and of the Netherlands as subject, it appears as though the idea of "distance to markets" can carry two meanings. For businesses which are orientated towards the agglomeration centres, the distance to those agglomeration centres is relevant. For businesses which are orientated towards serving local clientele, it is relevant whether the local markets are dispersed or not. This distinction might go some way to explain the large variance which we find in our measure "population density."

We cannot definitively say, whether negative spatial externalities and/or additional expenses in crowded places already played a role in 1930.

We have to reject the idea that it was principally the poverty of farmers which held back this occupational group from adopting a car in the period in question. The impression we gain from this regression analysis is rather that farmers adopted cars when they could afford them, and thus probably particularly in the prosperous West.

According to this interpretation, the Randstad was leading in car diffusion, because it combined “wealth” with considerable benefits derived from cars. These benefits might have stemmed from suburbanization, economic exchange with agglomeration centres, and in part from relatively dispersed markets. Likewise, the more rural parts of the Western Car Belt combined “wealth” with benefits related to "distance to markets."

We have touched upon two additional hypotheses regarding the first wave of diffusion and convergence, to wit hypothesis 3 addendum: Benefits from the car were higher in places with a lot of economic interaction with population agglomerations—if we
assume that the economic interaction between population agglomerations and other places reduced on a par with the distance between them, there is a negative correlation between distance to the next population agglomeration and car density level; and hypothesis 2 revised: The benefit from the car was greater for farmers who produced for direct consumption than for farmers who produced to service the processing industry. Therefore we expect a positive correlation between the share of agricultural goods produced for direct consumption, as a subdivision of the entire agricultural production, and the car density level.

5.3.3 The second wave of diffusion and convergence

Why did the once coherent structure dissolve during the second wave of diffusion and convergence in the Netherlands? Why did what used to be the periphery exceed the former leading areas in the Netherlands in car density levels? We get some way to answering these questions by comparing the Dutch regression results for 1950 and 1980 with each other, which are presented in table 5-4 and table 5-5 respectively.

Like for the 1930 regressions, we cannot determine which regression model is to be preferred for 1950 on statistical grounds: The R-squared of the SEM model and the SAR model are almost the same. In this instance, in both spatial regression models the same variables are significant and insignificant, so the interpretation is somewhat clearer. As discussed in section 5.2.2, we analyse the OLS model for the 1980 regression, since the value of Moran's I is insignificant.

Regarding economic opportunity, we see the following development: in the 1950 regressions, “income” is the only significant independent variable apart from “car density of the previous period.” It is highly significant and the value of its $\beta$-coefficient is high. This changed come 1980. In the regression model for this year, the “income” variable is no longer significant.

In 1930, the $\beta$-coefficient for “income” is bordering on 0.2, while the $\beta$-coefficient in 1950 revolves around the 0.3 mark. We cannot compare these two values directly, because the independent variables that are included within them are not the same. In any case, it shows that economic opportunity was still very important for car adoption choices in 1950.

We postulated for the Netherlands in hypothesis 1b that the effect of economic opportunity declined after the Second World War. Since the “income” variable was no longer significant in 1980, we draw the following conclusion: income restrictions vanished entirely as a determinant for spatially varying car adoption levels at the end of the second wave of diffusion and convergence in the Netherlands. Ostensibly, the combined effects of income equalization and the rise of prosperity lay the foundations of that. With the prospect of the 1980 results in table 5-5, we are obligated to reject hypothesis 1b, which in an alternative reading states that the economic barriers slackened to adoption during the second wave of diffusion and convergence. Instead, we claim that they ceased to be of any importance.
The restructuring of the spatial order as it had been established during the first wave of diffusion and convergence was most likely influenced by this change in relevant conditions. E.g. the formerly lagging regions caught up and partly reached higher adoption levels than those formerly leading, because restrictions in terms of economic opportunity no longer kept the lagging regions in their allotted place.

Table 5-4 Summary Regression Results 1950

<table>
<thead>
<tr>
<th>Model</th>
<th>OLS</th>
<th>SEM</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.206</td>
<td>0.228</td>
<td>0.236</td>
</tr>
<tr>
<td>ln (Car Density 1938)</td>
<td>0.561***</td>
<td>0.550***</td>
<td>0.537***</td>
</tr>
<tr>
<td>ln (Population)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln (Population Density)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Stops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln (Income per Capita)</td>
<td>0.339***</td>
<td>0.345***</td>
<td>0.278***</td>
</tr>
<tr>
<td>R-squared (Adjusted)</td>
<td>0.534</td>
<td>0.547</td>
<td>0.536</td>
</tr>
<tr>
<td>Moran's I</td>
<td>4.943***</td>
<td>0.188***</td>
<td>0.151***</td>
</tr>
<tr>
<td>lambda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of Adjustment Speed (^c)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Sources: See list of sources.

a "Ln" stands for logarithm to 10.

b *** significant on the 1% level.

c The coefficient of adjustment speed (\(\alpha\)) is calculated as in the following equation:

\[\alpha = -\ln (\beta\text{-coefficient for car density of the previous period divided by interval in years between the previous period and the regression year})\]

In this equation "ln" stands for logarithm to 10.
Table 5-5 Summary Regression Results 1980

Number of cases = 797  Dependent Variable: ln (Car Density 1980)
Row-Standardized Distance Circle: Four Nearest Neighbours

<table>
<thead>
<tr>
<th>Model</th>
<th>OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.615 ***</td>
</tr>
<tr>
<td>ln (Car Density 1975)</td>
<td>0.588 ***</td>
</tr>
<tr>
<td>ln (Population)</td>
<td></td>
</tr>
<tr>
<td>ln (Population Density)</td>
<td>-0.014 ***</td>
</tr>
<tr>
<td>Train Stations</td>
<td></td>
</tr>
<tr>
<td>Train Stops</td>
<td></td>
</tr>
<tr>
<td>ln (Income per Capita)</td>
<td></td>
</tr>
<tr>
<td>% Agricultural Workers</td>
<td></td>
</tr>
<tr>
<td>R-squared (Adjusted)</td>
<td>0.229</td>
</tr>
<tr>
<td>Moran's I</td>
<td>-0.037</td>
</tr>
<tr>
<td>Lambda</td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Adjustment Speedc</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Sources: See list of sources.

a "Ln" stands for logarithm to 10.
b *** significant on the 1% level.
c The coefficient of adjustment speed (α) is calculated as in the following equation:
\[ \alpha = -\ln (\beta\text{-coefficient for car density of the previous period divided by interval in years between the previous period and the regression year}). \]
In this equation "ln" stands for logarithm to 10.

We have seen in the previous section that we cannot pin-point a single main Dutch user group to the exclusion of workers from one of the other economic sectors, i.e. agriculture, manufacturing, and services. The “agricultural” variable is not significant in 1930. For 1950, we do not possess a variable with a comparable meaning. For 1980, we used the variable "share of agricultural workers in the population." Through this we were able to determine that, in 1980, the “agricultural” variable is also not significant. This is as we expected according to hypothesis 2b: During the second wave of diffusion and convergence, the influence of the location of the major user group on car density levels vanished. Formally, we cannot reject this hypothesis. However, it makes little sense to interpret the insignificance of the “agricultural” variable this way, because its parallel variable for 1930 is already insignificant. Since this particular variable did not appear to reflect any social diffusion as early as 1930, it is untenable that the insignificance of the “agricultural” variable in 1980 is the result of the widening of any of the user groups. Yet, if we emphasize the possibility that in 1930 there was a minor negative influence caused by rurality, we see that this influence has vanished by 1980. Basically, we can reject the idea that the Dutch late switch from urban cores of diffusion to decentralized leading areas is a late repetition of...
the American experience, in so far as the farmers suddenly becoming the dominant user group. If we track the social diffusion in the Netherlands as described by Staal, this possibility was out of question anyway. Staal stresses that the "countryside," which seems to have dominated in Dutch car diffusion from 1976 onwards, is at this point in time not rural any more. Rather, we are dealing here with the former countryside, which has become integrated into the urban system by suburbanization by the time that it assumed the lead in car diffusion. Our findings confirm this view as relayed by Staal. If the new leading areas had been rural in character, we would have seen a significant relationship between the "agricultural" variable and the level of car density. Evidently, social diffusion in the Netherlands can not be grasped by the distinction between the three economic sectors, and this has been the case since 1930.

How did the influence of the “population density” variable change during the second wave of diffusion and convergence? In 1930, “population density” was significant in the SAR model and not significant in the SEM model. In the regressions for the year 1950, the variable had dropped to completely insignificant. In 1980, “population density” remains the only significant variable in the reduced OLS model: it is highly significant on the 1% level. The value of its $\beta$-coefficient is somewhat lower in 1980 than in 1930: while in 1930 the $\beta$-coefficient was -0.03, it is down to -0.01 in 1980. The decline in $\beta$-coefficient does not mean that the “population density” variable became less influential—the figure must be smaller, because in the meantime the variation in “car density” was greatly reduced, while the variation in “population density” was not.

In our interpretation, however, we can focus on the significance of the “population density” variable, which changes over time. We have argued before that "population density" might have mattered in 1930 only for a specific subgroup of Dutch municipalities, and not for all municipalities. In 1950 "population density" is insignificant showing that an influence of this variable on car density levels is unlikely. In 1980, however, "population density" is highly significant. Thus one or more of the impulses measured by this variable clearly mattered to the car density levels in Dutch municipalities. In fact, any such impulse appears to be a principal determinant of the remaining spatial variation in car density level.

This can mean one out of three things:

1. The benefits of people who lived at some "distance to markets," where markets indicates those of a dispersed nature, became important during the second wave of diffusion and convergence. This is the most unlikely interpretation, since we do not have any theoretical grounds for this presumption. We suggested in the previous section that the “population density” measure can only capture a certain aspect of "distance to markets," namely that of "dispersed local markets." If this supposition is valid, then even with an increase in benefits related to "distance to markets," the expectancy shall still be that not all places follow the same pattern. In 1980, the relationship between "population density" and “car density” is clearly applicable to a wide range of cases. This would become visible, if we were to draw a plot with “population density” on one
axis and “car density” on the other. Unlike in 1930, the variance in “car density” with similar values of “population density” is rather small. On these grounds, we do not consider this option very likely.

2. The negative relationship between “population density” and “car density” increased after the Second World War as a result of suburbanization, change of lifestyle, and the diffusion of cars amongst private households. This interpretation corresponds exactly to hypothesis 5, which would thus hold true.

A slight modulation of our expectations expressed in section 4.3.2.2 seems appropriate. We have emphasized in the previous chapter that, through suburbanization, predominantly rich people escaped en masse from crowded places, their cars in tow. However, according to our findings it is not true that it was the rich people per se, who caused this pattern through an exodus from the denser places. In fact, income restrictions did not matter any longer in 1980. Furthermore, it is not strictly speaking the case that people avoided cities when in possession of a car. In as far as cars are concerned, the main objective was on escaping dense places—irrespective of their size.

3. The effect of spatial externalities increased over time, i.e. hypothesis 6b. We cannot be absolutely sure that the effects as stated in hypotheses 5 and 6b really increased, since we cannot compare the values of the β-coefficients with each other. What we do know, however, is that any one of the three considerations, or a combination of them, determined the remaining variation in car adoption levels in 1980. As a result, when compared with the situation between 1928 and 1950, the landscape of car diffusion changed entirely during the second wave of diffusion and convergence. The West-East divide was replaced by a divide between places with a low population density and those with a high population density.¹⁴⁹ The places within the Randstad which had a high population density experienced a relative loss in car adoption levels. Since places that possessed a high respectively low population density were not strongly clustered in certain Dutch regions, places with high respectively low adoption rates hardly clustered geographically either. The formerly lagging areas partly exceeded the former cores in car density levels, to the extent that they had rather low population densities.

Let us turn to the variables related to “public transport” and the underlying issue of "isolation." Neither in 1950 nor in 1980 is either of the two variables related to the “access to trains” significant. Car diffusion was by 1930 already not a phenomenon

¹⁴⁹ See also the map in figure 7-2 in appendix I.
linked to transport centres of the type that hosted train stations, busy or otherwise. The “new” car centres, which developed during the second wave of diffusion and convergence, remained independent from the traditional transport centres as specified by the access to trains. This means that we are not able to distil a clear pattern of either substitution or complementation from the data. As was apparently already the case in 1930, the additional benefits for cars in places with a low population density were not related to the alternative transport mode of trains. As far as trains are concerned, we can once again reject hypothesis 4.\textsuperscript{150}

This does not entail that the general rule pertaining to the relationship between access to public transport and the use of the car, namely that people with good access to public transport find it easier to dispense of the car, does not apply to the Netherlands. After all, commuting takes place with multiple kinds of public transport, e.g. the bus or metro. Furthermore, we deal here not with usage patterns, but with the decision to own a car.

Moving on to the hierarchy and the neighbourhood effect, we see that the “population” variable is not significant in the regressions for 1950 and 1980. Again, we could say that the hierarchy effect did not eventuate as expected. Alternatively, we argue that with such a high overall adoption level for 1980 the hierarchy effect no longer made a significant difference.

As we know, the value of Moran’s I is also not significant in 1980. This means that it did not matter any more to the adoption choices whether a place was surrounded by highly adoptive places or lowly adoptive places. This indicates that the neighbourhood effect was no longer relevant. Theoretically, everyone, at any location in the Netherlands, and with a certain frequency, had an equal chance of coming into contact with equally as many adopters. Therefore, social influence from adopters to non-adopters did not determine the spatially varying adoption levels any more.

By way of summary, car diffusion was not "pushed" any more by income variations towards the prosperous West by the end of the second wave of diffusion and convergence. At the same time, cars were "pulled" out of crowded places—whether large or small. The combination of these two forces created a dynamic in which the

\textsuperscript{150} Hypothesis 4 read: People who operated their cars in areas which were scarcely pervaded with public transport had a larger economic benefit from car adoption than people elsewhere. Therefore, good access to rail-bound modes of transport was negatively associated with car density levels.
regional divide was dissolved and replaced by a local diversity between more or less crowded places.

The switch from the dominance of urban to rural areas in the Netherlands in 1976, as described by Staal, was not a belated repetition of the rise of the American Midwest. Quite a different set of conditions shaped these two developments. In the Netherlands, it was not the wealth of the population, but the fact that “income” vanished as determinant of spatially varying car adoption levels which made the rise of the "countryside" possible. Though the name suggests otherwise, this "countryside" was not even rural. It is most likely that the incentive to reduce the sense of isolation did not play a role in this switch of leading areas. On the contrary, the desire to escape from crowded places might have governed this dynamic. Which role the "distance to markets" variable played at this point in the Dutch car diffusion process, is not certain.

5.4 Conclusion

In conclusion, we shall first point out the methodological restrictions of this analysis. Thereafter, we shall compare our findings with the American example.

Our analysis of particularly the first wave of diffusion and convergence remains quite vague. This is in part related to the fact that the SEM and the SAR model produced different results. The other part lies in the inadequacy of our measurement. The measurement "population density" is designed to measure various concepts at once. Furthermore, it might not adequately cover the concept "distance to markets," since this term can refer to dispersed local markets as well as to the distance to large markets, such as population agglomerations. Moreover, our analysis focuses on the effects which the features of an individual municipality have on the car density level of this municipality. By doing so, we ignore the influences of surrounding municipalities. A final methodological restriction is that benefits might differ in various areas of the country, e.g. the major benefits in suburbs within the Randstad might differ from those sought after in isolated rural places. The latter restriction can be addressed by using a regression analysis, which allows for different results per region.

In comparison with the US, the spatial dynamics in the Netherlands seem both later in time and different in cause and progression.

We see two ways in which the Netherlands was possibly delayed in this respect in comparison with the US.

In the US, affordability and perceived benefits joined forces in the Midwest. In the Netherlands, the perceived benefits were, in the long run, greater in places with a low population density than in those with a high population density. It appears, however, that this potential could not yet fully express itself during the first wave of diffusion and convergence, because many people in places with a low population density were not able to afford a car. In other words, perceived benefit and affordability did not co-occur in a broader area. As affordability lost its grip on the diffusion process after the Second World War, the perceived benefits could be transformed into higher car density levels.
We also argue that the perceived benefits in areas with a low population density were not yet developed in the same way as they were in the US. Due to the "cultural lag," dependencies on the car in areas with a low population density were presumably not yet as far-reaching as in the US.

We see a further three ways in which the Netherlands was different from the US in cause and progression. To begin with, farmers became the predominant user group in the US during the first wave of diffusion and convergence. This was obviously not the case in the Netherlands. Therefore, the American diffusion core included states incorporating a large countryside. In the Netherlands, we see a rather more mixed picture on a much smaller scale, in which predominantly urban municipalities, predominantly rural municipalities, as well as municipalities with mixed occupational structure, could all potentially gain high car density levels.

Secondly, in the larger country of the US, long distances were perceived as a major economic problem; the car was used to overcome this problem. Therefore it was used by farmers as a complement to the long-distance transport mode, i.e. the train. In the Netherlands, the main problem related to transport does not appear to have been covering long distances. Rather, the car, in its capacity as a utilitarian transport mode, was mainly used to help cover distances on regional scale. To the Netherlands, a small country, and here purposefully tackled on a small analytical scale, the distance to large markets does not seem to have mattered in the same way as it had done in the US. During the first wave of diffusion and convergence, municipalities with high car density levels were often located close to population agglomerations, most prominently in the Randstad. During the second wave of diffusion and convergence, the benefit from the car was strongest in municipalities with a low population density. We did not incorporate a measure for distance to population agglomerations, but the impression is that this tendency applied to all municipalities, notwithstanding their distance to population agglomerations. In both countries, the economic, overland transport demand had been addressed by a rail-bound transport mode prior to the coming of the car. In the US, trains had been built to connect the East and the West. In the Netherlands, a dense tram network had been constructed.

The third difference might lie in the social incentives to buy a car. In the densely populated Netherlands, the car movement seems to have been inspired by the desire of the Dutch people to escape the densely populated cities and other dense places. As soon as the car had spread amongst private households, it had probably been integrated into the suburbanization movement and was being used to escape the crowdedness. This intention is the reverse of the desire of Midwestern farmers to escape their social isolation. Dutch people tended to suffer from being surrounded by too many people, rather than from too few. After the Second World War, a combination of several factors apparently "pulled" the car out of densely populated places. One of these might be that places with a low population density became more and more appealing in their capacity as places which exude an attractive lifestyle and therefore they became the new suburbs.
The effect of these two opposite push factors was, however, similar, namely a high car density level in places with a low population density. Although, it is possible, and even to be expected, that the push factor presented by the crowdedness existed likewise in the US in those areas which were similarly densely populated as in the Netherlands. However, we cannot trace this very well on the large scale of states and groups of states.

Apart from the differences, there are also striking similarities between the geographical diffusion paths of these two countries. Firstly, income levels, and thus economic opportunity, were very important in shaping the location of diffusion cores and lagging regions in both countries. In the US, the general income level remained important until 1969. In the Netherlands, the influence of economic opportunity had vanished by 1980. Thus in both countries the diffusion cores were located where there was a ready infusion of wealth. In the US, this was the semi-rural Midwest, while in the Netherlands this was the population agglomeration the Randstad and the province Zeeland.

Secondly, we cannot exclude the possibility that in the Netherlands, like in the US, dependencies on the car already existed prior to the start of the Second World War. In the case of the Netherlands, the role of the suburbs would need to be emphasized here. Lastly, the fact that the core of the Dutch leading areas consisted of urban areas in the years 1928 to 1950 does not necessarily mean that the considerations related to “distance to markets” never applied, or only applied very late. Our evidence shows that an alternative interpretation might be valid: in the Netherlands of the Interbellum, regions existed in which members of various occupations were wealthy enough to express an additional demand for cars in places with geographically dispersed inhabitants.

There did, however, exist large differences between various rural regions. Thus, the relationship between the population agglomerations and their hinterland may have been important in shaping the diffusion cores and lagging regions in both countries. It seems possible that in both countries those remote places, which were the source of economic flows towards the population agglomerations, had high car density levels. "Distance," then, is indeed a relative term, since the distance between e.g. Zeeland and the Randstad is much smaller than the distance between the Midwestern states and the states along the Eastern coast.
6 Conclusion

In this conclusion, we shall summarize our main findings per chapter, discuss the consequences of these for the image of the Netherlands as motorization latecomer and point the reader to some of the main limitations of our results.

6.1 Summary of the findings of this book

As compared with the US, was the Netherlands late in the diffusion of cars? In this book we differentiated between many aspects of the perceived image of the Dutch delay in car diffusion. The traditional way to go about answering the initial question has been to look at the absolute penetration rate leading up to the Second World War. Up till then, the Netherlands was clearly slow in car adoption in comparison with the US, and even in comparison with some of the other European countries.

In chapter 2, we related the car adoption rate to a saturation rate which had been estimated on the basis of the agglomerated diffusion curve plotted until the year 2000. We saw that the overall diffusion speed has actually been quite high. There was, however, a large discrepancy between the diffusion speed of the first part of the diffusion process and that of the second. During the first part of the diffusion process, the process was quite slow. Nevertheless, the Netherlands has belonged to the large group of European catching-up countries.

In chapter 3, we saw that the US, as forerunner country, and the Netherlands, as catching-up country, have both undergone two diffusion waves, one before and one after the Second World War. Albeit on a widely different scale, we could observe that the geographical dynamics of car diffusion were almost the same per diffusion wave. The differences in diffusion speed, which could be observed on the agglomerated level, do not translate into a lag in geographical diffusion.

In both countries, the spatial heterogeneity of adoption levels was strongly reduced during either car diffusion wave. During the first wave of car diffusion, a clear geographical divide between diffusion cores and leading areas was erected. During the second wave of diffusion, the spatial structure degenerated, while the lagging areas caught up.

In chapter 4 and 5, it became clear that the Dutch geographical diffusion path was not merely interpretable as the result of a lag. Additionally, it can be interpreted as structurally different from the US. There seem to be two aspects, which make the Netherlands appear different from the US in respect to geographical car diffusion. The first one is that the Netherlands has been relatively densely populated throughout its regions, while in the US there are huge, scarcely populated areas. As a result, the Dutch used the car to fulfill their desire to escape from crowds, juxtaposed with the scarcely populated areas in the US where the main desire was to escape from social isolation.
The second difference would appear to have been that farmers in the American Midwest used the car in order to reach distant markets, while the Dutch middle classes addressed their regional markets.

In addition, we might also point to the "cultural lag" as exhibited by the Netherlands in comparison with the US. This is to say, consumerism and suburbanization were cultural traits, which the Netherlands in general adopted somewhat later than the US. To elaborate on this, it appears that the diffusion of cars amongst private households was later in the Netherlands than in the US.

6.2 The Netherlands: Car diffusion in a small and dense catching-up country

What are the consequences of our findings for the image of the Dutch car diffusion path, which exists in the literature on social car diffusion? We shall look at various structural differences between the US and Europe/the Netherlands, which subject we have pointed out to have been outlined in the literature (see section 1.2.1). We shall put our findings in a perspective in light of these structural differences.

Flik expresses the belief that negative externalities have been felt more intensely in European countries with a high population density than in the US. High negative externalities were translated into high running costs. In this sense, the population density might have contributed indirectly to the diffusion lag as experienced by densely populated countries. Nevertheless, we arrive at a different hypothesis here. We are of the opinion that Flik was right when stressing the importance of population density as a structural difference between the US and some European countries. However, he looked only at the economic consequences of this, which we deem a one-sided approach. The social desire to escape from the crowds might have actually stimulated car diffusion. According to our findings, this social desire might have already existed in the Netherlands as early as the 1920s and 1930s.

Related to that, it seems that the demand for cars was stronger in the US because of the strong desire of people in villages to reduce their sense of isolation. We do not agree with this point of view. Though it is indeed likely that a sense of isolation did not govern the geographical diffusion process in the Netherlands. It might alternatively be possible that there existed a fair equivalent to this strong desire in densely populated areas such as the Netherlands: the desire to reduce one's sense of crowdedness. Likewise, the economic desire to enlarge one's market and to increase the distribution speed does not seem a unique aspect of a forerunner country, like the US. The fact that Midwestern farmers were at a considerable distance to their markets does not necessarily mean that their perceived benefits from the car were higher than in Europe, or the Netherlands in particular.
Subsequently, the lag in car diffusion is sometimes related to the strong diffusion of two-wheelers in the Netherlands. It is said that two-wheelers were a cheaper substitute to cars and in this sense hampered car diffusion. In light of our analysis, this interpretation might once again be somewhat limited in perspective. Two-wheelers could only be attractive as substitutes for cars, because both were used for interurban travel with the intention to cover regional distances. In this perspective, the high penetration level for two-wheelers in the Netherlands is not only a sign of a lag, but rather a consequence of a different type of demand.

Finally, the importance of economic opportunity in the car diffusion process is stressed again. Unlike comparable literature, we did not deal with issues related to taxes or other kinds of running costs in this book. Thus, we cannot say whether differences in economic opportunity caused the Dutch delay in the agglomerated diffusion curve when it is compared with that of the US. However, since the influence of income variation on geographically varying adoption levels seems impressive, we would indeed be inclined to look at factors relating to economic opportunity, if we were of a mind to explain the late take-off in Dutch car diffusion.

So far, the literature has been focused on explaining the European lag with reference to structural differences. While qualifying the idea of a European/Dutch lag, we at the same time included similarities between the two countries discussed here in the perspective.

Particularly the first wave of diffusion and convergence seems to incorporate numerous similarities between the two countries: in both countries the diffusion cores were those areas in which prosperity and benefits, most likely of a vast array, amalgamated. Economic opportunity was thus very important to the car diffusion process in both countries. In both countries the function of the car as transport mode to bring goods and services to the markets more efficiently seems to have been central to car diffusion from the first wave of diffusion and convergence onwards.

It is furthermore possible that in those regions of the US which were roughly equal in population density to the Netherlands the desire to escape the crowded areas was also very important for the geographical dynamics of car diffusion.

The international comparison of chapter 2 puts the opposition between the forerunner, i.e. the US, and the European laggards in a new and broader perspective. The research agenda of social car history has so far been focused upon the comparison between the US as the single forerunner and the European laggards as a clustered follower. The clustering in our analysis of multiple countries, extensively covered in chapter 2, inspires new questions, e.g.: What, if any, have the structural similarities been amongst the countries identified as forerunners, i.e. Argentina, Australia, Canada, Great Britain and the US? Since we are able to distinguish between two types of catching-up countries, what, if any, have the structural differences been between the two groups of catching-up countries? In addition, the findings invite scholars to broaden the time
6.3 Limitations of this study

In this book we have looked in quantitative terms at evidence in support of a lag between the US and Netherlands, using car ownership figures as an indicator. Car diffusion is, of course, not a phenomenon which stands alone; it is embedded into much more general dynamics of cultural or economic transition. We have at times touched upon some of these related issues of economic and social transition in this book, without dealing with them in any depth.

We have experienced that certain issues related to car diffusion are hard to grasp in a quantitative manner, since good measurements are not readily available, that is at least what we encountered for the case of the Netherlands. Therefore, we either did not include any measurements on them, or used rather simple measurements. In order to work up suitable measurements, it would require additional work in those fields of study, to which these are central issues. We did not at any rate consult the specialized literature on these issues.

Because our conclusions are limited due to these omissions, we shall now point out some of these issues. If one were to focus on these issues, one might conceivably come to different conclusions regarding the image of the Dutch motorization process as being late to start.

We found it hard to give an interpretation of the benefits without satisfactory background knowledge on the usage patterns. We used the concepts of "social diffusion" and "car diffusion as a utilitarian vehicle." At the same time, however, we did not differentiate between these two concepts in our measurement in the regression analysis in chapter 5.

We did not integrate the discussion on the Dutch lag in car diffusion into a broader perspective of a transport system in transition and changing inter-artefactual relationships. This issue is much more complex than our variables on trams and trains are able to reflect. Not only were there many other transport modes which seem related to the diffusion of passenger cars, e.g. two-wheelers, busses, and horses, the latter pertaining to the first twenty to thirty years of car diffusion, more importantly, we did not touch upon questions such as: how can we characterize the transport system of a forerunner country, or of any catching-up countries, in the beginning of car diffusion, and how did this change during the diffusion of cars? This discussion might yet again shed a different light on the question in which ways Europe was, or was not, delayed in respect to the US.

We do not know how long-distance transport and short-distance transport were related to each other. The Randstad has facilitated international transport functions related to the harbours in Rotterdam, and Amsterdam, and to Luchthaven Schiphol, the national airport in the vicinity of Amsterdam from which it derives its English name Amsterdam.
Airport Schiphol. Furthermore, the Rhine has functioned as important, international transport vein. In our characterization of places, we did not take these long-distance transport veins into account. We stressed that suburbanization and the functions of places within the fabric of the urban system seem important to the understanding of car diffusion. We did not, however, delve in any detail into the history of urbanization and suburbanization in either the US or the Netherlands. Nor did we give an elaborate account of the development of the economic spatial structure in the Netherlands. We did not quantify infrastructural provisions in regard to car diffusion, the most notable example being the history of road building in the Netherlands. We did not use a measurement for this, not in the international comparison of chapter 2, nor in the chapters on Dutch geographical car diffusion. We did not deal with the influence of interest groups, and local transport, and economic policies.

In conclusion, John B. Rae expressed in 1965 the belief that "students of American society may well conclude sometime that the most important influence of the automobile on American life has been alleviating rural isolation and breaking down the age-old distinction between the country and the city dweller."\(^\text{151}\) We wish to follow this sentiment. Students of Dutch transport history may well conclude sometime that the Dutch likewise used the car in order to unify the rural and the urban.

7 Appendix

7.1 Appendix I Some background information on the Netherlands

Fig. 7-1. Twelve Dutch Provinces and the Main Dutch Cities

Note: Flevoland was established in 1956.
Date of the map displaying the provinces: January 1, 2000.
Map for the cities is of 1980.
Fig. 7-2.

Sources: See list of sources.
### 7.2 Appendix II A quantitative overview of the American geographical car diffusion dynamics as presented by Jarvis

Table 7-1
Regional Mean Change in Registered Automobiles per 100 Population in the US

<table>
<thead>
<tr>
<th>Region</th>
<th>Change in Registered Autos per 100 Population 1910-1929</th>
<th>Difference from U.S. Mean</th>
<th>Change in Registered Autos per 100 Population 1945-1969</th>
<th>Difference from U.S. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>18.14</td>
<td>-1.21</td>
<td>21.73</td>
<td>-1.74</td>
</tr>
<tr>
<td>South</td>
<td>13.56</td>
<td>-5.79</td>
<td>26.56</td>
<td>+3.09</td>
</tr>
<tr>
<td>Midwest</td>
<td>23.66</td>
<td>+4.31</td>
<td>20.49</td>
<td>-2.98</td>
</tr>
<tr>
<td>Far West</td>
<td>23.32</td>
<td>+3.97</td>
<td>24.70</td>
<td>+1.23</td>
</tr>
<tr>
<td>U.S. Mean</td>
<td>19.35</td>
<td></td>
<td>23.47</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-2
Mean Level of Autos per 100 Population by Urbanization Turning Point Years

<table>
<thead>
<tr>
<th>States categorized by:</th>
<th>1910</th>
<th>1920</th>
<th>1932</th>
<th>1945</th>
<th>1969</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urbanization</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.21</td>
<td>7.31</td>
<td>13.65</td>
<td>17.34</td>
<td>39.99</td>
</tr>
<tr>
<td>Medium</td>
<td>0.48</td>
<td>9.74</td>
<td>18.30</td>
<td>21.45</td>
<td>46.57</td>
</tr>
<tr>
<td>High</td>
<td>0.79</td>
<td>7.85</td>
<td>19.42</td>
<td>20.67</td>
<td>43.22</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.13</td>
<td>5.13</td>
<td>10.88</td>
<td>14.60</td>
<td>39.03</td>
</tr>
<tr>
<td>Medium</td>
<td>0.56</td>
<td>10.95</td>
<td>20.15</td>
<td>23.51</td>
<td>46.63</td>
</tr>
<tr>
<td>High</td>
<td>0.76</td>
<td>8.86</td>
<td>20.60</td>
<td>21.62</td>
<td>44.46</td>
</tr>
<tr>
<td><strong>Mean for all States</strong></td>
<td>0.49</td>
<td>8.32</td>
<td>17.16</td>
<td>19.82</td>
<td>43.30</td>
</tr>
</tbody>
</table>


Table 7-3
Mean Increase in Autos per 100 Population by Urbanization and Income Interval between Turning Point Years

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urbanization</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.21</td>
<td>7.10</td>
<td>6.34</td>
<td>3.69</td>
<td>22.65</td>
</tr>
<tr>
<td>Medium</td>
<td>0.48</td>
<td>9.26</td>
<td>8.56</td>
<td>3.15</td>
<td>25.12</td>
</tr>
<tr>
<td>High</td>
<td>0.79</td>
<td>7.06</td>
<td>11.57</td>
<td>1.25</td>
<td>22.55</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.13</td>
<td>5.00</td>
<td>5.75</td>
<td>3.72</td>
<td>24.43</td>
</tr>
<tr>
<td>Medium</td>
<td>0.56</td>
<td>10.39</td>
<td>9.20</td>
<td>3.36</td>
<td>23.12</td>
</tr>
<tr>
<td>High</td>
<td>0.76</td>
<td>8.10</td>
<td>11.74</td>
<td>1.02</td>
<td>22.84</td>
</tr>
<tr>
<td><strong>Mean for all States</strong></td>
<td>0.49</td>
<td>7.83</td>
<td>8.84</td>
<td>2.66</td>
<td>23.47</td>
</tr>
</tbody>
</table>

### Table 7-4 Regression Results Jarvis on Car Density

**Dependent Variable: Car Density**

<table>
<thead>
<tr>
<th>Year</th>
<th>1910a (Without Urbanization)</th>
<th>1910b</th>
<th>1920c</th>
<th>1932d</th>
<th>1945e</th>
<th>1969f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanization (Index)g</td>
<td>Xg</td>
<td>0.473*</td>
<td>-0.063</td>
<td>0.274</td>
<td>-0.100</td>
<td>0.323</td>
</tr>
<tr>
<td>Income per Capita</td>
<td>0.209</td>
<td>0.034</td>
<td>0.089</td>
<td>-0.077</td>
<td>0.684***</td>
<td>0.904**</td>
</tr>
<tr>
<td>Avg. Value Land and Buildings per Farmg</td>
<td>0.598***</td>
<td>0.447**</td>
<td>0.672**</td>
<td>0.709**</td>
<td>0.128</td>
<td>-0.072</td>
</tr>
<tr>
<td>%Tenantg</td>
<td>-0.139</td>
<td>-0.093</td>
<td>0.153</td>
<td>-0.88</td>
<td>0.390***</td>
<td>0.044</td>
</tr>
<tr>
<td>%Congestiong</td>
<td>0.075</td>
<td>-0.133</td>
<td>-0.256</td>
<td>-0.197</td>
<td>-0.512**</td>
<td>-0.522**</td>
</tr>
<tr>
<td>%African-Americansg</td>
<td>0.064</td>
<td>-0.086</td>
<td>-0.385*</td>
<td>-0.243</td>
<td>-0.668***</td>
<td>-0.081</td>
</tr>
<tr>
<td>Automobile Production Access (Index)g</td>
<td>0.222</td>
<td>0.069</td>
<td>-0.056</td>
<td>-0.046</td>
<td>0.147</td>
<td>-0.183</td>
</tr>
<tr>
<td>%Commuters with Public Transport</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-0.681</td>
</tr>
<tr>
<td>R-squared (Adjusted)</td>
<td>0.680</td>
<td>0.716</td>
<td>0.815</td>
<td>0.811</td>
<td>0.811</td>
<td>0.785</td>
</tr>
</tbody>
</table>


a Page 238.
b Page 239.
c Page 246.
d Page 252.
e Page 257.
f Page 262.
g Some variables occasionally are not drawn from the year of the regression. "Urbanization" and "%Congestion" are drawn from 1930 instead of 1932, 1940 instead of 1945 and 1960 instead of 1969.
"Value of land and buildings per farm" and "%farms operated by tenants" are drawn from 1930 instead of 1932 and 1959 instead of 1969.


h *** significant on the 0.01% level.
i ** significant on the 1% level.
j * significant on the 5% level.
Table 7-5 Regression Results Jarvis on Changes in Car Density Level

Dependent Variable: Growth in car density between turning points

<table>
<thead>
<tr>
<th>Period for Dependent Variable</th>
<th>1910 to 1920&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1920 to 1932&lt;sup&gt;b&lt;/sup&gt;</th>
<th>1932 to 1945&lt;sup&gt;c&lt;/sup&gt;</th>
<th>1945 to 1969&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of Independent Variables&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1910</td>
<td>1920</td>
<td>1932</td>
<td>1945</td>
</tr>
<tr>
<td>Car Density</td>
<td>0.379*&lt;sup&gt;h&lt;/sup&gt;</td>
<td>0.734***&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.753***</td>
<td>0.576**&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>Urbanization (Index)</td>
<td>-0.727***</td>
<td>0.126</td>
<td>0.079</td>
<td>-0.027</td>
</tr>
<tr>
<td>Income per Capita</td>
<td>0.089</td>
<td>0.288*</td>
<td>-0.176</td>
<td>0.541*</td>
</tr>
<tr>
<td>Avg. Value Land and Buildings per Farm</td>
<td>0.385*</td>
<td>0.057</td>
<td>-0.48</td>
<td>-0.124</td>
</tr>
<tr>
<td>%Tenant</td>
<td>0.281</td>
<td>-0.241*</td>
<td>0.107</td>
<td>-0.034</td>
</tr>
<tr>
<td>%Congestion</td>
<td>0.188</td>
<td>0.093</td>
<td>0.324**</td>
<td>-0.508*</td>
</tr>
<tr>
<td>%African-Americans</td>
<td>-0.631***</td>
<td>0.181</td>
<td>-0.398***</td>
<td>0.271</td>
</tr>
<tr>
<td>Car Production Access (Index)&lt;sup&gt;k&lt;/sup&gt;</td>
<td>-0.169</td>
<td>-0.016</td>
<td>0.176*</td>
<td>-0.068</td>
</tr>
<tr>
<td>R-squared (Adjusted)</td>
<td>0.759</td>
<td>0.880</td>
<td>0.867</td>
<td>0.692</td>
</tr>
</tbody>
</table>


<sup>a</sup> Page 242.
<sup>b</sup> Page 249.
<sup>c</sup> Page 254.
<sup>d</sup> Page 259.
<sup>e</sup> Some variables occasionally are not drawn from the year of the regression.
"Value of land and buildings per farm" and "%farms operated by tenants" are drawn from 1930 instead of 1932 and 1959 instead of 1969.
<sup>f</sup>*** significant on the 0.01% level.
<sup>g</sup> ** significant on the 1% level.
<sup>h</sup> * significant on the 5% level.
### 7.3 Appendix III Rail-bound transport in the Netherlands

Table 7-6
Tram Network Density per Province, 1930

<table>
<thead>
<tr>
<th>Province</th>
<th>Percentage of Municipalities with Interlocal Tram Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drenthe</td>
<td>70</td>
</tr>
<tr>
<td>Zeeland</td>
<td>62</td>
</tr>
<tr>
<td>Friesland</td>
<td>53</td>
</tr>
<tr>
<td>Noord-Holland</td>
<td>49</td>
</tr>
<tr>
<td>Limburg</td>
<td>47</td>
</tr>
<tr>
<td>Noord-Brabant</td>
<td>46</td>
</tr>
<tr>
<td>Groningen</td>
<td>45</td>
</tr>
<tr>
<td>Overijssel</td>
<td>41</td>
</tr>
<tr>
<td>Zuid-Holland</td>
<td>40</td>
</tr>
<tr>
<td>Gelderland</td>
<td>38</td>
</tr>
<tr>
<td>Utrecht</td>
<td>21</td>
</tr>
</tbody>
</table>

Sources: See list of sources.
Fig. 7-3. Number of Train Departures per Working Day, Summer Schedule 1980

Sources: See list sources.
Table 7-7 Concentration in Dutch Rail-Bound Transport: 1930, 1950 and 1980

<table>
<thead>
<tr>
<th>Year</th>
<th>1930</th>
<th>1950</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Cases in Data Set&lt;sup&gt;a&lt;/sup&gt;</td>
<td>950</td>
<td>1015</td>
<td>797</td>
</tr>
<tr>
<td>Number of Places with Both Train and Tram</td>
<td>143</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Places with Train Station</td>
<td>381</td>
<td>253</td>
<td>228</td>
</tr>
<tr>
<td>% Municipalities with Train Station</td>
<td>40.1</td>
<td>24.9</td>
<td>28.6</td>
</tr>
<tr>
<td>Sum Number of Train Departures</td>
<td>2889</td>
<td>2955</td>
<td>7814</td>
</tr>
<tr>
<td>Mean Train Departures</td>
<td>3.0</td>
<td>2.9</td>
<td>9.8</td>
</tr>
<tr>
<td>Minimum Train Departures amongst Places with Stations</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Maximum Train Departures</td>
<td>59</td>
<td>178</td>
<td>559</td>
</tr>
<tr>
<td>Std.&lt;sup&gt;b&lt;/sup&gt; Deviation Train Departures</td>
<td>6.4</td>
<td>10.0</td>
<td>34.2</td>
</tr>
<tr>
<td>Skewness Train Departures</td>
<td>3.9</td>
<td>9.5</td>
<td>9.1</td>
</tr>
<tr>
<td>Std. Error of Skewness</td>
<td>0.079</td>
<td></td>
<td>0.087</td>
</tr>
<tr>
<td>Number of Places with Tramline</td>
<td>426</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Places with Tramline</td>
<td>44.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: See list of sources.

<sup>a</sup> This number is not Identical with Number of Existing Municipalities for 1930 and 1980.

<sup>b</sup> "Std." stands for standard.
List of sources

Chapters 1 and 2

Passenger cars registered

European Commission / Directorate General Energy and Transport:

In addition for the following countries

Austria

Belgium

Canada

Denmark

France

Germany


**Netherlands**


**New Zealand**


**Norway**


**Sweden**


**USA**


*Kilometres of railway line open*


*Passengers transported on railways*


In addition for the following country:

Canada

**Metric tons transported on railways**


**Total passenger-kilometres in civil aviation**


**Total Cargo ton-kilometres in civil aviation**


In addition for the following countries

Belgium
Handel - Toerisme Verkeer en vervoer 1900-1961 Nationaal Instituut voor de statistiek België.

USA

Total kilometres flown in civil aviation

Population

Area
1898 for the countries Belgium, France, Germany, Italy, Netherlands and Sweden (re-calculated):
An Historical Geography of Europe, 1800-1914(Cambridge: Cambridge University Press)
1911 for the countries Belgium, Denmark, Finland, France, Greece, Germany, Italy, Netherlands and Great Britain (re-calculated):
The Development of the Economies of Continental Europe, 1850-1940 (London: George Allen & Unwin LTD)
1957:

Chapters 3 to 5
Agricultural workers, total 1980

Passenger cars registered
Income and wealth


Occupational structure 1930


Population


Population density and area

http://statline.cbs.nl (January 2005). Table: bevolkingsontwikkeling
Trains

Spoorboekje '80/'81. Geldig van 1 juni '80 – 30 mei '81.

Tramline 1930

References


English summary

Following America?
Dutch geographical car diffusion, 1900 to 1980

The main issue addressed in this thesis is the interpretation of the Dutch geographical car diffusion pattern, in comparison to the American example. This topic is analyzed in quantitative terms.

In the first part of this dissertation, we give a first impression of what characterizes the aggregate Dutch long-term car diffusion curve, compared to the U.S. and other capitalist countries. This analysis is based on time series about the diffusion of three transport modes – railways, airways and cars – for twenty-one countries. The Netherlands can be characterized as a catching-up country in respect to the adoption and ownership of cars. Its growth rate in car ownership level is particularly high during the second period of the diffusion process, relative to the earlier part.

In the second part of the dissertation, the Dutch long-term geographical diffusion path is described and analyzed. The context used for this analysis is borrowed from the analysis of diffusion in time and space by T. Hägerstrand. Our analysis is based on car ownership data for all Dutch municipalities for several benchmark years. We roughly distinguish four phases of geographical car diffusion. In the first phase, until around 1905, cars were adopted in a quite scattered way. The urban provinces in the middle of the country showed relatively high car adoption levels, however. Up to 1930, car adoption became concentrated in the West of the country. The car diffusion centers included the urban Randstad as well as rural Zeeland and Western Groningen. Until 1950 this situation remained quite stable. Thereafter, the regions with low car ownership levels caught up and even partly surpassed the former car diffusion centers. The Randstad became somewhat more heterogeneous in terms of adoption levels, where highly densely populated places fell – in relative terms – behind.

In terms of the periodization of the geographical car diffusion process, the Dutch car diffusion process seems to show great similarity to the American car diffusion process, notwithstanding the huge difference in scale between the two countries.

In the third part of the dissertation, a number of hypotheses with regard to the factors behind this diffusion path are articulated and tested with the help of (spatial) regression analysis. The theoretical roots of these hypotheses include demand theory, E. Rogers' notion of "social diffusion" and T. Hägerstrand's contagious diffusion model. The motivation to adopt cars seems to have changed drastically during the period in question. The car in the Netherlands could never grow to an exclusively urban phenomenon because of the hesitation of people living in crowded places to adopt cars.
If we interpret the differences and similarities in the car diffusion process between the U.S. and the Netherlands, it is important to pay attention to the factor "population density" besides the factor "income and costs".
Curriculum Vitae

Hanna Manuela Wolf was born on August, 11, 1974 in Haifa, Israel. She studied political science, philosophy, history and law at the Darmstadt University of Technology, Germany. She received her Master of Arts in Politics at the University of Essex, Great Britain. In 2002 she started a PhD project on the geographical diffusion of cars in the Netherlands at the Eindhoven Centre for Innovation Studies (ECIS), Eindhoven University of Technology. The research findings of this project are reported in the present dissertation.