VTI rapport 653/653A
Utgivningsår/Published 2009

www.vti.se/publikationer

Empiriska analyser av bilanvändning och bilägande i Sverige

Empirical analyses of car ownership and car use in Sweden

Roger Pyddoke

vti
FINDING A BETTER WAY

Utgivare:

vti

581 95 Linköping

Publikation:
VTI rapport 653/653A

Utgivningsår:	**Projektnummer:**	**Dnr:**
2009	92167	2006/0308-21

Projektnamn:
Empiriska analyser av drivkrafter till förändrad bilanvändning

Författare:
Roger Pyddoke

Uppdragsgivare:
Bisek

Titel:
Empiriska analyser av bilanvändning och bilägande i Sverige

Referat (bakgrund, syfte, metod, resultat) max 200 ord:

Syftet med den här rapporten är att beskriva och analysera hur individuellt bilägande och individuell bilanvändning i Sverige påverkas av kostnader, inkomst, kön och individens geografiska hemvist, samt att undersöka om boende i lands- och glesbygd är mer kostnads- och inkomstkänsliga i sitt bilägande och sin bilanvändning än övriga individer i Sverige.

Rapporten använder registerdata för hela Sveriges befolkning, körsträckor från Bilprovningen samt Glesbygdsverkets områdesklassificering: tätort, tätortsnära landsbygd och glesbygd.

Några av de nya deskriptiva resultaten är att invånare i tätortsområden äger och kör sina bilar i mindre utsträckning än landsbygdsinvånare. Skillnaden i körsträckor är dock liten. Skillnaden mellan tätortsnära landsbygd och glesbygd är mindre.

I modellanalyserna finner vi små skillnader mellan områdestyperna i känsligheten i användningen av privatägda bilar för förändringar i disponibel inkomst och kostnader. I analysen av individuellt bilägande är det viktigaste resultatet att bilägandet i Sverige är trögföränderligt. Den viktigaste faktorn för att förklara bilägande ett visst år är om individen äger eller inte äger en bil året innan. Landsbygdsbor är något mindre benägna att upphöra att äga bil och mer benägna att öka det till fler bilar än jämförbara individer i tätort. Män är betydligt mer benägna att skaffa bil när de ingen äger än kvinnor, och denna sannolikhet är större i landsbygd för båda könen. Förändringar i inkomst beräknas ha försumbara effekter på bilägande. Förändringar i kostnader har både förväntade och oförväntade effekter på sannolikheten för olika nivåer av bilägande.

Nyckelord:
bilägande, bilanvändning, körsträckor, tätort, glesbygd, landsbygd, bensinpris, inkomst

ISSN:	**Språk:**	**Antal sidor:**
0347-6030	Engelska och svenska	131

Publisher:

vti

SE-581 95 Linköping Sweden

Publication:
VTI rapport 653/653A

Published:	**Project code:**	**Dnr:**
2009	92167	2006/0308-21

Project:
Empiriska analyser av drivkrafter till förändrad bilanvändning

Author:
Roger Pyddoke

Sponsor:
Bisek

Title:
Empirical analyses of car ownership and car use in Sweden

Abstract (background, aim, method, result) max 200 words:

This purpose of this report is to describe and analyse how individual car ownership and car use in Sweden are affected by costs, income, sex and the place of residence of the individual and further to investigate whether inhabitants of rural areas close to urban areas or sparsely populated areas are more sensitive to costs and income with regard to car ownership and car use than other individuals in Sweden.

The report uses register data for the whole of the Swedish population, meter readings from the vehicle inspection, and the area categorisation of the National Rural Development Agency: urban area, rural area close to an urban area and sparsely populated area.

Some of the new descriptive results are that: inhabitants of urban areas own and use cars to a lesser extent than inhabitants of rural areas. The difference in driven distances, however, is small. The difference between rural areas close to urban areas and sparsely populated areas is less.

In the model analyses we find small differences between the area types in the sensitivity of the use of privately-owned cars due to changes in disposable income and costs. In the analysis of the model for individual car ownership the most important result is that car ownership in Sweden is slow to change. The most important factor to explain car ownership in a particular year is whether the individual owned or did not own a car the previous year. Inhabitants of rural areas are slightly less inclined to cease car ownership and more inclined to increase car ownership to several cars compared with comparable individuals in urban areas. Men are also considerably more inclined to acquire a car when they do not own one than women, and this probability is greater in rural areas for both sexes. Changes in income are estimated to have negligible effects on car ownership. Changes in cost have both expected and unexpected effects on the likelihood of car ownership levels.

Keywords:
car ownership, car use, driven distance, urban area, rural area, petrol price, income

ISSN:	**Language:**	**No. of pages:**
0347-6030	English and Swedish	131

Förord

Denna rapport har skrivits av Roger Pyddoke som också har varit projektledare för projektet. Urban Björketun har sammanställt och kontrollerat databasen samt utfört de statistiska beräkningarna.

För att sätta detta projekt i ett sammanhang beskrivs här kort dess tillblivelse. Den första ansökan föregicks av en förfrågan till Statistiska Centralbyrån om datakostnader. När inköpet av data skulle genomföras stod det dock klart att kostnaderna tyvärr var betydligt högre än ursprungligen uppskattat och det stod också klart att de hushållsdata som ansökan förutsatte inte fanns. Projektets mål och åtaganden anpassades därför till datatillgången och begränsningarna accepterades av Bisek. Detta ger bakgrunden till att denna studie utmynnar i flera observationer om möjligheter till ytterligare analyser som skulle kunna ha gjorts och som skulle kunna göras i framtida forskning.

Under arbetet med detta projekt har jag tagit emot värdefulla förslag från Henrik Andersson, Joyce Dargay, Mogens Fosgerau, Lina Jonsson, Gunnar Lindberg, Lena Nerhagen, Jan-Eric Nilsson, Jan-Erik Svärdh och Henrik Swahn. Jag vill särskilt tacka Gunnar Isacsson för den mycket ambitiösa och noggranna granskning han gjorde vid VTI:s kvalitetsgranskningsseminarium. Jag vill också tacka deltagarna vid VTI:s och Glesbygdsverkets seminarier för intressanta diskussioner och värdefulla förslag. Som alltid är ansvaret för alla återstående fel och brister mitt eget.

Stockholm Juni 2009

Roger Pyddoke

Kvalitetsgranskning

Granskningsseminarium genomfört 2008-10-30 där docent Gunnar Isacsson, VTI, var lektör och professor Jan-Eric Nilsson har granskat rapporten. Roger Pyddoke har genomfört justeringar av slutligt rapportmanus 2009-06-01. Projektledarens närmaste chef, Gunnar Lindberg, har därefter granskat och godkänt publikationen för publicering 2009-06-01.

Quality review

Review seminar was carried out on 30 October 2008 where Gunnar Isacsson, VTI reviewed and commented on the report and professor Jan-Eric Nilsson has examined the report. Roger Pyddoke has made alterations to the final manuscript of the report. The research director of the project manager Gunnar Lindberg examined and approved the report for publication on 1 June 2009.

Foreword

This report was prepared by Roger Pyddoke who also acted as project leader for the project. Urban Björketun assembled and checked the data and conducted the statistical computations.

To put the project into context we shortly describe its conception. The first application was preceded by a request for an estimate of data costs from Statistics Sweden. However, when the data purchase was finalised the costs unfortunately were considerably larger than the early estimates and it became clear that desired household data were not available. The projects objectives were adapted to the data availability and the limitations were agreed with Bisek. This gives the background to the fact that this study leads to several observations on the possibility for further analyses that could have been done and that could be done in future research.

During this project I have received valuable suggestions from Henrik Andersson, Joyce Dargay, Mogens Fosgerau, Gunnar Isacsson, Lina Jonsson, Gunnar Lindberg, Lena Nerhagen, Jan-Eric Nilsson, Jan-Erik Svärdh and Henrik Swahn. In particular I would like to thank Gunnar Isacsson for his ambitious and thorough examination of this work that he did for VTI quality review seminar.

I also want to thank the participants at VTI's and the National Rural Development Agency seminars for interesting discussions and suggestions. As always the remaining flaws and errors are solely my own.

Stockholm June 2009

Roger Pyddoke

Omslag/Cover: VTI/Hejdlösa bilder, Photos.com

Innehållsförteckning

Table of contents

Tabellförteckning

Diagramförteckning

List of Tables

List of Diagrams

Empirisk analys av bilägande och bilanvändning i Sverige

av Roger Pyddoke
VTI
581 95 Linköping

Sammanfattning

Syftet med den här rapporten är att beskriva och analysera hur individuellt bilägande och bilanvändning i Sverige påverkas av kostnader, inkomst, kön och individens geografiska hemvist. Ett särskilt mål är att undersöka om boende i lands- och glesbygd är mer kostnads- och inkomstkänsliga i sitt bilägande och sin bilanvändning än övriga individer i Sverige.

Rapporten består av en kappa och tre separata uppsatser och har utarbetats med finansiering från Bisek (Bilens sociala och ekonomiska betydelse). Samtliga studier i denna rapport använder registerdata för hela Sveriges befolkning från Skattemyndigheterna samt uppgifter om bilägande och mätarställningar från Bilprovningen.

Rapporten använder främst Glesbygdsverkets områdesklassificering: tätort, tätortsnära landsbygd och glesbygd. Tidigare studier har endast haft tillgång till små urval av invånare i lands- och glesbygd då dessa utgör endast 23 respektive 1,7 procent av den totala befolkningen.

Den första uppsatsens syfte är att beskriva samband i databasen. De viktigaste nya resultaten från den deskriptiva studien är de följande:

- Invånare i tätortsområden äger bilar i mindre utsträckning än landsbygdsinvånare
- Bilar ägda av invånare i tätortsområden körs mindre än bilar ägda av invånarna i landsbygdsområden, men skillnaden är liten
- Skillnaden mellan landsbygdsområden nära tätortsområden och glesbygdsområden är ännu mindre. Bilanvändning i landsbygdsområden nära tätortsområden är något större än i glesbygdsområden
- Skillnaderna i användning av bilar ägda av de olika könen och de olika inkomstgrupperna är stora. Bilar ägda av män används mer, vilket också gäller bilar ägda av höginkomsttagare
- Bilar ägda av personer över 67 år används mindre än bilar ägda av yngre människor
- Andelen bilägare som upphör att vara bilägare varierar kraftigt med hänsyn till inkomst. Låginkomsttagare avslutar oftare sitt bilägande
- Andelen bilägare, som avslutar sitt ägande, är ca 40 procent större i tätort än i landsbygdsområden
- Andelen kvinnor som avslutar sitt bilägande är mellan 30 och 70 procent större än motsvarande andel män med samma inkomst.

Syftet med den andra uppsatsen är att analysera **användningen** av privatägda bilar i Sverige och hur denna påverkas av disponibel inkomst, priset på bensin, ett bilinköpskostnadsindex, antalet barn och bilägarens avstånd till arbetet. Dessa faktorer analyseras separat för män och kvinnor, för individer boende i tätort, landsbygd nära tätort samt

glesbygd samt för kvartiler av disponibel inkomst. Vi analyserar särskilt hur låginkomsttagare i landsbygd nära tätort och i glesbygd anpassar sin bilanvändning till förändringar i disponibel inkomst och kostnader.

Vi finner små skillnader i känsligheten för förändringar i disponibel inkomst och kostnader. Bilanvändningens inkomstkänslighet avtar med disponibel inkomst. Den lägsta inkomstkvartilen har en icke-förväntad negativ inkomstkänslighet. Detta kan vara ett resultat av flera orsaker, varav en kan vara icke-deklarerad inkomst. Bilanvändningen är också något mer inkomstelastisk i landsbygdsområden än i tätorter. Invånare i landsbygd använder sina bilar något mer än tätortsinvånare när de har barn. I genomsnitt är bilanvändning något mer tröganpassad än i Storbritannien med avseende på förändringar i inkomst och kostnader. Skattningen av bilanvändningens bensinpriskänslighet är positiv, vilket strider mot ekonomisk teori.

Den tredje uppsatsen presenterar skattningar av en modell för individuellt **bilägande** i Sverige. I denna uppsats studeras perioden 1996–2005. Syftet är att jämföra bilägandets känslighet med avseende på inkomst och kostnadsförändringar för invånare i tätort och i landsbygd. Det viktigaste resultatet är att bilägandet i Sverige är trögföränderligt. Den viktigaste faktorn för att förklara bilägande ett visst år är om individen äger eller inte äger en bil året innan. Landsbygdsbor är något mindre benägna att upphöra att äga bil och mer benägna att öka det till fler bilar än jämförbara individer i tätort. Unga och pensionerade bilägare är mer benägna att upphöra äga bil. Denna sannolikhet är också större för kvinnor än för män. Män är också betydligt mer benägna att skaffa bil, när de ingen äger, än kvinnor och denna sannolikhet är större i landsbygd för båda könen. Förändringar i inkomst beräknas ha försumbara effekter på bilägande. En ökning av bensinpriset beräknas minska sannolikheten för att inte äga bil (vilket är oväntat) och beräknas öka sannolikheten för att äga två bilar (vilket är oväntat). En ökning av bilinköpskostnaderna har förväntat tecken för tätortsinvånare men inte för landsbygdsbor. Effekten av att ha barn på benägenheten att äga bil har det förväntade tecknet, men effekten är liten. Avståndet till arbetet har ingen effekt på benägenhet att äga bil.

Empirical analyses of car ownership and car use in Sweden

by Roger Pyddoke
VTI (Swedish National Road and Transport Research Institute)
SE-581 95 Linköping Sweden

Summary

This report is intended to describe and analyse how individual car ownership and car use in Sweden are affected by costs, income, sex and the place of residence of the individual. A special objective is to investigate whether inhabitants of rural areas close to urban areas or sparsely populated areas are more sensitive to costs and income with regard to car ownership and car use than other individuals in Sweden.

The report consists of an introduction and three separate essays and has been prepared with funding from Bisek (The Social and Economic Significance of the Automobile). All studies in this report use register data for the whole of the Swedish population from the tax authorities and information on car ownership and meter readings from the Swedish motor vehicle inspection company, Bilprovningen.

The report mainly applies the area categorisation of the National Rural Development Agency: urban area, rural area close to an urban area and sparsely populated area. Previous studies have only had access to small samples of inhabitants of rural and sparsely populated areas since these only make up 23 and 1.7 per cent respectively of the total population.

The purpose of the first essay is to describe correlations in the database. The most important new results from the descriptive study are as follows:

- Inhabitants of urban areas own cars to a lesser extent than inhabitants of rural areas.
- Cars owned by inhabitants of urban areas are driven less than cars owned by inhabitants of rural areas, although the difference is little.
- The difference between rural areas close to urban areas and sparsely populated areas is even less. Car use in rural areas close to urban areas is slightly greater than in sparsely populated areas.
- The differences in use of cars owned by the different sexes and income groups are great. Cars owned by men are used more, which also applies to cars owned by high-income earners.
- Cars owned by persons over 67 years of age are used less than cars owned by younger people.
- The proportion of car owners which ceases to own a car varies greatly taking into consideration income. Low-income earners more often cease owning a car.
- The proportion which ceases to be car owners is around 40 per cent greater in urban areas than in rural areas.
- The proportion of women who cease to own a car is between 30 and 70 per cent greater than the proportion of men with the same income.

The objective of the second essay is to analyse **the use** of privately-owned cars in Sweden and how this is affected by disposable income, the price of petrol, a car

purchase cost index, the number of children and the distance of the car owner to his or her work. These factors are analysed separately for men and women, for individuals living in urban areas, rural areas close to urban areas and sparsely populated areas as well as for quartiles of disposable income. We analyse in particular how low-income earners in rural areas close to urban areas and sparsely populated areas adapt their car use to changes in disposable income and costs.

We find small differences in responsiveness to changes in disposable income and costs. The income responsiveness of car use declines with disposable income. The lowest income quartile has a negative income responsiveness, which was not expected. There may be a number of causes of this result, one of which may be undeclared income. Car use is also slightly more income elastic in rural areas than in urban areas. Inhabitants of rural areas use their cars slightly more than inhabitants of urban areas when they have children. On average, there is greater inertia in car use than in the United Kingdom with regard to changes in income and costs. The estimate of the petrol price responsiveness of car use is positive, which conflicts with economic theory.

The third essay presents estimates of a model for individual **car ownership** in Sweden. This essay studies the period 1996–2005. The intention is to compare the responsiveness of car ownership with respect to income and cost changes for inhabitants of urban and rural areas. The most important result is that car ownership in Sweden is slow to change. The most important factor to explain car ownership in a particular year is whether the individual owned or did not own a car the previous year. Inhabitants of rural areas are slightly less inclined to cease car ownership and more inclined to increase car ownership to several cars compared with comparable individuals in urban areas. Young and retired car owners are more inclined to cease car ownership. This probability is also greater for women than for men. Men are also considerably more inclined to acquire a car when they do not own one than women, and this probability is greater in rural areas for both sexes. Changes in income are estimated to have negligible effects on car ownership. An increase in the price of petrol is estimated to reduce the probability of not owning a car (which is unexpected) and is estimated to increase the probability of owning two cars (which is unexpected). An increase in car purchase costs has the expected sign for urban areas but not for rural areas. The effect of having children on the likelihood of owning a car has the expected sign, although the effect is small. The distance to work has no effect on the inclination to own a car.

1 Introduktion med sammanfattning och slutsatser

1.1 Om rapporten

Den här rapporten från Statens väg- och transportforskningsinstitut (VTI) har utarbetats med hjälp av finansiering från Bisek (Bilens sociala och ekonomiska betydelse), som i sin tur är ett samarbete mellan följande organisationer: Vägverken i Sverige och Norge, VINNOVA, Folksam, Svenska motororganisationers samarbetsorganisation (Mosk), Norges Automobil-Forbund (NAF) samt Bil Sweden och Motorbranschens Riksförbund (MRF).

Rapporten baseras på tre engelskspråkiga uppsatser som tagits fram inom projektet. Den första uppsatsen utgör kapitel 3 där datamaterialet beskrivs. I kapitel 4 analyseras bilanvändning och i kapitel 5 bilägande. Till dessa tre uppsatser har en kappa fogats i en svensk version (kapitel 1, dvs. denna text) och i en engelsk version (kapitel 2). Kappan är skriven i två delar. Den första delen (avsnitt 2–9) syftar till att vara en sammanfattning och diskussion av resultaten i studien och vänder sig till en bredare läsekrets. Den andra delen (avsnitt 10 och 11) är en mera teknisk problematiserande diskussion av skattningsresultaten från modellanalyserna.

Målet har varit att kapitel 4 och 5 ska kunna utgöra underlag för vetenskaplig publicering som ett led i en vidare kvalitetssäkring och vetenskaplig spridning av resultaten.

1.2 Syfte: Analys av sårbara och potentiella personbilsanvändare i Sverige

Stigande bränslepriser i kombination med farhågor för att målet att tygla klimatförändringen kan kräva ännu högre bränslepriser gör det angeläget att belysa vilka välfärds- och inkomstfördelningskostnader detta kan medföra för den privata bilanvändningen. En analys av frågan på individnivå och med hög geografisk upplösning, kräver goda data. Sådana data finns tillgängliga i några länder antingen som s.k. hushållspaneler eller som registerdata.

Det finns ett antal olika typer av anpassningar som skulle kunna analyseras för den privata bilanvändningen. Därför kan olika typer av analyser av bilanvändarnas anpassning till förändrade kostnader genomföras. En första typ av analys avser substitutionseffekten av förändringar på grund av ändrade bränslepriser och bilinköpskostnader, dvs. vilka konsekvenser sådana prisförändringar får för bilägande och bilanvändning. En andra typ av analys avser effekterna av inkomstförändringar för innehav och körbeteende. En tredje typ av effekter som kan analyseras är inkomstfördelningseffekterna, dvs. hur det som olika individer och hushåll kan nödgas avstå från på grund av kostnadsökningar kan variera mellan olika inkomstgrupper.

Avsikten är att i den här rapporten genomföra de två första typerna av analyser för att på så sätt lägga grunden till den tredje. Vi har därför undersökt de empiriska sambanden mellan å ena sidan kön, disponibel realinkomst, antal barn, vilken områdestyp individen bor i, avstånd till arbetsplats (och för bilägandemodellen även individens ålder), och å andra sidan de privatägda personbilarnas körsträckor och individuellt bilägande. Särskild uppmärksamhet har ägnats bilanvändningens och bilägandets känslighet för ändringar av disponibel inkomst och bränslepris.

Ett mål för den här studien är att belysa bilanvändning inom grupper som tidigare har använt bil i mindre utsträckning än medelbilisten, exempelvis kvinnor, unga och äldre

personer och i synnerhet äldre kvinnor. En förväntan är att kunna ge ett litet men viktigt bidrag till den omfattande kunskapsmassa som finns om bilanvändning. Vi hoppas vidare kunna replikera tidigare studiers elasticitetsberäkningar och öka denna kunskapsmassa genom att tillhandahålla en uppsättning elasticiteter differentierade efter kön, disponibel inkomst och vilken områdestyp individen bor i. Med elasticiteter menas en beroende variabels känslighet för förändring av en oberoende variabel. Den mäts som procentuell förändring genom procentuell förändring.

Det viktigaste verktyget för analys av transportefterfrågan i Sverige är de olika modeller som används för att bedöma hur efterfrågan på resor kommer att utvecklas. Den nationella efterfrågemodellen för persontransporter Sampers är ett exempel på detta. Sådana modeller baseras primärt på den officiella resvaneundersökningen (Riks-RVU) som för närvarande innehåller cirka 50 000 observationer av individuella redogörelser för resor som genomförs ett antal dagar fram till 2005.

Resvaneundersökningarna och efterfrågemodellerna är båda effektiva verktyg för förståelse av bilanvändning. De har dock en nackdel i och med att det finns relativt få observationer av enskilda bilförare i glesbygder jämfört med personer som bor i tätbebyggda områden. Efterfrågemodellerna baseras också vanligtvis på analyser av resvanor under ett år, varför dynamiska effekter – dvs. förändringar i beteendemönstret över tid – inte kan modelleras.

Syftet är således att närmare studera bilägande och bilanvändning (körsträcka) för sådana bilägare som är särskilt beroende av sina bilar, bilägare som är mer sårbara i sin bilanvändning (t.ex. låginkomsttagare och äldre) och potentiella bilägare som står inför en tröskel att använda bil (t.ex. låginkomsttagare och unga). För detta syfte har avstånd till en tätort och ett inkomstmått använts som indikatorer på bilberoende respektive sårbarhet. Vi förväntade oss att låginkomsttagare i lands- och glesbygdsområden skulle ha inkomst- och priskänslighet som skulle skilja sig från värdena för individer med högre inkomster eller invånare i tätbebyggda områden. Om känsligheten i dessa avseenden skulle vara lägre, skulle detta kunna tolkas som ett större beroende av bilen. Om känsligheten däremot skulle vara större, skulle detta också kunna tolkas som en högre grad av sårbarhet. Båda utfallen har alltså en tolkning.

1.3 Politik för bilägande och bilanvändning

Om man vill analysera ett styrmedels (t.ex. bensinskatten) effektivitet är det viktigt att vara medveten om de motiv som kan finnas för att styrmedlet används men också för att andra styrmedel som verkar på en målvariabel (t.ex. bilanvändning) används. I ekonomisk välfärdsteori finns en uppsättning villkor för när en marknad åstadkommer en samhällsekonomiskt effektiv resursfördelning. Teorin presenterar också en omfattande uppsättning omständligheter, under vilka en marknad som lämnats utan ingrepp, inte kommer att nå en sådan samhällsekonomisk effektiv resursfördelning. Sådana omständigheter kallas ibland för marknadsmisslyckanden. Ineffektivitet kan också uppkomma till följd av politiska åtgärder. När ineffektivitet råder kan olika slag av åtgärder i form av priskorrektioner eller regleringar vara användbara.

Användningen av vägar och bilresor är normalt förknippade med marknadsmisslyckanden. Dessa uppkommer till följd av att väganvändarna inte automatiskt bär den fulla samhällskostnadsbörda som de ger upphov till genom att använda vägarna. Orsaken till detta är att bilanvändning har biverkningar (så kallade externaliteter), t.ex. olyckor och miljöföroreningar, som i regel inte är fullt prissatta. Detta ger upphov till en

klyfta mellan de av bilförarna betalda kostnaderna och de totala marginalkostnaderna för samhället.

Denna klyfta fylls i varierande grad av skatter eller skatteavdrag för bränsle- och fordonskostnader. Bränsleskatterna är emellertid inte tillräckligt flexibla för att fullt ut återspegla externaliteters variationer i tid och rum. Problemet att hitta en god avvägning mellan den exakthet med vilken skatterna återspeglar de faktiska samhällskostnaderna och de ökade transaktionskostnaderna för sådana precisa skatter är ett eget forskningsområde. Vidare uppstår nya ineffektiviteter av de ökade resekostnaderna som sådana skatter ger upphov till i kombination med inkomstbeskattningen. Därför är ytterligare aspekter av utformningen av skattesystemet att minska de negativa incitamenten, för resor till arbetsplatsen och för att använda privata bilar i arbetet. Exempel på regler som syftar till att minska dessa oönskade incitament är skatteavdrag för kostnader för arbetsresor och ersättningar från arbetsgivaren och motsvarande skatteregler för privat användning av tjänstebilen.

Eftersom bilen har blivit det viktigaste transportmedlet, har också dess användning viktiga inkomstfördelningsaspekter. Trots detta vet vi relativt litet om möjligheterna att förbättra välfärden för vissa grupper (t.ex. äldre eller handikappade personer) genom att göra bilägande och bilanvändning mer överkomliga. Vi vet också relativt litet om de inkomstfördelningsrelaterade konsekvenserna av stigande bränslepriser. Svenska studier (t.ex. Jansson och Wall 1994), har främst fokuserat på bränsleutgifternas andel av hushållens sammanlagda utgifter i olika inkomstgrupper.

De viktigaste verktygen för att påverka inkomstfördelningen är inkomstskatter, transfereringar och subventioner av grundläggande nyttigheter som utbildning, sjukvård och äldreomsorg. Vi vet däremot mycket litet om de transportpolitiska åtgärdernas relativa effektivitet för att nå de allmänna inkomstfördelningsmålen.

1.4 Implikationer från ekonomisk teori för bilägande och bilanvändning

Klassisk mikroekonomisk konsumtionsteori

I den klassiska konsumtionsteorin för individer och hushåll härleds efterfrågan för alla varor från nyttomaximering. Därmed blir efterfrågan en funktion av inkomst och priser på alla varor och tjänster som konsumenten kan välja mellan. Vanligtvis fokuseras sambandet mellan efterfrågad kvantitet och priset på den studerade varan när alla andra priser och inkomsten är oförändrade.

I den ekonomiska teorin finns några kraftfulla förutsägelser för hur efterfrågan på de flesta varor och tjänster varierar när priser eller inkomster förändras. För normala varor leder en prisökning till lägre efterfrågan, och ökad inkomst till ökad efterfrågan. Om bilägande och bilanvändning är normala varor, kan ökad inkomst förväntas leda till ökat bilägande och ökad bilanvändning. På motsvarande sätt skulle ökade kostnader för bränsle och andra kostnader för att äga och köra bilen – allt annat lika – leda till minskat bilägande och minskad bilanvändning. Sannolikheten för att en individ med en viss inkomst och andra karaktäristika äger och använder en personbil påverkas dessutom av hur nära arbetsplatsen och andra resmål individen bor.

Antagandet att bilanvändning är en normal vara kan ifrågasättas från olika utgångspunkter, då det finns delbarhets- och mättnadsaspekter. En individ kan inte vistas i mer än en bil samtidigt, och dygnet har bara 24 timmar. Därför finns det rimligen ett tak för

hur mycket bilanvändning en individ kan konsumera. Detta torde främst påverka personer med höga inkomster. I många fall kan individer också resa tillsammans när de vill göra samma resa och när de föredrar att resa tillsammans. Bilen är också odelbar på så sätt att även en liten privat bilanvändning kräver tillgång till en bil.

Enligt ekonomisk teori kan också en rad andra ekonomiska variabler påverka den efterfrågade körsträckan. Här ska vi endast översiktligt identifiera de förhållanden som kan vara aktuella.

Beroende på vilken vara som studeras används begreppen individ eller hushåll. När hushållet består av flera individer kan man tänka sig att hushållet fattar vissa konsumtionsbeslut som *en* enhet. Detta kan innebära att hushållets individer väger samman sina inkomster och tänkbara utgifter för att välja konsumtionsnivå. Det är emellertid inte uppenbart om det är individ- eller hushållsbegreppet som är mest relevant för att studera bilanvändning. I en relativt nyligen publicerad översikt (Vermeulen, 2002) diskuteras olika synsätt på individers respektive hushålls konsumtion. Vermeulen inleder med att konstatera att det typiska för ekonomisk analys av efterfrågan är att man inte gör en tydlig distinktion mellan individ och hushåll. Antingen analyseras individens efterfrågan eller hushållets, men med samma antaganden och teoretiska utgångspunkter. Det är först på senare tid som särskilda teoretiska ansatser börjat byggas upp för att ta hänsyn till att hushåll (som består av mer än en individ) också kan behöva beskriva de ingående individernas preferenser och hur det påverkar efterfrågans egenskaper.

I den här rapporten inskränker sig analysen till att diskutera implikationer av att analysera data med den teoretiska utgångspunkten att efterfrågan kommer från en individ eller ett hushåll som agerar som *en* beslutsenhet. Studien genomfördes utifrån hypotesen att data på individnivå skulle kunna fungera. Detta visade sig dock inte vara fallet. Vi återkommer till en mer detaljerad diskussion om detta senare.

I definitionen av disponibel inkomst ingår också kapitalinkomst. Vi har dock inte analyserat förmögenhetens effekt. Detta är ett potentiellt problem eftersom individens och hushållets förmögenhet, liksom bostads- och lånekostnader (ränta och uppläggningskostnader) påverkar konsumtionsutrymmet.

Bilägande och bilanvändning kan dessutom påverkas av vilka fordon som finns tillgängliga på marknaden och vilka egenskaper dessa har med avseende på exempelvis bränsleförbrukning och säkerhet. I detta sammanhang har naturligtvis kostnaden för det specifika fordonet också betydelse. En viktig anpassning till ökade bränslekostnader är förmodligen att byta till ett fordon med mindre bränsleförbrukning. Det finns också indikationer på att individer anpassar körstil och fordonsunderhåll vid ändrade bränslepriser (se Jansson och Wall (1994)). Det skulle därmed ge upphov till en skillnad mellan skattningen av sambandet mellan bensinpris och bensinkonsumtion respektive bensinpris och körsträcka eftersom det senare påverkas av bensinförbrukning per körsträcka. Om man antar att bensinförbrukning per körsträcka påverkas negativt av en bensinprishöjning finns det anledning att tro att körsträckeelasticiteterna med avseende på bensinpris skulle vara lägre än bensinefterfrågans priselasticitet.

Andra rörliga kostnader som exempelvis kostnaderna för att försäkra bilen kan påverka användningen och vem som skrivs som ägare. Individens priser för och tillgänglighet till kollektivtrafik (buss, tåg och flyg) påverkar efterfrågad körsträcka. Kollektivtrafikens egenskaper med avseende på restider och bekvämlighet har också betydelse.

Även dynamik kan spela en viktig roll för val av transportmedel, t.ex. vanor, sökprocesser som leder till tidsmässiga eftersläpningar av anpassningarna och anpassningar till förändrad uppfattning om den egna livsinkomsten.

Koppling mellan teori och ekonometri

Ett ideal för empiriskt arbete med ekonomiskt beteende är att härleda beteendesambanden (som t.ex. efterfrågefunktioner) från nyttomaximering. För ekonometriska studier – dvs. statistiska analyser som baseras på ekonomisk teori – används då en form av nyttofunktioner som gör det möjligt att härleda precisa efterfrågefunktioner. Man kan därefter skatta dessa efterfrågefunktioner med hjälp av de data som finns tillgängliga. I så fall får man en bild av hur efterfrågan på den marknad som studeras varierar när priser och inkomster förändras.

I många sammanhang kan det dock vara rimligt att nöja sig med förenklingar av denna generella metodik. I den här studien av bilanvändning har vi bedömt att det kan räcka med att använda en linjär form på efterfrågan som funktion av pris och inkomst.

I studien av bilägande används emellertid ett något mer komplicerat efterfrågesystem. Teorin bakom den ekonometriska modellen baseras på McFaddens teori för diskreta val. Den utgår ifrån att varje individ väljer bland ett begränsat antal istället för ett kontinuerligt antal alternativ. Man utgår också från att forskaren saknar information om individernas preferenser, övriga relevanta individegenskaper samt de tillgängliga alternativen. Därför modelleras de individuella beteendena bestämda inte enbart av kända faktorer utan också av en slumpfaktor som är tänkt att fånga in faktorer som inte observeras av forskaren. I denna analys är vi primärt intresserade av att undersöka skillnader mellan landsbygdsbor och tätortsbor med avseende på sannolikheten att äga olika antal bilar respektive förändra ägandet av bil. Därför beräknas i denna studie främst effekter på **sannolikheten** för att olika ägare ska ändra beteende – dvs. köpa eller sälja bil – när priser och inkomster förändras.

1.5 Tidigare empiriska studier av bilägande och bilanvändning

I stora drag finns det fyra kategorier av empiriska analyser av bilanvändning. Den första kategorin är studier som analyserar bilanvändningens känslighet för bränsleprisförändringar. Åtskilliga sådana studier har gjorts. Många av dessa undersöker trafikarbetets (fordonskilometer) och bränsleefterfrågans aggregerat. Den andra kategorin är kartläggningar av bilanvändning på grundval av data från undersökningar av resvanor. Den tredje kategorin är analyser av modeller för reseefterfrågan. Sådana modeller är ofta baserade på tvärsnittsdata. För det fjärde finns det paneldataansatser för att modellera individers eller hushålls anpassningar över tid med avseende på bilägande och bilanvändning.

Det mesta av vad vi vet om bilanvändning kommer från de tre första kategorierna av data och modellering. Detta gäller även Sverige, där både nationella undersökningar av resvanor och hushållsutgiftsdata har varit viktiga informationskällor. Undersökningarna om resvanor har även använts vid framtagning av modeller för reseefterfrågan. Såväl undersökningarna om resvanor som hushållsutgiftsdata har dock en nackdel i det att observationerna av bilanvändning i lands- och glesbygdsområden är få. Resvaneundersökningarna och därmed efterfrågemodellerna har dessutom nackdelen att man inte kan följa samma individ över tiden. Önskan att skapa ett mer tillförlitligt datamaterial för

bilanvändning på landsbygden och att följa individer över tiden har varit viktiga anledningar för att konstruera datamaterialet i denna studie.

En viktig fördel med paneldata i den form vi använder är således att de gör det möjligt att studera hur individer eller hushåll anpassar sig till växlande villkor över tid, i motsats till tvärsnittsstudier där slutsatser dras från skillnader mellan individer. Med observationer från flera år med avseende på varje individ i panelen blir det möjligt att studera effekterna från tidigare år på det innevarande året. I den här studien har vi begränsat analysen av de dynamiska effekterna till effekterna av beslut ett tidigare år.

Dargay (2007) synes höra till de första studier som direkt analyserar bilanvändning på hushållsnivå med paneldatametoder. Till andra tidiga försök att analysera bilanvändning med paneldatametoder hör de Jong (1990), Rouwendal och de Vries (1999) samt Bjørner (1999).

Bland tidiga bilägandemodeller, där paneldatabaserade tillvägagångssätt används, kan nämnas Goodwin (1986), Kitamura (1989) och Kitamura och Bunch (1990). En slutsats, som dessa studier har gemensamt, är att tidigare bilägande är en stark prediktor för nuvarande bilägande.

En liknande modell har också byggts av sannolikheten att en individ blir bilägare respektive upphör att vara ägare för Sverige (Matstoms, 2002). Matstoms modell bygger också på paneldata och är dynamisk och men den är inte en egentlig paneldatamodell.

1.6 Modeller

Efter att ha studerat den tidigare litteraturen valde vi i denna studie att så nära som möjligt replikera studierna av Dargay (2007) för bilanvändning respektive Dargay och Hanly (2007) för bilägande. Syftet var att välja variabler och data så nära dessa studier som möjligt men där det var möjligt att expandera data med registerdata.

Det är sedan länge väl känt att dynamiska faktorer kan spela en viktig roll för val av transportmedel. Till sådana mekanismer hör vanor, sökprocesser som leder till tidsmässiga eftersläpningar av anpassningarna och anpassningar till förändrad uppfattning om den egna framtida inkomsten. Paneldata ger möjlighet att koppla individuella anpassningar till förändringar i inkomster, levnadskostnader och andra exogena faktorer. Därför har man i de mest avancerade studierna av bilägande och bilanvändning använt paneldatametoder. Det finns emellertid relativt få lämpliga paneler för bilägande och bilanvändning.

De grundläggande metoderna i paneldatastatistiska skattningar är fix effektmodellen (fixed effects) och slumpeffektmodellen (random effects). Fix effektmodellen går ut på att man kontrollerar med avseende på icke-observerbara skillnader hos de observerade individerna. Den modellen är bäst när det kan finnas korrelationer mellan den icke-observerade individuella effekten som är konstanta över tid och de förklarande variablerna. Slumpeffektmodellerna används när det är rimligt att anta att den icke-observerade individuella effekten inte är korrelerad med någon av de enskilda förklarande variablerna.

När man studerar dynamik används ofta den förklarade variabelns värde tidsperioden innan för att analysera tillståndsberoende. Detta leder emellertid till en risk för bias på grund av såväl korrelationen mellan förklaringsvariabeln och feltermen som av icke-observerad heterogenitet. Detta kan undvikas med ett förfarande där man använder slumpeffektmodellen eller med ett instrumentvariabelförfarande.

1.6.1 Bilanvändningsstudien

I studien av bilanvändning skattas efterfrågad körsträcka som en funktion av körsträckan året innan, disponibel inkomst, pris på bensin, fordonsprisindex, avstånd till arbetet, antal barn, och en individdummy. Den senare innebär att panelstrukturen används genom att kontrollera för icke-observerad heterogenitet hos individerna, med en fix-effekt för varje individ. Den dynamiska aspekten kommer in genom att körsträckan året innan används.

Då den disponibla inkomsten för en individ förändras över tid, kan även klassificeringen av individen med avseende på inkomstkvartil förändras. I den här studien har vi valt att låta observationen av en individ följa vederbörandes klassificering med avseende på disponibel inkomst. Därför kan observationer av en individ under olika år uppträda som basen för olika inkomstgruppmodeller. Samma gäller även vederbörandes bostadsadress. Om vederbörande flyttar till en annan typ av område, blir observationerna av den individen basen för den nya områdestypen. Detta innebär att vi inte alltid har alla observationer av en individ i en modell, dvs. vi använder obalanserade paneler för varje modell.

1.6.2 Bilägandestudien

I studien om bilägande används en s.k. ordered probitmodell. Ordered probitmodellen är en generalisering av probitmodellen, där en individs val bland två alternativ modelleras som en slumpfunktion av olika bakgrundsvariabler. Probitmodellen använder normalfördelningen, medan den parallella logitmodellen använder den logistiska fördelningen. I ordered probitmodellen väljer individen mellan mer än två alternativ. I vår modell är det 0, 1, 2 och 3 eller flera bilar.

Ordered probitmodellen har varit den metod som valts i några studier om bilägande, baserade på paneldata (Hanly och Dargay, 2000b; Hanly och Dargay, 2007 samt Kitamura och Bunch, 1990). Därför valde vi att studera samma slag av bilägandemodell som har använts av Dargay och Hanly (2000 och 2007) för att förenkla jämförelsen med resultaten i dessa arbeten.

I modellen skattas en indikatorvariabel som en funktion av bilägandet året innan, disponibel inkomst, pris på bensin, fordonsinköpsindex, avstånd till arbetet, antal barn och två åldersdummys. Eftersom vi har mer än 108 miljoner observationer, av vilka 94 miljoner kommer från tätorter, kan det enorma antalet observationer ha bidragit till att maximum likelihood beräkningarna inte konvergerade inom rimlig tid. Därför beslöt vi att bara välja en procent av tätortobservationerna genom ett slumpmässigt urval. För landsbygdsområdesmodellen (både tätortsnära och glesbygd) gick det att hantera samtliga totalt 14 miljoner observationer. De tidsödande beräkningarna ledde oss dock till att slopa försöken att använda fix-effekter för kontroll av icke-observerad heterogenitet. En förenkling som vi inte har provat är att reducera modellen till den klassiska probitmodellen med enbart tvåalternativsfallet: att äga bil eller att inte äga bil.

1.7 Tillgängliga och använda data

Jämfört med många länder har Sverige relativt lättillgängliga personuppgifter för samtliga invånare i officiella register, som i många fall kan göras tillgängliga för forskare. Sådana data har tidigare använts i VTI:s bilinnehavsmodell Matstoms (2002), som syftar till resefterfrågemodellering. Det här är dock, oss veterligen, första gången som registerdata har sammanställts för att modellera bilanvändning.

De variabler som vi använder är de årliga uppgifterna om varje individ i Sverige över 18 års ålder från 1998 till 2005. För varje individ och observation använder vi kön, ålder, antal barn (i alla åldrar) som bor med individen, disponibel inkomst, bostadens belägenhet, avståndet till arbetsplatsen, sysselsättningssituation samt antalet ägda bilar. Det inkomstbegrepp som använts är den disponibla inkomsten, vilken definieras som "summan av alla både skattepliktiga och skattefria inkomster plus alla statliga transfereringar minus skatter och negativa transfereringar"[1]. Alla dessa värden har noterats för december månad under respektive år. Den disponibla inkomsten har deflaterats med SCB:s konsumentprisindex (KPI) (den fastställda indexserien med 1980 = 100).

Det finns inga systematiska studier av underdeklarationer av inkomster i svenska registerdata. Vi vet dock från svenska hushållsutgiftsundersökningar att sådana underdeklarationer förekommer. Det är välkänt att om man använder förklarande variabler med mätfel, kan det uppstå bias. Detta betyder att både koefficientskattningens och dess skattade varians kan ha bias. I detta projekt har vi inte analyserat förekomsten av bias till följd av mätfel i disponibel inkomst.

De studier av bilanvändning och bilägande som vi har jämfört är baserade på data hämtade från undersökningar av hushållsutgifter. I svenska hushållsundersökningar används data om den disponibla inkomsten, hämtade från register. Den brittiska familjeutgiftsundersökningen (*Family Expenditure Survey*, förkortat FES) förefaller också använda liknande registerdata, även om deras inkomstbegrepp[2] inte är helt analogt med det svenska begreppet "disponibel inkomst" (se bilagan till denna introduktion med en mer detaljerad definition av det svenska begreppet [på svenska]).

Källan till våra data för körsträckor, individers privata bilägande och personuppgifter är SCB, som i sin tur erhåller data om kilometeravläsningar från Bilprovningen, data om bilägande kommer från Vägverkets centrala bilregister (CBR) och personuppgifter från Riksskatteverket (RSV). I föreliggande studie summerar vi körsträckor för av en individ privat ägda bilar. Dessa har korrigerats för att bilbesiktningen oftast inte inträffar vid årsskiftet. Tidigare studier, t.ex. Dargay (2007) har skattat körsträckor på grundval av bränsleutgifter i hushållsutgiftsundersökningar (vilket förutsätter att alla fordon har samma bränsleförbrukning). Å ena sidan bedömer vi att våra körsträcketal är mer tillförlitliga. Å andra sidan är körsträckorna knutna till bilen och inte till individen. Om bilen bytt ägare under året så tillskrivs den förre ägarens körsträcka den nya ägaren.

---

[1] Se t.ex. skriften *Beskrivning av statistiken – Hushållens ekonomi. Statistiska centralbyrån HE0103* 2008. En postlista från SCB på svenska bifogas som bilaga.

[2] Följande citat, som gäller FES i Storbritannien, är hämtat från det brittiska *Department for Work and Pensions (DWP)* hemsida. "Definitionen av disponibel inkomst … har använts … i linje med rekommendationerna i *Methodological Review* (1996). Det finns åtskilliga skillnader i jämförelse med den definition av disponibel inkomst som tidigare använts för FES. I denna undersökning (FES) gäller följande:

- Kompletterande frivilliga avgifter till ålderspensionsplaner och eventuella avgifter till privata pensioner drogs ej av i FES före 1996.
- *Social Fund*, moderskapspenning, begravningsbidrag eller kommunala vårdbidrag ingår ej.
- Återbetalningar av lån från *Social Fund* dras av från den disponibla inkomsten. Erhållande av lån från *Social Fund* räknas inte som disponibel inkomst; underhålls- och vårdnadsbidragsbetalningar dras ej av.
- Kompletterande studielån är inte inkluderade i den disponibla inkomsten.
- Ingen jämkning för föräldrabidrag har gjorts.
- Ingen rensning görs vid beräkningen av hypoteksränta i sådana fall där upplåning har skett i andra syften än bostadsköp."

För såväl bilanvändnings- som bilägandestudien har vi enbart använt data om privatägda bilar. Informationen om kilometeravläsningar har sammanställts med det primära syftet att beräkna det totala årliga trafikarbetet i Sverige. Därför har SCB även uppskattat körsträckor för bilar för vilka inga fordonsbesiktningar görs, t.ex. bilar under deras tre första "levnadsår". Eftersom det finns ett stort antal faktiska observationer, har vi så långt vi kunnat identifiera dem, valt att eliminera dessa modellgenererade observationer. För körsträckeanalysen använder vi data från 1998 till 2005 och för bilägandeanalysen data från 1996 till 2005.

I denna studie har vi valt att inte analysera bilar ägda av juridiska personer. Utgångspunkten är att dessa mestadels används i näringsverksamhet. Bilar som ägs av juridiska personer får dock användas för privat bruk under förutsättning att detta deklareras som bilförmån.

På ett tidigt stadium i detta projekt övervägde vi att använda data om förmånsbilar. Enligt svensk skattelagstiftning får företagare och anställda, som behöver en bil för sitt arbete, disponera en personbil som tillhandahålls av företaget. I sådana fall tillhandahålls bilen av företaget, och kostnaderna för bilen och dess bränsle och underhåll betalas av företaget. I de flesta sådana fall får bilens mottagare använda bilen för privata ändamål. Då måste emellertid vederbörande betala inkomstskatt, på värdet av den privata bilanvändningen, det s.k. förmånsvärdet. Av kostnadsskäl har vi valt att inte inkludera data om förmånsbilar. Om det är så att bilar ägda av juridiska personer i betydande utsträckning används för privat bruk av vissa individer utan att detta deklareras kan slutsatserna i denna studie påverkas genom att bilanvändningen för dessa individer underskattas.

Det faktum att våra datamaterial inte täcker den privata användningen av förmånsbilar innebär att våra data inte tillåter oss att analysera privat bilanvändning i dess fulla utsträckning. Det är dock bara en relativt liten andel svenskar som har möjlighet att utnyttja bilförmånen. År 2005 har antalet förmånsbilar uppskattats vara mindre än sex procent av antalet privatägda bilar[3]. Därför bedömer vi inte risken för bias på grund av denna urvalsbegränsning är något betydande problem. Det totala antalet fordon som ägs av juridiska personer var ungefär 25 procent av det totala antalet privatägda personbilar. Därför gör vi bedömningen att vi i stort sett har en tillförlitlig bild av den privata bilanvändningen. Detta kan möjligen ifrågasättas för glesbygd då von Bahr (2009) har presenterat uppgifter som indikerar att förekomsten av bilar som är ägda av juridiska personer i glesbygd är större än i tättbebyggda områden.

De bränslepris som använts är de årliga genomsnittspriserna på bensin, redovisade och tillhandahållna av Svenska petroleuminstitutet (SPI). Dessa värden har deflaterats av SCB:s konsumentprisindex (KPI). Då bensin- och dieselpriserna är starkt korrelerade i Sverige, har vi inte använt dieselpriser.

För bilinköpskostnaderna använder vi SCB:s bilprisindex vilket är ett subindex till SCB:s konsumentprisindex. Detta är i sin tur konstruerat av två subindex för nya och begagnade bilar. Bilinköpskostnaden har också deflaterats med KPI. Detta innebär att vi bortser från all variation i individuella inköpskostnader och från uppfattade kapitalkostnader för fordon. Dessa kan påverkas av ett antal faktorer, exempelvis konjunkturer, geografiska variationer och årstidsvariationer. Dessa variationer skulle eventuellt kunna få genomslag för skattningen av bilkostnader och därmed indirekt för andra skattningar.

[3] Antalet förmånsbilar var 190 000 år 2005. Samtidigt fanns det ca 4,1 miljoner personbilar, av vilka ca 80 procent (dvs. 3,3 miljoner) var privatägda.

Vi känner dock inte till någon möjlig alternativ källa till inköpskostnadsdata för hela bilstocken.

Vi har också övervägt att använda data avseende individuella försäkringsutgifter. Vi har emellertid valt att inte försöka detta, då vi har bedömt individuella försäkringsutgifter vara både svårtillgängliga och alltför dyra att köpa.

Avstånd till arbetsplatsen beräknas som det fågelvägsavståndet mellan individens bostadsadress och vederbörandes arbetsplats i december varje år. Detta döljer givetvis också eventuell förändring som kan ha ägt rum under årets lopp.

1.8 Beskrivningar av data och empiriska observationer om bilanvändning och bilägande

I kapitel 3 presenterar vi några grundläggande mönster från vårt datamaterial om bilanvändning. Detta datamaterials omfattning är unikt i bilanvändnings- och bilägande-analyser. Vi har data om alla vuxna svenskar (omkring sju miljoner) varje år, och vi använder data från 1996 till 2005 avseende bilägande (cirka 3,4 miljoner individer år 2005) och från 1998 till 2005 för bilanvändning (cirka 2,4 miljoner år 2005). Flertalet analyser i kapitel 3 gäller 2005.

För det mesta bekräftar beskrivningarna observationer i tidigare studier om bilanvändning i Sverige, vilka sammanfattats i VTI:s första rapport till Bisek (Vagland och Pyddoke, 2006):

- Invånare i storstäder äger bilar i mindre utsträckning än invånarna i mindre städer.
- Män äger bilar i större utsträckning än kvinnor.
- Män har längre avstånd till sina arbetsplatser än kvinnor.
- Mäns bilar används (körs) mer än kvinnors.
- Höginkomsttagare äger och använder bilar i större utsträckning än låginkomsttagare.
- En vanlig uppfattning om var bilanvändningen är mest omfattande, dvs. i Norrland och inte i södra Sverige, bekräftas inte.

I föreliggande analys används ett nytt geografiskt kriterium för första gången för att analysera bilanvändning och bilägande. Kriteriet definierar tre områdestyper: tätort, landsbygd nära en tätort och glesbygd. Resultaten som vi kommit fram till är kanske inte överraskande, men är baserade på avsevärt fler observationer och är därför mer tillförlitliga. Detta gäller i synnerhet för landsbygds- och glesbygdsområden. Nämnda data möjliggör också analyser med avsevärd upplösning för särskilda områden eller kommuner. De viktigaste nya resultaten är följande:

- Invånare i tätortsområden äger bilar i mindre utsträckning än landsbygds-invånare.
- Bilar ägda av invånare i tätortsområden används mindre än bilar ägda av invånarna i landsbygdsområden, men skillnaden är liten.
- Skillnaden mellan landsbygdsområden nära tätortsområden och glesbygds-områden är ännu mindre. Bilanvändning i landsbygdsområden nära tätorts-områden är något större än i glesbygdsområden.

- Skillnaderna i bilanvändning mellan könen och de olika inkomstgrupperna är stora. Mäns bilar används mer, vilket också gäller bilar ägda av höginkomsttagare.
- Bilar ägda av personer över 67 år används mindre än bilar ägda av yngre personer.
- Skillnaderna i bilanvändning mellan olika glesbygdsverksregioner är små.
- Andelen bilägare som upphör att vara bilägare varierar kraftigt med hänsyn till inkomst. Låginkomsttagare avslutar oftare sitt bilägande.
- Andelen bilägare, som avslutar sitt ägande, är större bland bilägare i tätortsområden än i landsbygdsområden. Andelen bilägare, som avslutar sitt ägande, är ca 40 procent större i tätort än i landsbygdsområden.
- Andelen kvinnor som avslutar sitt bilägande är mellan 30 och 70 procent större än motsvarande andel män med samma inkomst.

1.9 Resultat av modellanalyser

1.9.1 Skillnader i effekterna av kostnader och inkomster på privat bilanvändning i Sverige 1999–2005

Kapitel 4 kan ses som ett första steg i analysen av socioekonomiska och geografiska skillnader i svensk bilanvändning. Det unika datamaterialet, öppnar möjligheter till mer detaljerade analyser av bilanvändning i olika sociala grupper och i olika geografiska områden. I denna studie har vi inlett denna process. En huvudmålsättning är att granska hur bilanvändare med låga inkomster i lands- och glesbygdsområden anpassar sin bilanvändning till kostnads- och inkomstförändringar.

Rent allmänt hittar vi små geografiska skillnader i känsligheten för ändringar i disponibel inkomst och kostnader. Skattade inkomstelasticiteter minskar med ökande disponibel inkomst. Detta kan tyda på viss mättnad med avseende på bilanvändning, som inträder när den disponibla inkomsten ökar. Skattningarna för inkomstelasticiteter förefaller rimliga (utom för den lägsta inkomstkvartilen) och bygger på observationer från alla individer. De skattade körsträckeelasticiteterna med avseende på disponibel inkomst är mindre än de körsträckeelasticiteter med avseende på hushållsinkomst som skattats i Storbritannien.

Modellerna för den lägsta inkomstkvartilen har negativa elasticiteter för bilanvändning med avseende på den disponibla inkomsten. Detta innebär att ökningar av den disponibla inkomsten kommer att leda till minskad bilanvändning.

De skattade bilanvändningsfunktionerna indikerar också olika känslighet beroende på om en bil registreras i ett landsbygdsområde (både tätortsnära och glesbygd) eller i ett urbant område. Bilanvändningen är mer inkomstelastisk i landsbygdsområden än i tätortsområden. Detta innebär att landsbygdsinvånare med låga disponibla inkomster vill öka sin bilanvändning mer än motsvarande tätortsinvånare när deras inkomster ökar. Detta kan tolkas som att de har ett större behov av bilanvändning som inte tillfredsställs när de har låga inkomster. Detta kan också tolkas som att landsbygdsinvånarnas bilanvändning och därmed rörlighet är mer sårbar än tätortsinvånarnas.

Avståndet mellan bostad och arbetsplats påverkar också bilanvändningen mest i landsbygdsområden nära tätortsområden och minst i glesbygdsområden, med tätortsområden

däremellan. Barnantalets effekt på bilanvändningen är större i landsbygdsområden än i tätortsområden.

Effekten av bilanvändningen året innan – trögheten – är större än motsvarande effekt skattad för hushåll i Storbritannien. Det tar alltså längre tid för svenska bilanvändare att anpassa sig till förändringar av kostnader och inkomster än för brittiska.

Kvinnors och mäns anpassning av bilanvändning skiljer sig klart från varandra. Männens bilanvändning är mer inkomstelastisk i de två mittenkvartilerna. Kvinnors bilanvändning är genomsnittligt mer känslig för avståndet mellan bostad och arbetsplats.

Våra skattningar av bilanvändningens bränslepriselasticitet är positiv för de flesta kvartilerna. Vi tror dock inte att höjda bränslepriser leder till ökad konsumtion av bilanvändning, allt annat lika. Eventuellt skulle detta resultat påverkas med ett bättre mått på den disponibla inkomsten. Ett sådant bättre mått skulle kunna tillhandahållas genom sammankoppling av individer i samma hushåll. Koefficientestimaten för fordonsinköpskostnadsindex är också positiva. Bägge dessa indikationer talar därigenom mot de teoretiska prediktionerna och kontrasterar mot Dargays forskningsresultat för hushåll i Storbritannien.

Fler barn ökar bilanvändningen, mer för låginkomsttagare än for höginkomsttagare. Även detta kontrasterar med Dargays resultat för hushåll i Storbritannien, nämligen att barn minskar bilanvändningen.

Genom att kombinera dessa observationer kan vi formulera följande slutsatser om låginkomsttagares bilanvändning i landsbygdsområden. De äger bilar i lägre grad än personer med högre inkomster i landsbygdsområden, men mer än individer med samma inkomst i tätortsområden. Med undantag för personer med de lägsta inkomsterna tycks låginkomsttagares bilanvändning vara mer inkomstelastisk. Detta innebär att låginkomsttagare kommer att vilja använda sina bilar avsevärt mer, om de får högre inkomster.

Våra skattningar av koefficienter för bensinpris och bilköpskostnad ger inte de teoretiskt förväntade tecknen. Genom att jämföra med våra skattningar för aggregerad bilanvändning och med andra studier, och i beaktande av att våra resultat inte ger de teoretiskt förväntade resultaten, bedömer vi inte att våra resultat utgör grund för att förändra bedömningen att bilanvändningselasticiteten med avseende på bensinpris ligger i storleksordningen -0,2. Vi drar inte heller någon slutsats om bilanvändningselasticiteten med avseende på bilinköpskostnadsindex.

De generella konsekvenserna av exempelvis höjda bensinskatter är att hushållen inledningsvis till största delen kommer att absorbera prishöjningarna genom att minska andra former av konsumtion. I ett längre perspektiv kommer höjda bensinpriser att påverka valet av biltyp. Vi kan också dra slutsatsen att hos en majoritet av befolkningen finns det fortfarande en stark preferens för ökad bilanvändning när den disponibla inkomsten ökar.

Bilanvändningsmönstret för glesbygdsområden skiljer sig inte mycket från andra landsbygdsområden. I motsats till vitt spridda föreställningar förefaller det inte finnas något behov av politiska åtgärder, som är särskilt utformade för att subventionera glesbygdsbefolkningens bilanvändning i allmänhet. Bristen på rörlighet i termer av bilanvändning synes främst vara ett problem för den lägsta inkomstgruppen, särskilt för ungdomar och äldre människor.

Inkomstfördelningskonsekvenserna av höjda bensinpriser kommer sålunda att vara tämligen jämnt fördelade mellan bilägare i de olika områdestyperna, men kommer att slå hårdare mot låginkomsttagande bilägare, eftersom dessa ofta använder en större del av sin disponibla inkomst till inköp av fordonsbränsle. En åtgärd för att motverka negativa inkomstfördelningseffekter av ökade bränslepriser bör därför snarare riktas mot inkomst än boendeområde.

1.9.2 En dynamisk modell för individuellt privat bilägande i Sverige 1996–2005

De flesta resultaten från vår bilägandestudie, som täcker perioden 1996 till 2005, är analoga med resultaten från en tidigare svensk bilägandemodell (Matstoms, 2002) för perioden 1980 till 1995. Vissa resultat går emellertid längre än den föregående studien genom att de explicit modellerar valet av antal bilar och genom att de införlivar följande ytterligare förklarande variabler: avstånd till arbetsplats, antal barn samt bilköpskostnadsindex. Vi kan också urskilja skillnader i bestämningsfaktorer för bilägande i tätortsområden och landsbygdsområden (både tätortsnära och glesbygd) genom att använda Glesbygdsverkets områdesdefinitioner.

Vi har analyserat tätortsområden och landsbygdsområden separat med avsikten att belysa skillnaderna i bilägande mellan dessa områden. Vi finner att landsbygdsinvånare är mer benägna att fortsätta att äga bil och mindre benägna att avsluta sitt ägande, när de äger en bil, än tätortsinvånare. Landsbygdsinvånare är också mer benägna att skaffa en bil och mindre benägna att fortsätta att inte äga bil, när de ej äger en bil, än tätortsinvånare. Detta är de förväntade skillnaderna men de är förvånansvärt små om man jämför med beskrivningen av data i kapitel 3 som visar på stora skillnader i bilägande mellan tätortsområden och landsbygdsområden. Detta kan indikera att vi saknar någon viktig förklaringsvariabel för bilägande som t.ex. tillgången till alternativa transportmedel.

Det mest iögonfallande resultatet av analysen är att bilägande är mycket beständigt. Bilägande året innan har en helt dominerande effekt på nuvarande bilägande och svarar för drygt 80 procent av sannolikheten för att en individ fortsätter att äga eller att inte äga *en* bil. För män med medianinkomsten och som inte äger bil är den prognostiserade sannolikheten för att fortsatt inte äga bil högre än 80 procent. Om han å andra sidan äger en bil, är sannolikheten för fortsatt ägande mer än 80 procent. Detta resultat stödjer resultaten i tidigare studier. Föreliggande studie indikerar att denna beständighet är starkare i landsbygdsområden än i tätortsområden.

Resultat för avslutning och inledning av bilägande stödjer också de tidigare resultaten. Män kan i mindre utsträckning förväntas upphöra med sitt bilägande och kan med större sannolikhet förväntas köpa en bil, om de inte har någon, än vad som gäller för kvinnor. Män är också mer benägna att öka sitt ägande än kvinnor, vid lika förutsättningar i övrigt enligt modellen.

Beträffande unga män (18–24 år) finner Matstoms (2002) för perioden 1980–1995 att de har haft den starkaste benägenheten att förvärva bilar, om de inte hade någon året innan. Denna benägenhet sjönk dock under 1990-talet, och i föreliggande studie finner vi en svagare benägenhet att skaffa bil än vad vi gör för den stora åldersgruppen mellan 25 och 67 år. Under perioden 1996–2005 är benägenheten att avsluta bilägande störst bland dem som är över 67 år gamla, följda av ungdomar och sedan de medelålders. Den är signifikant högre för kvinnor. I föreliggande studie finner vi att

landsbygdsbefolkningen är mindre benägen att upphöra med bilägandet och mer benägen att köpa en bil, om de inte har någon, än stadsbor.

Ett anomalt resultat är att de skattade effekterna från den disponibla inkomsten är insignifikanta och nära noll, vilket inte är det förväntade resultatet. Detta står i tydlig kontrast till fynden i den deskriptiva analysen, där en stark korrelation mellan inkomst och bilägande noterades. Frånvaron av inkomsteffekt i modellskattningarna kan vara en följd av beständighetens starka verkan. Hos Matstoms ges inga kvantitativa elasticiteter för bilägandesannolikheter med avseende på inkomst. Matstoms säger emellertid att bilförvärvselasticiteterna har rätt tecken.

En andra anomali är att höjda bensinpriser ökar sannolikheten för ägande av två bilar och minskar sannolikheten för att inte äga någon bil. De skattade effekterna av prishöjningar för bensin i tätortsområden är att de ökar sannolikheten för att vederbörande äger två bilar och minskar sannolikheten för ägande av *en* bil. I landsbygdsområden minskar sannolikheten att inte äga bil och sannolikheten för att äga två bilar ökar.

Effekterna av höjda bilköpskostnader har de förväntade effekterna i tätortsområden, men inte i landsbygdsområden, där de minskar sannolikheten för att inte äga någon bil och ökar sannolikheten för att äga två bilar. Effekterna av avståndet till arbetsplatsen är obefintliga för sannolikheten att äga en bil. Effekten av att ha tre barn i stället för inget barn är att benägenheten att ha ingen eller *en* bil minskar och att benägenhet att ha två bilar ökar i både tätortsområden och landsbygdsområden. Den skattade effekten av skillnader i avstånd till arbetsplatsen är mycket liten.

Det finns inga direkt jämförbara beräkningar i Dargay och Hanly (2007). Dargay och Hanly noterar att bilägande är positivt relaterat till bilägande året innan. Denna kommentar – jämte det relativt låga parametervärdet i Dargay och Hanlys studie – tyder på att effekten av tidigare bilägande är starkare i våra data och i vår modell.

Vidare noterar Dargay och Hanly att bilägandet ökar med stigande inkomst. De finner också att bilägande förekommer i mindre utsträckning för ensamstående kvinnor med barn. Vi undersöker individuellt bilägande i denna studie och förfogar inte över data om vilka individer som ingår i hushållet. Vi finner dock lägre sannolikhet för bilägande hos kvinnor, allt annat lika.

I Dargay och Hanlys skattningar har bilköpskostnaderna en stark negativ effekt på bilägandet. Detta genomslag är svagt i vår modell. De drar slutsatsen att antalet barn är den minst viktiga faktor som styr bilägandet. I våra resultat har antalet barn liten genomslagskraft, men är större än för andra oberoende variabler.

De erhållna resultaten utvidgar de kända sambanden för Sverige med vilka vi kan beskriva det enskilda bilägandets känslighet för förändringar med avseende på kostnader, disponibel inkomst samt dess avhängighet av kön och typ av bostadsområde. Sambanden kräver dock ytterligare utveckling innan tillförlitliga resultat kan nås för alla effekter. Då skulle modellen kunna tillämpas på olika delar av befolkningen och olika geografiska områden, vilka kan behöva fördjupad analys.

1.10 Transportpolitiska implikationer av studiens resultat

Den nationella transportpolitiken formuleras och uppdateras återkommande i transportpolitiska propositioner, nu senast i *Mål för framtidens resor och transporter* prop. 2008/09:93. Det övergripande målet innehåller både en samhällsekonomisk effektivitetsaspekt och en fördelningsaspekt. De transportpolitiska åtgärder och

konsekvenser som kan belysas med hjälp av resultaten i denna studie är framför allt skatter som påverkar kostnader för fordon och körsträckor (t.ex. bränsleskatter). De konsekvenser som diskuteras här är hur detta påverkar bilanvändning och bilägande.

De politiska diskussionerna om konsekvenser av kostnadsökningar för bilanvändare tenderar att närmast reflexmässigt anta att detta drabbar landsbygdsbor särskilt hårt. Detta bygger på uppfattningen att landsbygdsbor använder sina bilar mer än tätortsbor. Den genomsnittliga användningen av bilar ägda av landsbygdsbor är också större än användningen av bilar ägda av tätortsbor. Denna studie visar att detta beror dels på att genomsnittsanvändningen är något större för det stora flertalet på landsbygd, dels på att det fåtal individer som använder sina bilar riktigt mycket andelsmässigt är något fler på landsbygd. För det stora flertalet är dock de geografiska skillnaderna i bilanvändning små. Skillnaderna i bilanvändning är större mellan de lägsta och högsta inkomsterna eller mellan könen.

Bilanvändning förändras långsamt. Bilanvändningens låga elasticitet med avseende på bensinpris innebär att merparten av anpassningen till bensinprisförändringar kommer att vara i termer av annan konsumtion på kort sikt och mer i termer av anpassning av fordonsval på längre sikt.

Inkomstkonsekvenserna av höjda bensinpriser är att bilägare på landsbygd drabbas i genomsnitt något mer än bilägare i tätort men effekterna är ändå tämligen jämnt fördelade mellan bilägare i de olika områdestyperna. Däremot slår den hårdare mot låginkomsttagande bilägare, eftersom dessa ofta använder en större del av sin disponibla inkomst till inköp av fordonsbränsle. Det faktum att en individ använder bil mycket innebär dock inte självklart en omständighet som bör vara föremål för fördelnings-politiska åtgärder.

Även bilägande förändras långsamt. Landsbygdsinvånare är mer benägna att fortsätta äga bil och mindre benägna att avsluta sitt bilägande än tätortsbor. Skillnaderna mellan olika geografiska områden är dock förvånansvärt små. Även delstudien av bilägande indikerar att andra möjligheter till anpassning till höjda kostnader, än att upphöra med bilägande används. Liksom för bilanvändning innebär det faktum att en individ äger flera bilar (eller en dyrare bil) inte en omständighet som självklart bör vara föremål för fördelningspolitiska åtgärder.

Våra resultat indikerar således att åtgärder för att motverka negativa inkomstfördel-ningseffekter av ökade bränslepriser och andra bilkostnader därför snarare bör riktas mot individer med låga inkomster än mot boendeområde. Därmed skulle även kvinnor i större utsträckning än män komma att kompenseras.

1.11 Problematiserande diskussion av oväntade skattningsresultat

1.11.1 Bilanvändningsmodellen

De oväntade resultaten i bilanvändningsmodellen är

- inkomstens effekt på körsträcka i de lägsta inkomstkvartilerna
- bensinprisets effekt på körsträcka i de flesta modellerna
- bilprisets effekt på körsträcka i de flesta modellerna.

I det följande ska tänkbara metoder för att komma tillrätta med dessa resultat diskuteras. I vissa fall finns också hypoteser om samband som inte kan observeras med befintliga

data och som eventuellt skulle kunna förklaras med ytterligare data eller alternativa metodansatser[4].

Inkomsteffekten

- För det felaktiga tecknet för inkomstens effekt på körsträcka i de lägsta inkomstkvartilerna finns hypotesen att det skulle kunna tänkas finnas en negativ samvariation mellan deklarerad och odeklarerad inkomst i den lägsta inkomstkvartilen. Mätfel avseende den disponibla inkomsten kan generera bias i skattningen. Vi vet att det finns inkomstmätningsfel för låginkomsttagare eftersom det förekommer att hushåll med låga inkomster i hushållsutgiftsundersökningar deklarerar större konsumtion än inkomst. Vi kan därför inte utesluta sådana fel i mätningen av inkomsten även för de högre inkomstgrupperna. Sådana fel skulle kunna generera systematisk underskattning av effekten av inkomst. Detta innebär att koefficienternas absoluta värden skulle vara lägre än de faktiska värdena.
- Gemensam användning av bilar i hushållen och mellan hushåll skulle kunna vara en annan förklaring till inkomstens negativa effekt på körsträcka i den lägsta inkomstkvartilen på följande sätt:
    - Om en bil används av flera individer i ett hushåll och ägs av en individ så överskattas körsträckan för ägaren i förhållande till inkomsten.
    - Samma om mer än en bil skriven på en individ, samtidigt som den används av flera i hushållet.
    - Om det är vanligare att flera delar bil i låginkomsthushåll så ger det upphov till ytterligare snedvridningar.
    - Till detta kan läggas att bilen även kan användas av individer utanför hushållet. Om detta är vanligare i låginkomsthushåll så påverkar också detta resultaten.
- Med tillgång till uppgifter om individens civilstånd respektive med eller utan barn skulle följande tester kunna göras av hur gemensam användning av fordon i hushåll påverkar skattningen av modellens koefficienter. Principen bygger på att välja ut individer i tänkbara en-person-hushåll och jämföra med individer i tänkbara par. Därefter jämförs resultaten för att se om de är olika. Uppgifter om civilstånd finns inte i studiens databas, men antal barn finns.
    - Modellerna skattas separat för gifta och ogifta utan barn. Ogifta utan barn borde vara den grupp som modellen passar bäst för.
    - Skatta modellerna separat för individer med och utan barn. Modellen borde fungera bättre för individer utan barn. Detta kan vi göra med tillgängliga data.
    - Liknande uppdelning kan göras av individer som äger en eller flera bilar. Modellen borde fungera bra för ogifta med en bil.
- Den genomförda studien använder en bilindivids körsträcka och tillskriver ägaren vid årsskiftet hela körsträckan. Om bilen bytt ägare under året blir det ett mätfel

[4] Flera av dessa har föreslagits av Gunnar Isacsson vid VTI:s granskningsseminarium den 30 oktober 2008.

avseende den nye ägarens körsträcka. Om individer med låg inkomst ofta köper sina bilar från individer som använder bilen mer och leder detta till överskattning av låginkomstindividens bilanvändning. Om dessa individer dessutom oftare byter sina bilar förstärks denna effekt ytterligare.

- Heterogenitet på bilnivå beaktas inte. Effekten av inkomst borde rimligen bero på hur mycket bensin bilen drar. I det befintliga datamaterialet saknas uppgifter om bilindividens bensinprisförbrukning. Med bilindividens modell och modellens bensinförbrukning skulle vi få ett mer precist mått på vad det kostar att köra en kilometer. Detta kräver i så fall särskilda data och eventuellt analyser då varje modell t.ex. Volvo V40 har flera varianter och därmed flera olika motorer. Fullständig precision nås dessutom inte då heller eftersom faktisk bensinförbrukning inte stämmer med teoretisk och då förbrukningen troligen påverkas av bilens ålder. Några hypoteser om bensinförbrukningens effekter kan formuleras så här:
    - Om vi antar att låginkomsttagare i genomsnitt äger bilar som drar mindre bränsle än höginkomsttagare så kommer de att vara mindre bensinprискänsliga än om alla bilar drog lika mycket.
    - Om vi istället antar att låginkomsttagare i genomsnitt äger bilar som drar lika mycket eller mer bränsle än de bilar som ägs av höginkomsttagare, så är en möjlig hypotes att detta i kombination med deras lägre inkomst kommer att göra deras körsträckor mer bensinpriskänsliga än höginkomsttagarnas.
    - Båda dessa effekter gäller om bilen körs ungefär lika mycket och om den kostar ungefär lika mycket. Detta saknar vi för närvarande data för att analysera.
- Studien använder årsinkomster och tar inte hänsyn till att de som inträder på arbetsmarknaden under året får lägre årsinkomst än de som arbetar hela året. Dessutom kan både bilanvändning och bilägande kan vara korrelerade med inkomsten när man får sitt första arbete. När man inträder i arbete är det tänkbart att bilanvändningen ökar mer än proportionellt med inkomstökningen. Därmed skulle inkomsten kunna vara mindre korrelerad med körsträckan för individer som inträder på arbetsmarknaden än vad den är bland sysselsatta vid olika inkomstnivåer.

Bensinpriseffekten

Också det felaktiga tecknet för bensinprisets effekt på körsträcka kan tänkas ha flera orsaker[5]. För bensinpriset använder vi årliga konsumentprisgenomsnitt. Detta innebär att vi bortser från geografiska variationer, variationer under året och variationer i individens bensinköpskostnader. Vi bedömer dock inte detta sammantaget som någon större felkälla. Å andra sidan kan följande förhållanden påverka skattningsresultaten:

- Gemensam användning av bilar i ett hushåll kan, liksom för effekten av inkomstvariation, också störa skattningen av sambandet mellan bensinpris och körsträcka genom samma mekanismer som nämns för inkomst ovan. Dessa fel påverkar alla inkomstgrupper.

[5] Ekonometriska läroböcker redovisar en rad möjliga källor till bias och metoder för korrigeringar. För en fyllig sammanställning av metoder för felsökning och korrigering hänvisas till Kennedy (2005).

- Heterogenitet bland bilindivider kan också tänkas påverka skattningen av bensinprisets effekt på hur mycket bensin bilen drar. En hypotes om bensinprisets effekter kan formuleras så här: Om de som kör långa sträckor i genomsnitt äger bilar som drar mindre bränsle än de som kör korta sträckor så kommer individerna med långa körsträckor att vara mindre bensinpriskänsliga än om alla bilar drog lika mycket.
- Det faktum att vi använder så få observationer (sju) i sig självt vålla en bias i de skattade varianserna för koefficientestimaten (påvisat av Kloek, 1981 och Moulton, 1990). Det har föreslagits några metoder för korrigering av sådan bias (t.ex. Petersen 2006 och Donald och Lang 2007) som vi inte har provat. Detta leder troligen till en stor korrigering uppåt av de skattade standardfelen. Detta påverkar dock inte tecknet på skattningen.
- Vi kan också tänka oss att ett ökat bensinpris minskar förbrukningen per körd sträcka genom annat körsätt eller fordonsunderhåll. Det skulle medföra en lägre körsträckeelasticitet än bensipriselasticitet men kan dock inte förklara en poistiv elasticitet.
- Både ökat bensinpris och ökningar av andra kostnader kan leda till att de som kan försöker välja en bil som tillhandahålls av deras arbetsgivare, s.k. förmånsbilar. Därmed försvinner deras bilanvändning ur datamaterialet.

Bilpriseffekten

Sambandet mellan bilpris och körsträcka är inte teoretiskt självklar. Visst kan man tänka sig en hög grad av anpassning av vilket fordon och därmed vilken kapitalkostnad som är förenad med bilanvändningen. Kopplingen kan se ut så här; ökat bilpris leder till ökad kostnad under bilens livslängd. Detta kan leda till att individen byter till en mindre och bensinsnålare bil. Därmed skulle effekten av ökat bilpris kunna leda till att den initiala negativa effekten av ökat bilpris på körsträcka dämpas. Om kostnaden för alla bilar ökar så bör en renodlad substitutionseffekt vara negativ. Detta förutsätter dock att man väl kan kontrollera för prisvariationen. Detta kan vi nu inte eftersom vi inte har data om den individuella bilens pris eller kostnad.

Beträffande bilpriset konstateras att heterogeniteten i bilarna gör bilprisvariabeln trubbig. Vi konstaterar därför att följande ytterligare analyser kan vara intressanta att göra:

- Kontrollera om priset på nya och begagnade bilar ökar olika mycket.
- Kontrollera om priset på olika biltyper (i grupperna nya och begagnade) ökar olika mycket.
- Som nämnts ovan skulle mer individuella data om överlåtelsetidpunkt, bilindivider bränsleeffektivitet och kostnader kunna vara användbara.

Resonemanget ovan om bias i de skattade standardfelen för koefficientestimaten för bensinpris gäller även här.

1.11.2 Bilägandemodellen

De oväntade resultaten i bilägandemodellen är

- Bilägandets försumbara inkomstelasticitet
- Bilägandets försumbara elasticitet med avseende på avstånd till arbetet

- För vissa övergångssannolikheter har bensinprisförändringar oväntat tecken
- För vissa övergångssannolikheter har bilprisförändringar oväntat tecken.

Även för bilägande finns anledning att analysera hur gemensamt ägande av bilar i hushåll kan påverka skattningar av benägenhet att förändra sitt bilägande. Om en individ står som ägare till hushållets bil(-ar) leder det till att:

- Benägenheten för individen att äga bil överskattas.
- Om det är vanligare för låginkomsttagare att i realiteten samäga bilar så överskattas deras benägenhet mera.
- Även för bilägandemodellen kan inkomstförändringar under året leda till under- respektive överskattning av benägenhet att förändra sitt bilägande.
- Effekterna av bensinpris och bilpris innehåller också tänkbara källor till bias genom vi inte har ideala data.

Dessa problem behöver dock inte alla samtidigt eller ens någon av dem vara den verkliga förklaringen till de observerade resultaten.

Bilägandets låga känslighet för inkomstförändringar kan bero på att stora grupper har stabila inkomster och att bilägandet inte varierar så mycket med förändring av inkomst i breda inkomstintervall. Detta utesluter dock inte att bilägandet kan variera mer med inkomst i vissa grupper. På liknande sätt kan den låga känsligheten för avstånd till arbetet bero på att avståndet till arbetet varierar lite i stora grupper och att bilägandet inte varierar så mycket med förändring av avståndet till arbetet för de flesta. Detta utesluter inte att bilägandet kan variera mer med avståndet till arbetet i vissa grupper. Ytterligare strategier för att testa bilägandets känslighet för inkomst och avstånd till arbete skulle kunna vara följande:

- Genom att dela upp observationerna i inkomstgrupper som i bilanvändningsstudien skulle inkomsteffekter för varje inkomstgrupp kunna skattas separat.
- Att samtidigt analysera anpassningen av det ägda fordonets värde. Detta kan vi inte göra med det nuvarande datasetet.
- Genom att dela upp observationerna i olika grupper med avseende på avstånd till arbetet skulle avståndets effekter för olika grupper kunna skattas separat.

Utöver de ovan nämnda hypoteserna om tänkbar bias finns följande hypoteser om hur skattningsresultaten skulle kunna vara snedvridna. Skattas modellen om med dessa alternativa ansatser kan det tänkas att de ovanstående resultaten påverkas.

- Instrumentvariabel metod för att minska risken för inkonsistenta skattningar.
- Ordered logit istället för ordered probit.
- Hantera asymmetrin i att öka respektive att minska bilägande.

Tröghetsvariabeln (bilägandet året innan) är starkt korrelerad med bilägandet innevarande år. Om man tar bort denna förklaringsvariabel så skulle förmodligen effekten av inkomst bli något större. Det kan mycket väl samtidigt vara så att det finns inkomsttrösklar där individer utan bil blir mer benägna att skaffa bil respektive när individer med bil upphör att äga bil samtidigt som det kan vara så att när en individ äger en bil så är individen uthållig i att fortsätta äga bil även om inkomsten varierar. Det finns ju ganska stora möjligheter att anpassa kostnaderna för att äga en bil genom att välja mer

eller mindre kostsamma bilar. En sådan hypotes skulle kunna testas genom att skatta modellen för enbart handlingsalternativen icke äga bil och äga bil.

1.12 Ideala data för studien

Eftersom metodvalet i denna studie innebär att så nära som möjligt replikera studierna av Dargay (2007) respektive Dargay och Hanly (2007) med registerdata för individer valde vi att använda variabler och data som låg så nära dessa modeller som möjligt. I den meningen har vi haft näst intill ideala data.

Givet att vi finner oväntade resultat uppstår dock frågan om vi med bättre data hade kunnat kontrollera för samband och därmed finna skattningar som bättre svarar mot de teoretiska prediktionerna. Vi kan inte i förväg veta vilka dessa data är men ett försök att beskriva hur en mer ideal datamängd ser ut följer här.

En idealisk databas för individer skulle helst bygga på individens egen körsträcka för olika bilar (egna och andras). Den skulle också knyta individens egen kostnadsbörda för de respektive körsträckorna. Det skulle t.ex. innebära individens egna utgifter för bränsle genom information om inköpt kvantitet och genomsnittligt pris under året. Med tätare observationer av inköpt kvantitet och genomsnittligt pris skulle bristerna i skattningarna av standardfel till följd av få observationer av priser kunna undvikas. Allmänt sett vore det värdefullt med flera mättidpunkter avseende bostadsort, disponibel inkomst, etc.

En motsvarande idealisk databas för hushållet skulle knyta samman uppgifterna om samtliga individer som ingår i samma hushåll. Kostnaderna för de olika körsträckorna skulle också registreras.

För både individer och hushåll vore det värdefullt med mer information om bilindividerna. När förvärvades en bilindivid och när avyttrades bilindividen och till vilket inköpspris respektive försäljningspris? Det vore också värdefullt med utgifter för bränsle liksom bilindividens bränsleförbrukning. Andra kostnader som har betydelse för bilens användning är utgifter för underhåll, skatt och försäkring av bilindividen. Med dessa data skulle bristerna i skattningarna av standardfel till följd av få observationer kunna undvikas.

Vi hoppas att vi genom våra analyser och hypoteser om förbättringar samt idéer om ytterligare analyser kan inspirera till vidare forskning inom området.

2 Introduction with summary and conclusions

2.1 About the report

This report from The Swedish National Road and Transport Research Institute (VTI) has been produced with the aid of funding from Bisek (The Social and Economic Significance of the Automobile), which is in turn a collaboration between the following organisations: The National Road Administrations in Sweden and Norway, VINNOVA, Folksam, Svenska motororganisationers samarbetsorganisation (Mosk), The Norwegian Automobile Federation (NAF) as well as Bil Sweden and The Swedish Association for Motor Trades and Repairs (MRF).

The report is based on three essays in English which have been produced within the project. The first essay constitutes Chapter 3 where the data material is described. Car use is analysed in Chapter 4 and car ownership in Chapter 5. An introduction has been included with these three essays in a Swedish version (Chapter 1) and in an English version (Chapter 2). The introduction consists of two parts. The first part (sections 2–9) is intended to be a summary and discussion of the results of the study and is addressed to a broader readership. The second part (sections 10 and 11) is a more technical problematised discussion of estimate results from the model analyses.

The aim has been for Chapter 4 and 5 to serve as the basis for scientific publication as a link in further quality assurance and scientific dissemination of the results.

2.2 Intention: Analysis of vulnerable and potential car users in Sweden

Increasing fuel prices in combination with concerns that the goal of countering climate change will require even higher fuel prices make it important to shed light on the welfare and income distribution costs that this may entail for private car use. An analysis of this issue at the individual level and with a high geographic resolution requires good data. This data is available in some countries either as “household panels” or as register data.

There are a number of types of adaptations which could be analysed for private car use. Different types of analyses of adaptation by car users to changed costs can therefore be carried out. A first type of analysis relates to the substitution effect of changes due to changed fuel prices and car purchase prices, i.e. the consequences that such price changes have for car ownership and car use. A second type of analysis concerns the effects of changes in income on ownership and driving behaviour. A third type of effect that may be analysed is income distribution effects, i.e. how what different individuals and households may be obliged to give up because of cost increases may vary with income.

The intention of this report is to carry out the first two types of analyses in order to provide a basis for the third. We have therefore investigated the empirical correlations between, on the one hand, sex, disposable real income, the number of children, which type of area an individual lives in, distance to workplace (and for the car ownership model also the individual’s age) and, on the other hand, the distances driven by the privately-owned cars and individual car ownership. Special attention has been devoted to the responsiveness of car use and car ownership to changes in disposable income and fuel prices.

One goal of this study has been to shed light on car use in groups that have previously used cars to a smaller extent than the average car driver, for example women, young and elderly persons and in particular elderly women. We expect to be able to make a small but important contribution to the extensive body of knowledge that exists about car use. We also hope to be able to replicate the elasticity calculations of earlier studies and to increase this body of knowledge by providing a set of elasticities differentiated according to sex, disposable income and the type of area where the individual lives. Elasticity means the responsiveness of a dependent variable to change in an independent variable. It is measured as a percentage change divided by percentage change.

The most important tool for analysis of transport demand in Sweden is the different models used to determine how demand for travel will develop. The national demand model for passenger transport Sampers is an example of this. Such models are based primarily on the official travel survey (Riks-RVU) which currently contains around 50,000 observations of individual reports on journeys carried out on a number of days up to 2005.

The travel surveys and demand models are both effective tools for the understanding of car use. However, they have one disadvantage since there are relatively few observations of individual car drivers in sparsely populated areas compared with persons living in urban areas. Demand models are also usually based on analyses of travel during a year, so that dynamic effects – i.e. changes in patterns of behaviour over time – cannot be modelled.

The intention is accordingly to study car ownership and car use (distance driven) in more detail for those car drivers that are particularly dependent on their cars, car owners who are more vulnerable in their car use (for example, low-income earners and the elderly) and potential car users who have a threshold for car use (e.g. low-income earners and the young). To this end, distance to an urban area and an income measure are used as indicators of car dependence and vulnerability respectively. We expected that the responsiveness to changes in prices and income of low-income earners in rural areas close urban areas and sparsely populated areas would differ from the values for individuals with higher income or inhabitants of urban areas. If responsiveness was lower in these respects, this could be interpreted as greater dependence on the car. If, however, responsiveness was greater, this could also be interpreted as a higher extent of vulnerability. There is accordingly an interpretation for both outcomes.

2.3 Policy for car ownership and car use

If it is wished to analyse the efficiency of a policy instrument (for example, petrol tax), it is important to be aware of the reasons that may exist for using the instrument but also for using other policy instruments affecting a goal variable (e.g. car use). There is a set of conditions in economic welfare theory for when a market achieves a socially efficient distribution of resources. The theory also presents an extensive set of circumstances under which a market, in the absence of intervention, will not achieve a socially efficient distribution of resources of this kind. These circumstances are sometimes referred to as market failures. Inefficiency may also arise as a result of political measures. When there is inefficiency, different kinds of measures in the form of price corrections or regulations may be useful.

The use of roads and car travel is normally associated with market failures. These occur due to road users not automatically bearing the full burden of social costs that they give

rise to by using the roads. This is caused by car use having side effects ("externalities"), e.g. accidents and pollution, which as a result are not fully priced. This gives rise to a gap between the costs paid for by car drivers and the total marginal costs for society.

This gap is filled – to a varying extent – by taxes or tax deductions for fuel and vehicle costs. Fuel taxes are, however, not sufficiently flexible to fully reflect the variations of externalities in time and space. The problem of finding a good balance between the exactness with which taxes reflect the actual social costs and the increased transaction costs for exact taxes of this kind is a separate field of research. Furthermore, new inefficiencies arise from the increased travel costs that such taxes give rise to in combination with income taxation. Therefore, further aspects of the design of the tax system are to reduce the negative incentives, for travel to the workplace and to use private cars for work. For example, rules that aim at reducing these undesired incentives are tax deductions for the cost of work travel and payments from employers and corresponding tax rules for private use of the car provided by the employer.

Since the car has become the most important mode of transport, its use also has important income distribution aspects. Despite this, we know relatively little about the possibilities of improving welfare for certain groups (for example, elderly or disabled persons) by making car ownership and car use more affordable. We also know relatively little about the consequences for income distribution of rising fuel prices. Swedish studies (e.g. Jansson and Wall 1994), have primarily focused on the share of fuel expenditure of total household expenditure in different income groups.

The most important tools for affecting income distribution are income taxes, transfers and subsidies of basic services such as education, health care and care of the elderly. However, we know very little about the relative efficiency of transport policy measures to achieve the general goals of income distribution.

2.4 Implications from economic theory for car ownership and car use

Classic microeconomic consumption theory

In classical consumption theory for individuals and households, demand for all goods is derived from the maximisation of utility. Demand will then become a function of income and prices of all goods and services that the consumer can choose between. Normally, the focus is on the correlation between the desired quantity and the price of the studied good when all other prices and income are unchanged.

There are some powerful predictions in economic theory for how demand for most goods and services varies when prices or incomes change. In the case of normal goods, a price increase leads to lower demand, and increased income to higher demand. If car ownership and car use are normal goods, increased income can be expected to lead to increased car ownership and increased car use. Correspondingly, increased costs for fuel and other costs for owning and driving a car – all other things being equal – will lead to reduced car ownership and reduced car use. The probability of an individual with a particular income and other characteristics owning and using a car will moreover be affected by how close to the workplace and other destinations for journeys the individual lives.

The assumption that car use is a normal commodity can be called into question from various starting points, since there are aspects of divisibility and saturation. An

individual cannot be in more than one car at the same time, and there are only 24 hours in a day. There is therefore reasonably a ceiling for how much car use an individual can consume. This should mainly affect people with higher income. In many cases, individuals can also travel together when they want to make the same journey and when they prefer to travel together. The car is also indivisible in that even a small amount of private car use requires access to a car.

According to economic theory, a number of other economic variables can affect the desired distance driven. We will only briefly identity the conditions that may be relevant.

Depending on the good studied, the concepts individual or household are used. When the household consists of a number of individuals, it is conceivable that the household makes certain consumption decisions as *one* unit. This may mean that the household's individuals weigh their income and conceivable expenditure together to choose the level of consumption. However, it is not obvious whether it is the individual or household concept which is most relevant to study car use. In a recently published survey (Vermeulen 2002), different views were discussed of individuals and household consumption. Vermeulen starts by noting that it is typical for economic analysis of demand that a clear distinction is not made between individual and household. Either individual demand or household demand is analysed, although with the same assumptions and theoretical bases. It is only recently that special theoretical approaches have started to be developed to take into consideration that all households (which consist of more than one individual) can also need to describe the preferences of the constituent individuals and how this affects the characteristics of demand.

In this report, the analysis confines itself to discussing the implications of analysing data on the theoretical basis that demand derives from an individual or a household which acts as a single decision-making unit. This study was carried out on the basis of the hypothesis that data at the individual level would function. However, this proved not to be the case. We will take up a more detailed discussion of this later.

Income from capital is also included in the definition of disposable income. However, we have not analysed the effects of wealth. This is a potential problem since the individual and the household's wealth, like housing and loan costs (interest and loan arrangement costs) affects the scope for consumption.

Car ownership and car use may moreover be affected by the vehicles that are available on the market and their characteristics with respect to, for example, fuel consumption and safety. In this context, the cost for the specific vehicle is naturally also important. An important adaptation to increased fuel costs is probably to change to a car with lower fuel consumption. There are also indications that individuals adapt their driving style and vehicle maintenance to changed fuel prices (see Jansson and Wall (1994)). This would then give rise to a difference between estimation of the correlation between the price of petrol and fuel consumption and fuel prices and distances driven respectively since the latter are affected by fuel consumption per distance driven. If it is assumed that fuel consumption per distance driven is affected negatively by an increase in the price of petrol, there is reason to believe that the elasticity of the driven distance with respect to the price of petrol would be lower than the elasticity of petrol demand with respect to petrol price.

Other variable costs such as the costs of insuring the car may affect the use and who is registered as owner. The individual's prices for, and access to public transport

(bus/coach, train and air) also affect the desired distance driven. The characteristics of public transport with respect to travel times and comfort are also important.

Dynamics can also play an important role for choice of means of transport, e.g. habits, search processes which lead to time lags of adaptations and adaptations to changed views of one's own life income.

Link between theory and econometrics

An ideal for empirical work with economic behaviour is to derive behavioural correlations (such as demand functions) from maximisation of utility. For econometric studies – i.e. statistical analyses based on economic theory – a form of utility functions are sometimes used which make it possible to derive exact demand functions. It is then possible to estimate these demand functions with the aid of available data. In such cases, a picture is obtained of how demand on the market studied varies when prices and incomes change.

However, in many contexts, it may be reasonable to content oneself with simplifications of this general method. In this study of car use, we have considered that it is sufficient to use a linear form of demand as a function of price and income.

In the study of car ownership, however, a slightly more complicated system of demand is used. The theory underlying the econometric model is based on McFadden's theory on discrete choices. This is based on every individual choosing among a limited number instead of a continuous number of alternatives. It is also assumed that the researcher lacks information about the individuals' preferences, other relevant characteristics of the individual as well as about the available alternatives. The individual behaviours are therefore modelled not only on known factors but also on a random factor which is intended to capture factors that are not observed by the researcher. In this analysis, we are primarily interested in investigating the difference between inhabitants of rural areas and urban areas with respect to the probability of owning a number of different cars and changing the ownership of cars respectively. Therefore calculations are mainly made in this study of the effects on **the probability** of different owners changing behaviour – i.e. buying or selling a car – when prices and incomes change.

2.5 Previous empirical studies of car ownership and car use

Broadly, there are four categories of empirical analyses of car use. The first category is studies that analyse the responsiveness of car use to changes in the price of fuel. Numerous studies of this kind have been made. Many of these investigate vehicle kilometres and aggregate demand for fuel. The second category is descriptions of car use on the basis of data from travel surveys. The third category is analyses of models for travel demand. Such models are often based on cross-section data. The fourth category consists of panel data approaches to model adaptations by individuals or households over time with respect to car ownership and car use.

Most of what we know about car use derives from the first three categories of data and modelling. This is also the case for Sweden, where both national travel surveys and data on household expenditure have been important sources of information. Travel surveys have also been used in production of models for travel demand. Both travel surveys and household expenditure have, however, a disadvantage since there are few observations of car use in rural areas close to urban areas and sparsely populated areas. Travel

surveys and thus demand models have moreover the disadvantage that it is not possible to track the same individual over time. The desire to create a more reliable data material on car use in rural areas and to track individuals over time have been important reasons for the construction of the data material in this study.

An important advantage of panel data in the form we use is accordingly that it makes it possible to study how individuals or households adapt to changing conditions over time, in contrast to cross-section studies where conclusions are drawn from differences between individuals. With observations from a number of years for each individual in the panel, it will be possible to study the effects from previous years on the current year. In this study, we have limited the analysis of the dynamic effects to the effects of decisions in one previous year.

Dargay (2007) appears to belong to the first studies that directly analyse car use at household level with panel data methods. Among other early attempts to analyse car use with panel data methods are de Jong (1990), Rouwendal and de Vries (1999) as well as Bjørner (1999).

Among early car ownership models, where panel data-based approaches are used may be mentioned Goodwin (1986), Kitamura (1989) and Kitamura and Bunch (1990). One conclusion, which these studies have in common, is that previous car ownership is a strong predictor for current car ownership.

A similar model has also been constructed of the probability that an individual will become a car owner or cease to be an owner for Sweden (Matstoms, 2002). Matstoms' model is also based on panel data and is dynamic although it is not really a panel data model.

2.6 Models

After having studied the earlier literature, we chose in this study to replicate the studies by Dargay (2007) for car use and by Dargay for car use and Hanly (2007) for car ownership respectively. The intention was to choose variables and data as close to these studies as possible, and when this was possible, to expand the data by register data.

It has been known for a long time that dynamic factors can play an important part in the choice of means of transport. Such mechanisms include habits, search processes that lead to time lags of adaptations and adaptations to changed views of one's own future income. Panel data makes it possible to link individual adaptations to changes in income, living costs and other exogenous factors. Panel data methods have accordingly been used in the most advanced studies of car ownership and car use. However, there are relatively few suitable panels for car ownership and car use.

The basic methods in panel data statistic estimates are the fixed effects model and the random effects model. The fixed effects model entails controlling non-observable differences at the observed individuals. This model is best when there may be correlations between the non-observed individual effect which is constant over time and the explanatory variables. The random effects models are used when it is reasonable to assume that the non-observed individual effect is not correlated with any of the individual explanatory variables.

When dynamics are studied, the value of the explanatory variable for the preceding time period is often used to analyse state dependence. However, this leads to a risk of bias both due to the correlation between the explanatory variable and the error term and by

non-observed heterogeneity. This can be avoided with a procedure where a random effects model or an instrument variable procedure is used.

2.6.1 The car use study

In the study of car use, the desired distance driven is estimated as a function of the distance driven the preceding year, disposable income, the price of petrol, the car purchase cost index, the distance to work, the number of children and an individual dummy. The latter entails that the panel structure is used through controlling for non-observed heterogeneity among individuals with a fix effect for each individual. The dynamic aspect comes in through the distance driven the previous year being used.

Since the disposable income of an individual changes over time, the classification of the individual with respect to the income quartile may also change. In this study, we have chosen to let the observation of an individual follow the particular person's classification with respect to disposable income. Observations of an individual during different years may therefore appear as the basis for different income group models. The same also applies to the residential address of the individual in question. If the person moves to another type of area, the observations of the individual will serve as the basis for the new type of area. This means that we do not always have all observations of an individual in a model, i.e. we use unbalanced panels for each model.

2.6.2 The car ownership study

An ordered probit model is used in the study of car ownership. An ordered probit model is a generalisation of the probit model where an individual's choice between two alternatives is modelled as a random function of different background variables. The probit model uses normal distribution, while the parallel logit method uses the logistic distribution. In the ordered probit model, the individual chooses between more than two alternatives. In our model, there are 0, 1, 2 and 3 or more cars.

The ordered probit model has been the method chosen in some studies of car ownership, based on panel data (Hanly and Dargay, 2000b, Hanly and Dargay, 2007 as well as Kitamura and Bunch, 1990). We therefore chose to study the same kind of car ownership model used by Dargay and Hanly (2000 and 2007) to simplify comparison with the results of these studies.

In the model, an indicator variable is estimated which is a function of car ownership in the previous year, disposable income, the price of petrol, the car purchase cost index, the distance to work, the number of children and two age dummys. Since we have more than 108 million observations, of which 94 million are from urban areas, the enormous number of observations may have contributed to the maximum likelihood of the calculations not converging within a reasonable time. We therefore decided to choose only one per cent of the urban observations through random selection. It was possible to process a total of 14 million observations for the rural area model (both close to urban area and sparsely populated). The time-consuming calculations led us, however, to discontinue the attempts to use fix effects to control non-observed heterogeneity. One simplification which we have not tried is to reduce the model to the classical probit model with only the two-alternative case: to own a car or not to own a car.

2.7 Available and used data

Compared with many countries Sweden has relatively easily available personal particulars for all inhabitants in official registers, which in many cases can be made available to researchers. Such data have previously been used in VTI's car ownership model (Matstoms, 2002), which aims at travel demand modelling. However, to the best of our knowledge, it is the first time that register data have been compiled to model car use.

The variables that we use are the annual data on every individual in Sweden over the age of 18 from 1998 to 2005. For every individual and observation, we use sex, age, the number of children (of all ages) who live with the individual, disposable income, the location of the home, the distance to the place of work, employment situation and the number of cars owned. The income concept used is disposable income, which is defined as "the total of all both taxable and tax-free income plus all government transfers less taxes and negative transfers"[6]. All these values have been noted for the month of December in the respective year. The disposable income has been deflated by Statistics Sweden's consumer price index (CPI) (the fixed index series with 1980 = 100).

There are no systematic studies of too little income being declared in Swedish register data. We know, however, from Swedish household expenditure surveys that such underestimates of income do occur. It is well-known that bias may arise if explanatory variables with measurement errors are used. This means that both the coefficient estimate and its estimated value can have a bias. In this project, we have not analysed the occurrence of bias due to measurement errors in disposable income.

The studies of car use and car ownership which we have compared are based on data obtained from surveys of household expenditure. In Swedish household surveys, data have been used on disposable income, obtained from registers. The British Family Expenditure Survey (FES) also seems to use similar register data, even if the income concept[7] is not wholly analogous with the Swedish term "disposable income" (see appendix to this introduction for a more detailed definition of the Swedish concept [in Swedish]).

---

[6] See, for example, the brochure *Beskrivning av statistiken – Hushållens ekonomi. Statistics Sweden HE0103* 2008. A post list from Statistics Sweden (in Swedish) is included as an appendix.

[7] The following quote, which applies to FES in the United Kingdom has been obtained from the British *Department for Work and Pensions (DWP)* website. "Definition of disposable income … has been used … in line with the recommendations in the *Methodological Review* (1996). There are numerous differences in comparison with the definition of disposable income previously used for FES. In this survey (FES), the following applies:

- Supplementary voluntary contributions to old age pension schemes and any contributions for private pensions were not deducted in FES prior to 1996.
- *Social Fund*, maternity benefit, burial grant or municipal childraising allowance are not included.
- Repayments of loans from the *Social Fund* are deducted from disposable income. Receipt of loans from the *Social Fund* is not treated as disposable income; child support and childraising allowance payments are not deducted.
- Supplementary study loans are not included in disposable income.
- No adjustment for parental benefit has been made.
- No purging has taken place when calculating mortgage interest in such cases where borrowing has taken place for other purposes than house purchase.

The source of our data on distances driven, individuals' private car ownership and personal data is Statistics Sweden, which has in turn obtained data on kilometre readings from Bilprovningen, data on car ownership comes from the Swedish National Road Administration's central car register (CBR) and personal particulars from the National Tax Agency (RSV). In the present study, we added distances driven for cars owned by an individual. These have been corrected since vehicle inspection most often does not take place at the year-end. Previous studies, for example, Dargay, 2007, estimated distances driven on the basis of fuel expenditure in household expenditure surveys (which assume that all vehicles have the same fuel consumption). On the one hand, we assess that our distance driven figures are more reliable. On the other hand, the distances driven are linked to the car and not to the individual. If the car has changed owner during the year, the distance driven by the previous owner will be credited to the new owner.

In both the car use and car ownership surveys, we have only used data on privately-owned cars. Information about kilometre readings has been compiled with the primary aim of calculating the total annual traffic performance in Sweden. Statistics Sweden has therefore estimated distances driven for cars for which no vehicle inspections have been made, for example, cars during the first three "years of life". Since there are many actual observations, we have chosen to eliminate these model-generated observations as far as we have been able to identify them. For the distance driven analysis, we use data from 1998 to 2005 and for the car ownership analysis data from 1996 to 2005.

In this study, we have chosen not to analyse cars owned by legal entities. The point of departure is that these are mostly used in business activity. Cars owned by legal entities may, however, be used for private purposes provided that this is declared as a car benefit.

At an early stage in this project, we considered using data on cars provided to the individual by her employer. According to Swedish tax legislation, entrepreneurs and employees, who need a car for their work, may have at their disposal a car provided by the employer. In such cases the car is provided by the employer and the costs of the car and its fuel and maintenance are paid for by the employer. In most cases, the car's recipients may use the car for private purposes. However, the person concerned must pay income tax on the value of the private car use, the "value of the benefit". For reasons of cost, we have opted not to include data about cars provided by employers. If cars owned by legal entities are used to a considerable extent for private purposes by certain individuals without this being declared for tax purposes, the conclusions in this study may be affected by underestimating the car use of these individuals.

The fact that our data material does not cover private use of a car provided by the individual's employer means that our data does not permit us to analyse private car use to its full extent. However, only a relatively small proportion of Swedes are able to use the car benefit. In 2005, the number of employer provided cars was estimated to be less than six per cent of the number of privately-owned cars[8]. We therefore do not consider the risk of bias due to this sample limitation to be a major problem. The total number of vehicles owned by legal entities was around 25 per cent of the total number of privately-owned cars. We therefore make the assessment that we largely have a reliable picture of private car use. This can possibly be called into question for sparsely populated areas

[8] There were 190,000 employer provided cars in 2005. At the same time, there were around 4.1 million cars, of which around 80 per cent (i.e. 3.3 million) were privately-owned.

since von Bahr (2009) has presented data that indicate that the occurrence of cars owned by legal entities is greater in sparsely populated areas than in urban areas.

The fuel prices used are the annual average prices for petrol, provided by the Swedish Petroleum Institute (SPI). These values have been deflated by Statistics Sweden's consumer price index (CPI). We have not used diesel prices since there is a strong correlation in Sweden between fuel and diesel prices.

For car purchase costs, we use Statistics Sweden's car price index which is a sub-index of Statistics Sweden's consumer price index. This is in turn constructed of two sub-indexes for new and used cars. The car purchase index has also been deflated by CPI. This means that we disregard all variation in individual purchase costs and from individual capital costs of vehicles. These may be affected by a number of factors, for example, business cycles, geographical variations and seasonal variations. These variations would possibly have an impact on the estimate of car costs and thus indirectly on other estimates. However, we do not know of any possible alternative source of purchasing cost data for the whole car fleet.

We have also considered using data for individual insurance expenditure. However, we have decided not to try to do this since we have assessed that individual insurance expenditure to be both difficult to access and too expensive to purchase.

The distance to the workplace is calculated as the distance as the crow flies between the individual's home address and his or her workplace in December each year. This conceals, of course, any change that may have taken place in the course of the year.

2.8 Descriptions of data and empirical observations on car use and car ownership

In Chapter 3, we present some basic patterns from our data material on car use. The extent of this data material is unique in car use and car ownership analyses. We have data on all adult Swedes (around seven million) each year, and we use data from 1996 to 2005 for car ownership (around 3.4 million individuals in 2005) and from 1998 to 2005 for car use (around 2.4 million in 2005). The majority of analyses in Chapter 3 apply to 2005.

For the most part, the descriptions confirm observations in previous studies of car use in Sweden, which was summarised in VTI's first report to Bisek (Vagland and Pyddoke, 2006):

- Inhabitants in big cities own cars to a lesser extent than inhabitants of smaller cities.
- Men own cars to a greater extent than women.
- Men have a greater distance to their workplaces than women.
- Men's cars are used (driven) more than women's.
- High-income earners own and use cars to a greater extent than low-income earners.
- A common view of where car use is most extensive, i.e. in Norrland and not in southern Sweden, is not confirmed.

In the present analysis, a new geographical criterion is used for the first time to analyse car use and car ownership. This criterion defines three types of area: urban area, rural area close to urban area and sparsely populated area. The results that we arrive at are perhaps not surprising, but are based on considerably more observations and are therefore more reliable. This is particularly the case for rural areas close to urban areas and sparsely populated areas. The aforesaid data also makes possible analyses with considerable resolution for special areas or municipalities. The most important new results are as follows:

- Inhabitants in urban areas own cars to a lesser extent than people in rural areas.
- Cars owned by inhabitants in urban areas are used less than cars owned by inhabitants of rural areas, although the difference is small.
- The difference between rural areas close to an urban area and sparsely populated areas is even less. Car use in rural areas close to an urban area is slightly greater than in sparsely populated areas.
- Differences in car use between sexes and the different income groups are great. Men's cars are used more, which also applies to cars owned by high-income earners.
- Cars owned by persons aged over 67 are used less than cars owned by younger persons.
- Differences in car use between different regions as defined by the National Rural Development Agency are small.
- The proportion of car owners who cease to be car owners varies strongly taking into consideration income. Low-income earners more often cease to own a car.
- The proportion of car owners, who cease to own a car, is greater among car owners in urban areas than in rural areas. The proportion of car owners who conclude their ownership, is around 40 per cent greater in urban than in rural areas.
- The proportion of women who terminate their car ownership is between 30 and 70 per cent greater than the corresponding proportion of men with the same income.

2.9 Results of model analyses

2.9.1 Differences in the effects of costs and income on private car use in Sweden 1999–2005

Chapter 4 may be regarded as a first step in the analysis of socio-economic and geographic differences in Swedish car use. The unique data material opens possibilities for more detailed analyses of car use in different social groups and in different geographical areas. We have initiated this process in this study. One main aim is to examine how car users with low-incomes in rural areas close to urban areas and sparsely populated areas adapt their car use to changes in costs and income.

In general, we find small geographical differences in responsiveness to changes in disposable income and costs. Estimated income elasticities decrease with increased disposable income. This may indicate some saturation with respect to car use, which takes place when disposable income increases. The estimates of income elasticities

seem reasonable (except for the lowest income quartile) and are based on observations from all individuals. The estimated driving distance elasticities with respect to disposable income are less than the driving distance elasticities with respect to household income which are estimated in the United Kingdom.

The models for the lowest income quartile have negative elasticities for car use with respect to disposable income. This means that increases in the disposable income lead to reduced car use.

The estimated car use functions also indicate differing responsiveness depending on whether the car has been registered in a rural area (both rural areas close to an urban area and sparsely populated areas) or in an urban area. Car use is more income elastic in rural areas than in urban areas. This means that inhabitants of rural areas with low disposable incomes wish to increase their car use more than the corresponding inhabitants of urban areas when their income rises. This can be interpreted as their having a greater need for car use which is not satisfied when they have a low income. This can also be interpreted as the car use of inhabitants of rural areas and thus their mobility being more vulnerable than that of the inhabitants of urban areas.

The distance between the home and the workplace also affects car use most in rural areas close to urban areas and least in sparsely populated areas, with urban areas being in an intermediate position. The effect of the number of children on car use is greater in rural areas than in urban areas.

The effect of car use the previous year – inertia – is greater than the corresponding effect estimated for households in the United Kingdom. It thus takes longer for Swedish car users to adapt to changes in costs and income than for British.

Women's and men's adaptation of car use clearly differs from one another. Men's car use is more income elastic in the two middle quartiles. Women's car use is on average more responsive for the distance between home and the workplace.

Our estimates of the fuel price elasticity of car use are positive for most quartiles. However, we do not believe that increased fuel prices leads to increased consumption of car use, everything else being equal. It is possible that this result would be affected by a better measure of disposable income. This measure could be obtained by linking together individuals in the same household. The coefficient estimate for the car purchase cost index is also positive. Both these indications argue, thus against the theoretical predications and contrast with Dargay's research results for households in the United Kingdom.

More children increase car use, more for low-income earners than for high-income earners. This also contrasts with Dargay's results for households in the United Kingdom, namely that children reduce car use.

By combining these observations, we can formulate the following conclusions on the car use of low-income earners in rural areas. They own cars to a lesser extent than persons with higher income in rural areas although more than individuals with the same income in urban areas. With the exception of persons with the lowest incomes, the car use of low-income earners would seem to be more income elastic. This means that low-income earners will use their cars considerably more, if they have higher income.

Our estimates of coefficients for the price of petrol and the car purchase cost do not provide the theoretically expected signs. By comparing our estimates of aggregated car use with other studies and taking into consideration that our results do not provide the

theoretically expected results, we do not consider that our results provide a basis for changing the assessment that the car use elasticity with respect to the price of petrol is in the range of -0.2. We do not either draw any conclusion about the car use elasticity with respect to the car purchase cost index.

The general consequences of, for example, increased petrol taxes are that households initially absorb most of the price increases by reducing other forms of consumption. In a longer perspective, the higher petrol prices will affect the choice of car type. We can also draw the conclusion that there is a strong preference among the majority of the population for increased car use when disposable income increases.

The pattern of car use for the sparsely populated areas does not differ greatly from other rural areas. In contrast to widespread ideas, there does not seem to be any need for political measures, which are specially designed to subsidise the car use of the population of sparsely populated areas in general. The lack of mobility in terms of car use would primarily appear to be a problem for the lowest income group, in particular for young and elderly persons.

The income distribution consequences of increased petrol prices may thus be rather evenly distributed among car owners in the different types of areas, but will have a greater effect on car owners on low incomes since these often use a greater part of their disposable income for purchase of vehicle fuel. A measure to counteract negative income distribution effects from increased fuel prices should therefore be focused on income rather than area of residence.

2.9.2 A dynamic model for individual private car ownership in Sweden 1996–2005

Most of our results from the car ownership study, which cover the period 1996 to 2005, are analogous with results from a previous Swedish car ownership model (Matstoms, 2002) for the period 1980 to 1995. However, certain results go further than the previous study by their explicitly modelling the choice of the number of cars and by their incorporating the following additional explanatory variables: the distance to the workplace, the number of children and the car purchase cost index. We can also distinguish differences in determinants for car ownership in urban and rural areas (both rural areas close to urban areas and sparsely populated areas) by using the area definitions of the National Rural Development Agency.

We have analysed urban and rural areas separately with the intention of shedding light on the differences in car ownership between these areas. We find that inhabitants of rural areas are more likely to continue to own a car and less willing to terminate their ownership when they own a car than inhabitants of urban areas. Inhabitants of rural areas are also more likely to acquire a car and less likely to continue not to own a car, when they do not do so, than inhabitants of urban areas. These are the expected differences although they are surprisingly small when compared with the description of data in Chapter 3 which indicates greater differences in car ownership between urban and rural areas. This may indicate that we lack some important explanatory variable for car ownership such as access to alternative means of transport.

The most striking result of the analysis is that car ownership is very enduring. Car ownership the previous year has a wholly dominant effect on current car ownership and accounts for over 80 per cent of the probability that an individual will continue to own or not to own *one* car. For men with a median income and who do not own a car, the

forecast probability of still not owning a car is higher than 80 per cent. If he, on the other hand, owns a car, the probability of continued car ownership is more than 80 per cent. This result supports the results of previous studies. Previous studies indicate that this persistence is stronger in rural areas than in urban areas.

The result for ceasing and starting to own a car also supports the previous results. Men can to a lesser extent be expected to cease car ownership and can with greater probability be expected to purchase a car, if they do not have one, than is the case for women. Men are also more inclined to increase their ownership than women, in the case of the prerequisites being otherwise the same according to the model.

As regards young men (18–24 years old), Matstoms (2002) finds for the period 1980–1995 that they have had the strongest inclination to acquire cars, if they had not done so the previous year. This inclination decreased, however, during the 1990s, and in the present study, we find a weaker inclination for this group to acquire a car than we do for the large group between the ages of 25 and 67. During the period 1996–2005, the inclination to cease car ownership was greatest among those over the age of 67, followed by young people and then the middle-aged. It is significantly higher for women. In the previous study, we find that rural inhabitants are less inclined to cease car ownership and more inclined to purchase a car if they did not own one than urban inhabitants.

An anomalous result is that the estimated effects from the disposable income are insignificant and close to zero, which is unexpected. This is in clear contrast to the findings in the descriptive analysis, where a strong correlation between income and car ownership was noted. The absence of an income effect in the model estimates may be a result of the strong effect of persistence. Matstoms does not provide any quantitative elasticities for car ownership probabilities with respect to income. Matstoms says, however, that car acquisition elasticities have the correct signs.

Another anomaly is that the increased petrol prices increase the probability of ownership of two cars and decrease the probability of not owing a car. The estimated effects of price increases for petrol in urban areas are that they increase the probability for the person concerned to own two cars and reduce the probability for owning *one* car. In rural areas, the probability of not owing a car decreases and the probability of owning two cars increases.

The effects of increased car purchase costs has the expected effects in urban areas but not in rural areas, where they reduce the probability of not owing a car and increase the probability of owning two cars. The effects of the distance to the workplace are non-existent for the probability of owning one car. The effect of having three children instead of no child is that the likelihood of having none or *one* car decreases and the likelihood of having two cars increases both in urban areas and rural areas. The estimated effect of differences in distance to the workplace is very small.

There are no directly comparable calculations in Dargay and Hanly (2007). Dargay and Hanly note that car ownership is positively related to car ownership the year before. This comment – as well as the relatively low parameter value in Dargay and Hanly's study – indicates that the effect of previous car ownership is stronger in our data and in our model.

Furthermore, Dargay and Hanly note that car ownership increases with rising income. They also find that single women with children are less likely to own a car. We investigate individual car ownership in this study and do not have access to data on

which individuals belong to the household. However, we find a lower probability among women, everything else being equal.

In Dargay and Hanly's estimates, car purchase costs have a strongly negative effect on car ownership. This impact is weak in our model. They draw the conclusion that the number of children is the least important factor that governs car ownership. In our results, the number of children has a small impact although it is greater than for other independent variables.

The results obtained expand the known correlations for Sweden with which we can describe the responsiveness of individual car ownership to changes with respect to costs, disposable income as well as its dependence on sex and type of residential area. However, these correlations require further development before reliable results can be obtained for all effects. The model could then be applied to different parts of the population and different geographical areas, which may require more in-depth analysis.

2.10 Transport policy implications of the results of the study

National transport policy is regularly formulated and updated in transport policy bills, most recently in *Objectives for future transport and travel (Mål för framtidens resor och transporter*) Government Bill 2008/09:93. The overall objective includes both the aspects of socio-economic efficiency and distribution. The transport policy measures and consequences that can be shed light upon with the aid of the results of this study are above all taxes that affect costs for vehicles and distances driven (e.g. fueltaxes). The consequences discussed here are how this affects car use and car ownership.

The political discussions on the consequence of costs increased for car users tend to assume, almost as a reflex action, that this has a particularly great effect on inhabitants of rural areas. This is based on the view that inhabitants of rural areas use their cars more than inhabitants of urban areas. The average use of cars owned by inhabitants of rural areas is also greater than use of cars owned by inhabitants of urban areas. This study shows that this is partly due to average use being slightly greater for the great majority in rural areas and to the fact that the proportion of individuals who make very great use of their cars is somewhat greater in rural areas. However, for the great majority, the geographic differences in car use are slight. The differences in car use are greater between the lowest and highest incomes or between sexes.

Car use changes slowly. The low elasticity of car use with respect to the price of petrol means that the major part of adaptation to petrol price changes will be in terms of other consumption in the short term and more in terms of adaptation of choice of vehicle in the long term.

The income consequence of increased petrol prices are that car owners in rural areas are affected somewhat more on average than car owners in urban areas although the effects are none the less quite evenly distributed between car owners in the different types of areas. However, these affect car owners on a low-income harder since they often use a greater part of their disposable income for purchase of vehicle fuel. The fact that an individual uses a car a lot is not, however, self-evidently a circumstance that should be the object of distribution policy measures.

Car ownership also changes slowly. The inhabitants of rural areas are more inclined to continue to own a car and less inclined to cease their car ownership than inhabitants of urban areas. The differences between different geographic areas are, however, surprisingly small. The car ownership study also indicates that other possibilities of

adaptation to increased costs, than ceasing to own a car are used. Just as for car use, the fact that an individual owns several cars (or a more expensive car) is not self-evidently a circumstance that should be the object of distribution policy measures.

Our results thus indicate that measures to counteract negative income distribution effects of increased fuel prices and other car costs should therefore rather be focused on individuals with low income than on the area of residence. In this way, women would also be compensated to a greater extent than men.

2.11 Problematised discussion of unexpected estimation results

2.11.1 The car use model

The unexpected results in the car use model are

- the effect of income on distance driven in the lowest income quartiles
- the effect of fuel price on distance driven for most models
- the effect of car price on distance driven in most models.

In the following section, conceivable methods for tackling these results are discussed. In certain cases, there are also hypotheses on correlations which cannot be observed with existing data and which could eventually be explained by additional data or alternative method approaches[9].

The income effect

- For the incorrect sign for the effect of income on distance driven in the lowest income quartile, there is the hypothesis that it is conceivable that there is a negative covariation between declared and undeclared income in the lowest income quartile. Measurement errors relating to the disposable income can generate bias in the estimate. We know that there are income measurement errors for low-income earners since it happens that low-income households in household expenditure surveys declare greater consumption than income. We cannot therefore exclude such errors of measurement for the higher income groups as well. Such errors could generate a systematic underestimation of the effect of income. This means that the absolute values of the coefficients would be lower than the actual values.
- Common use of cars in households and between households could be another explanation for the negative effect of income on distance driven in the lowest income quartile in the following way:
    - If a car is used by several individuals in a household and is owned by one individual, the distance driven for the owner is overestimated in relation to income.
    - The same if more than one car is registered by one individual, at the same time as it is used by more members of the household.
    - If it is more common that several persons share cars in low-income households, this would give rise to further distortion.

[9] Several of these have been proposed by Gunnar Isacsson at VTI's quality review seminar on 30 October 2008.

    - Furthermore, the car may also be used by individuals outside the household. If this is more common in low-income households, this would also affect the results.

- With access to information about the individual's civil status and with or without children, the following tests could be made of how common use of vehicles in households affects the estimate of the model's coefficients. The principle is based on selecting individuals in conceivable one-person households and comparing these with individuals in conceivable couples. The results are then compared to see whether they are different. Information about civil status is not included in the study's database although the number of children is available.
    - The models are estimated separately for married and unmarried persons without children. Unmarried men should be the group that the model fits best.
    - Estimate the models separately for individuals with and without children. The model should function better for individuals without children. We can do this with available data.
    - A similar breakdown can be made of individuals who own one or more cars. The models should work well for unmarried persons with one car.
- The study carried out uses an individual cars' distance driven and credits the owners at the year-end with the whole distance driven. If the ownership of the car has changed during the year, there will be a measurement error for the new owner's distance driven. If individuals with a low income often purchase their cars from individuals who use the car more, this will lead to an overestimation of the car use of low-income individuals. If these individuals often change their cars, this effect will be further reinforced.
- Heterogeneity at car level is not taken into account. The effect of income should reasonably depend on the petrol consumption of the car. Information is lacking about the individual car's petrol price consumption in the existing data material. With the individual car's model and the model's petrol consumption, we would obtain a more exact measure of the cost of driving a kilometre. In this case, this requires special data and possibly analyses when each model, for example Volvo V40, has several variants and thus different engines. Complete precision will moreover not be obtained then either since the actual petrol use does not accord with the theoretical and since consumption is probably affected by the age of the car. Some hypotheses on the effects of petrol consumption can be formulated as follows:
    - If we assume that low-income earners on average own cars that use less fuel than high-income earners, they will be less sensitive to petrol prices than if all cars had the same fuel consumption.
    - If we instead assume that low-income earners on average own cars that have the same or more fuel consumption than cars owned by high-income earners, it is a possible hypothesis that this, in combination with their lower income, will make their distances driven more sensitive to petrol prices than those of high-income earners.
    - Both these effects apply if the car is driven approximately as much and if it costs approximately as much. At present, we lack data to analyse this.

- The study uses annual incomes and does not take into consideration that those who enter the labour market during the year have a lower annual income than those who work the whole year. Moreover, car use and car ownership can both be correlated with income when a person obtains their first job. When entering the labour market, it is conceivable that car use increases more than proportionally with increased income. In this way, income could be less correlated with distance driven for individuals that enter the labour market than among the employed ate different levels of income.

The petrol price effect

There are several conceivable reasons for the incorrect sign for the effect of the price of petrol on distance driven[10]. We use the annual consumer price average for the petrol price. This means that we disregard geographic variations, variations during the year and variations in the individual's petrol price costs. However, we do not assess these variations to be a major source of error. On the other hand, the following circumstances may affect the estimated results:

- Common use of cars in a household may, as well as for the effect of income variation, also disturb the estimate of the correlation between petrol price and distance driven through the same mechanisms as mentioned for income above. These errors affect all income groups.
- Heterogeneity among individual cars may also conceivably affect the estimate of the effects of the petrol price on the petrol consumption of the car. One hypothesis on effects of the petrol price can be formulated as follows: If those who drive long distances on average own cars that use less fuel than those who drive short distances, the individuals driving long distances will be less sensitive to petrol prices than if all cars had the same fuel consumption.
- The fact that we us so few observations (seven) may per se lead to a bias in the estimated variances for the coefficient estimate (shown by Kloek, 1981 and Moulton, 1990). Some methods have been proposed for correction of such bias (e.g. Petersen, 2006 and Donald and Lang, 2007) which we have not tested. This probably leads to a large correction upwards of the estimated standard errors. However, this does not affect the sign of the estimate.
- We can also conceive that an increased petrol price reduces consumption per distance driven by a different way of driving or vehicle maintenance. This would entail a lower driving distance elasticity than petrol price elasticitity but could, however, not explain a positive elasticity.
- Both increased petrol price and increases of other costs can lead to that those who can try to choose a car supplied by their employers. In this way, their car use disappears from the data material.

The car price effect

The correlation between car price and distance driven is not theoretically self-evident. A high degree of adaptation of which vehicle and thus which capital cost is associated

[10] Econometric textbooks present a number of possible sources of bias and methods for correction. See Kennedy (2005) for a detailed summary of methods for fault tracing and correction.

with car use is conceivable, of course. The link may look as follows: an increased car price leads to increased cost during the lifetime of the car. This may lead to the individual changing to a smaller car with lower petrol consumption. In this way, the effect of an increased car price could lead to the initial negative effect of the increased car price on the distance driven being dampened. If the cost of all cars increases, a pure substitution effect should be negative. However, this assumes that the price variation can be controlled well. We cannot do this now since we do not have data on the price or cost of the individual car.

As regards the car price, it is noted that heterogeneity of cars makes the car price variable blunt. We therefore note that it may be of interest to make the following additional analyses:

- Check whether the price of new and used cars increases to a different extent.
- Check whether the price of different types of cars (in the groups new and used) increases to a different extent.
- As mentioned above, more individual data on the date of transfer, the fuel efficiency of individual cars and costs could be useful.

The above reasoning on bias in the estimated standard errors for the coefficient estimate of the petrol price also applies here.

2.11.2 The car ownership model

The unexpected results in the car ownership model are

- The negligible income elasticity of car ownership.
- The negligible elasticity of car ownership with respect to distance to work.
- Petrol price changes have unexpected signs for certain transitional probabilities.
- Car price changes have unexpected signs for certain transitional probabilities.

There is also reason for car ownership to analyse how joint ownership of cars in households can affect estimates of the likelihood of changing one's car ownership. If one person is registered as owner of the household's car(s), this will lead to:

- An overestimation of the inclination of the individual to own a car.
- If it is more common for the low-income earner to own cars jointly, this inclination will be overestimated more.
- Also in the case of the car ownership model, income changes during the year can lead to under- and overestimates respectively of the inclination to change one's car ownership.
- The effects of petrol price and the car price also include conceivable sources of bias through our not having ideal data.

However, these problems do not have to be all at the same time or even any of them to be the real explanation of the results observed.

The low responsiveness to income changes of car ownership may depend on large groups having stable incomes and that car ownership does not vary so much with change of income in broad income ranges. However, this does not exclude that car ownership may vary more with income in certain groups. Similarly, the low

responsiveness for distance to work may depend on the distance to work varying little in large groups and that car ownership does not change so much with change of distance to work for most people. This does not exclude that car ownership can vary more with distance to work in certain groups. Further strategies for testing the responsiveness of car ownership for income and distance to work could be the following:

- Through dividing up the observations in income groups as in the car use study, the income effects for each income group could be estimated separately.
- To at the same time analyse the adaptation of the value of the car owned. We cannot do this with the current data set.
- By dividing up the observations in different groups with respect to distance to work, the effect of distance for different groups could be estimated separately.

In addition to the above-mentioned hypotheses on conceivable bias, the following hypotheses exist on how estimate results could be distorted. If the model is re-estimated with these alternative approaches, it is conceivable that the above results would be affected.

- Instrument variable method to reduce the risk of inconsistent estimates.
- Ordered logit instead of ordered probit.
- Handle the asymmetry in increasing and decreasing car ownership.

There is a strong correlation between the inertia variable (car ownership in the previous year) and car ownership in the current year. If this explanatory variable is removed, the effect of income would probably be slightly greater. It may be the case at the same time that there are income thresholds where individuals without cars become more inclined to acquire a car or where individuals with cars cease to be car owners at the same time as it may be the case that when an individual owns a car, the individual is persistent in continuing to own a car despite varying income. There are, after all, large possibilities of adjusting the costs of ownership of a car by choosing more or less expensive cars. A hypothesis of this kind could be tested by estimating the model for the sole alternative of not owing a car and owning a car.

2.12 Ideal data for the study

Since the choice of method in this study means to the greatest extent replicating the studies of Dargay (2007) and Dargay and Hanly (2007) with register data for individuals, we chose to use variables and data that were as close to these models as possible. In this sense, we have almost ideal data.

Given that we find unexpected results, the question arises, however, of whether we would have been able to control for correlations with better data and thus find estimates that better correspond with the theoretical predictions. We cannot know which these data are in advance although an attempt to describe how a more ideal data set appears as follows.

An ideal database for individuals would preferably be based on the individual's own distance driven for different cars (own and others). It would also be linked to the individual's own cost burden for the respective distances driven. This would, for example, entail that the individual's own expenditure for fuel by information on the purchased quantity and the average price during the year. With more frequent

observations of purchased quantity and average price, it would be possible to avoid the deficiencies of estimates of standard errors due to an insufficient number of observations of prices. In general, it would be valuable with several measurement times for place of residence, disposable income, etc.

A corresponding ideal database for the household would link together information on individuals included in the same household. The costs of the different distance driven could also be registered.

For both individuals and households, it would be valuable with more information about all individual cars. When was an individual car acquired and at what purchase and sale price? It would also be useful with expenditure on fuel and the individual car's fuel consumption. Other costs that are important for the use of the car are expenditure for maintenance, tax and insurance of the individual car. With these data, the deficiencies of the estimates of standard errors due to too few observations could be avoided.

We hope that our analyses and hypotheses on improvements and ideas for further analyses will inspire further research in this area.

Appendix till Introduktion och sammanfattning

En detaljerad redovisning av Disponibel inkomst

+ Kontant bruttolön, semesterersättning, provision m.m.
+ Andra skattepliktiga förmåner än kontant lön
+ Ersättning från försäkringskassa som utgör inkomst av anställning
+ Ersättning från arbetslöshetskassa vid arbetslöshet
+ Ersättning från arbetslöshetskassa vid arbetslivsutveckling
+ Utbildningsbidrag för doktorander
+ Ersättning från vuxenutbildningsnämnd
+ Dagpenning vid frivillig krigsförbandsövning eller särskild övning
+ Vårdbidrag
+ Arbetsskadelivränta
+ Ersättning som utgör inkomst av anställning, AGS, TFA
+ Ersättning från försäkringskassa, annat förvärvsarbete
+ Vårdnadsbidrag

+ Erhållen kostnadsersättning
- Kostnadsavdrag
+ Allmän pension eller tjänstepension
+ Privat pensionsförsäkring och livränta
+ Andra skattepliktiga ersättningar som inte är pensionsgrundande, hobby
+ Periodiskt understöd
+ Inkomst som grundar egenavgifter/särskild löneskatt
+ Vissa ersättningar och förmåner från fåmansföretag
= Inkomst av tjänst

+ Inkomst av aktiv näringsverksamhet
+ Inkomst av passiv näringsverksamhet
= Inkomst av näringsverksamhet

= Sammanräknad förvärvsinkomst

+ Sjöinkomst
+ Inkomstränta och utdelning minus räntebidrag
+ Inkomst vid uthyrning av privatbostad
+ Positiv räntefördelning
+ Realisationsvinst (minus ev. realisationsförlust, dock min 0)

- Slutlig skatt (exkl. egenavgifter, allmän löneavgift för egenföretagare, Särskild löneskatt på förvärvsinkomster, avkastningsskatt, skogsvårdsavgift, särskild löneskatt på egna och anställdas pensionskostnader, inbetald utgående moms, och avdragsgill fastighetsskatt)
- Sjömansskatt
+ Skattefri del av barnpension
+ Skattefri del av livränta

+ Handikappersättning
+ Särskilt pensionstillägg
+ Kommunalt bostadstillägg (KBT)
+ Bostadsbidrag för barnfamiljer samt makar och ensamstående utan barn
+ Studiebidrag
+ Återbetalningspliktiga studielån
- Återbetalt belopp studielån under året
+ Lån i samband med utbildningsbidrag vid arbetsmarknadsutbildning
+ Skattefri sjukpenning
+ Skattefri frivillig pension
+ Dagersättning för värnpliktiga
+ Utryckningsbidrag för värnpliktiga
+ Bostadsbidrag för värnpliktiga
+ Utryckningsbidrag för värnpliktiga
+ Bidragsförskott, erhållet belopp
- Underhållsbidrag utgivet belopp
+ Allmänt och förlängt barnbidrag
+ Flerbarnstillägg
+ Socialbidrag och introduktionsersättning för flyktingar

= disponibel inkomst

Källa: Mejl från Håkan Schultz Statistiska Centralbyrån

3 Income distribution, car ownership and distance driven in Sweden*

3.1 Introduction

The purpose of this study is to examine differences in car use and car ownership in Sweden and in particular to examine car use in rural areas. Travel surveys only have small samples for rural areas. Therefore a unique database has been compiled to facilitate the analysis. Annual data for all adult Swedes (around 7 million observations) is available, as is information about car ownership from 1980 to 2005 (around 3.4 million individuals owned cars for private use in 2005) and about car use (around 2.4 million individuals in 2005). The major part of the analyses in this paper however relate to 2005.

This data allows us to examine deeply held convictions that rural inhabitants are more dependent on their cars and that they use their cars much more than do urban inhabitants.

The observations relating to car use largely confirm those made in the Swedish National Road and Transport Institute's (VTI) first report to Bisek (Vagland and Pyddoke 2006). The most important results were as follows:

- Inhabitants of large cities own cars to a lesser extent than those who do not live in large cities.
- Men own a car to a greater extent than women.
- Men work at a longer distance from their home than women.
- Men use (drive) their cars more than women.
- Those with higher incomes own a car to a greater extent and also use their cars more.
- Popular ideas that car owners in northern Sweden use their cars much more than car owners in southern Sweden, are not confirmed.

The present analysis of car use benefits from a distinction between three different area types developed by the National Rural Development Agency: urban area, rural area close to an urban area and sparsely populated area. The results we obtain are perhaps not so surprising although they are based on considerably more observations. The increased number of observations means above all that the descriptions of car use of inhabitants of rural areas close to urban areas and sparsely populated areas will be more reliable since they are based on considerably more observations. This data also makes it possible to zoom in on certain areas or locations, which we have only done to a limited extent to date. The following observations are made:

- Inhabitants of urban areas own cars to a lesser extent than those who live outside urban areas.
- Inhabitants of urban areas use their cars less than inhabitants in rural areas close to urban areas and sparsely populated areas. However, these differences are small.

* Data processing and design of tables and diagrams have been carried out by Urban Björketun.

- The differences between rural areas close to urban areas and sparsely populated areas are smaller. Use of cars owned by people living in rural areas close to urban areas is slightly greater than the corresponding use of cars owned by people in sparsely populated areas.
- There are large differences in car use between income groups and between the sexes. Cars owned by individuals with higher income are used more and cars owned by men are used more than cars owned by women.
- Use of cars owned by individuals older than 67 is clearly less than use of cars owned by middle-aged persons.
- There are small differences in car use between inhabitants of different regions as defined by the National Rural Development Agency.
- The proportion ceasing to own a car varies highly with income. People on low incomes more often give up owning a car.
- The proportion of car owners who cease to own a car is clearly higher among car owners in urban areas than those outside urban areas. The proportion which ceases to own a car is around 40 percent higher in urban areas than elsewhere.
- The proportion of women who cease to own a car is between 30 and 70 percent greater than the proportion of men with the same income!
- Car acquisition has not been analysed in this memorandum and no conclusions have therefore been drawn about the net effect of individuals ceasing to own a car or acquiring a car.

3.2 Definitions and starting points

The majority of the descriptions we make in this memorandum are based on data from 2005. The data base comprises a total of 7.11 million people aged 18 or over, of which 3.49 million are men and 3.61 million women. 3.38 million of the total population are car owners, of which 2.20 million are men and 1.18 million women. As private individuals, they own 4.44 million cars. We have access to observed distance driven for a large part of these cars while Statistics Sweden (SCB) has model-generated distances driven for cars which were not subjected to the vehicle inspection test. The observations affected by model-generated distances driven have been eliminated to the greatest possible extent.

Individual database

A database has been created based on government registers. Accordingly, we also have register data for the years 1980–2004 for persons aged over 18, the number of cars owned and the distances driven by the cars to the extent shown below.

The following variables have been obtained from SCB for these individuals:

Year of birth
Sex
Number of children (of all ages)
living with the individual from 1998
Geographic co-ordinates of home

Employment status	from 1985
Study status	from 1985
Business sector code	from 1985
Geographic co-ordinates of workplace	from 1985
Disposable income	
Assets	
Number of cars owned	
Annual distance driven for each car	almost completely from 1998
Holder of class B driving licence	from 2003

Area definitions

There are two definitions of an urban area. Statistics Sweden SCB (2002) defines it as "all groups of houses with at least 200 inhabitants, provided that the distance between houses does not normally exceed 200 metres". The definition used by the National Rural Development Agency (Glesbygdsverket Fakta 2007) is that urban areas are "places with more than 3,000 inhabitants and the area within 5 minutes travel by car from the place."

Additional to urban areas, the National Rural Development Agency defines the following area types: rural area close to urban area and sparsely populated area. A rural area close to an urban area is defined as "areas within 5 to 45 minutes' car journey of the nearest urban area" and a sparsely populated area is defined as "areas with more than 45 minutes' car journey of the nearest urban area". Islands without a permanent connection to the mainland are also considered as sparsely populated areas. We will not analyse sparsely populated island areas in this study.

The National Rural Development Agency has kindly provided a set of GIS polygons for this project. These have been used to digitalise the area criterion.

Of the 7,11 million persons, 5,45 million lived in urban areas (according to the National Rural Development Agency's definition), 1,51 million in rural areas close to urban areas and 0,12 million lived in sparsely populated areas. Others lived in sparsely populated island areas. See Appendix 2 for a map.

For some analyses, we have used the National Rural Development Agency's regions: the Inner parts of the Forest Counties, The coastal parts of the Forest Counties, Metropolitan Regions and the rest of Sweden (see map in Appendix 1).

How does this study differ from previous studies, for example, travel surveys and surveys of household expenditure? All individuals are included. This means that we have much more data each year than all travel surveys together. This entails a considerably greater ability to investigate specific regional differences in car use. This memorandum has only scraped at the surface of these possibilities.

3.3 Disposable income distribution in Sweden in 2005

Diagram 3.1 provides an image of the income distribution of all who have a non-negative disposable income. The median is represented by 1, which is around 154 000 kronor. In this and the following diagrams the frequencies in the right tail have been summed to the rightmost point in the diagram. In this diagram this means that the rightmost point represents all individuals with incomes higher than twice the median disposable income.

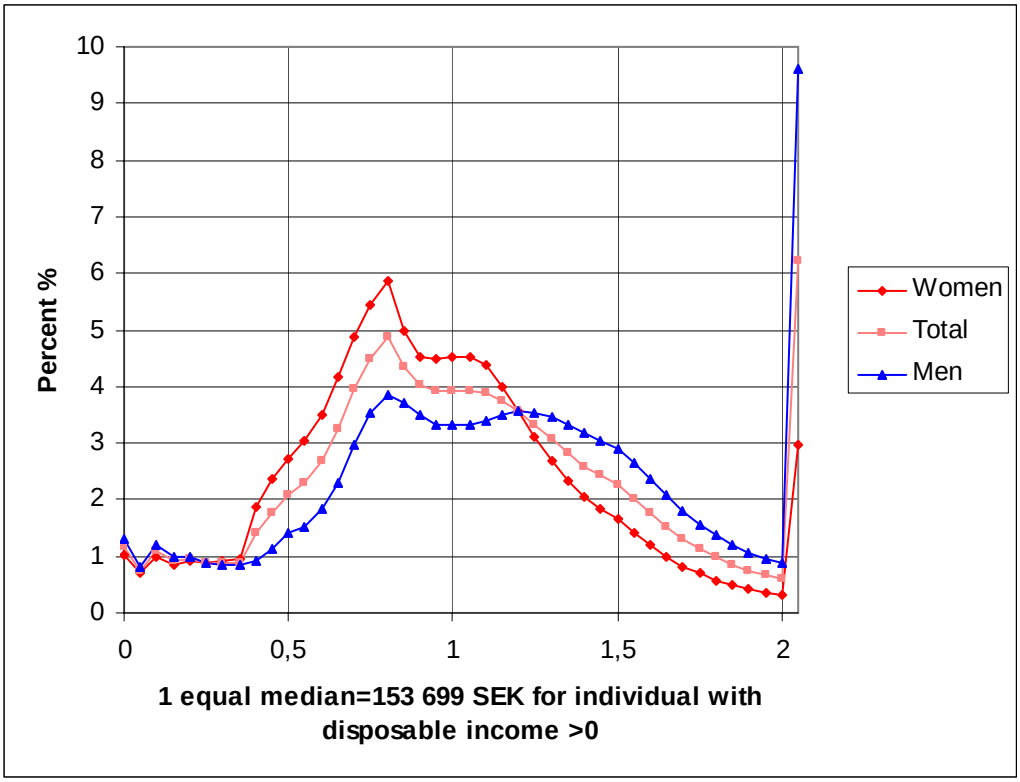


Diagram 3.1 Disposable income distributions per sex and in total.

The diagram shows that men are much less frequent than women for disposable incomes of under around 190 000 kronor and clearly more frequent than women for disposable incomes over this threshold. Diagram 3.2 shows that many of the oldest (68–97) and youngest (18–27) have disposable incomes below the median. Considerably more have incomes above the median in the age group 28–57.

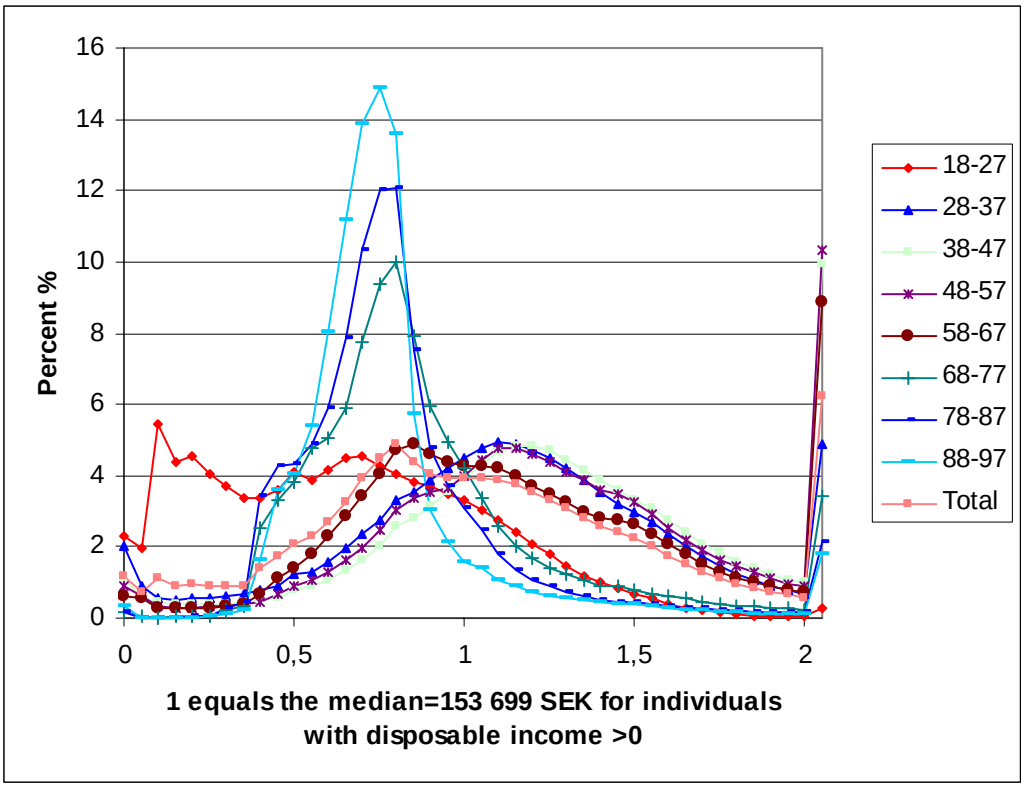


Diagram 3.2 Distribution of disposable income by age class and in total.

Diagram 3.2 shows that many of the oldest (68–97) and youngest (18–27) have disposable incomes below the median. Considerably more individuals have incomes above the median in the age group 28–57.

3.4 Distribution of disposable income by region and by type of area in 2005

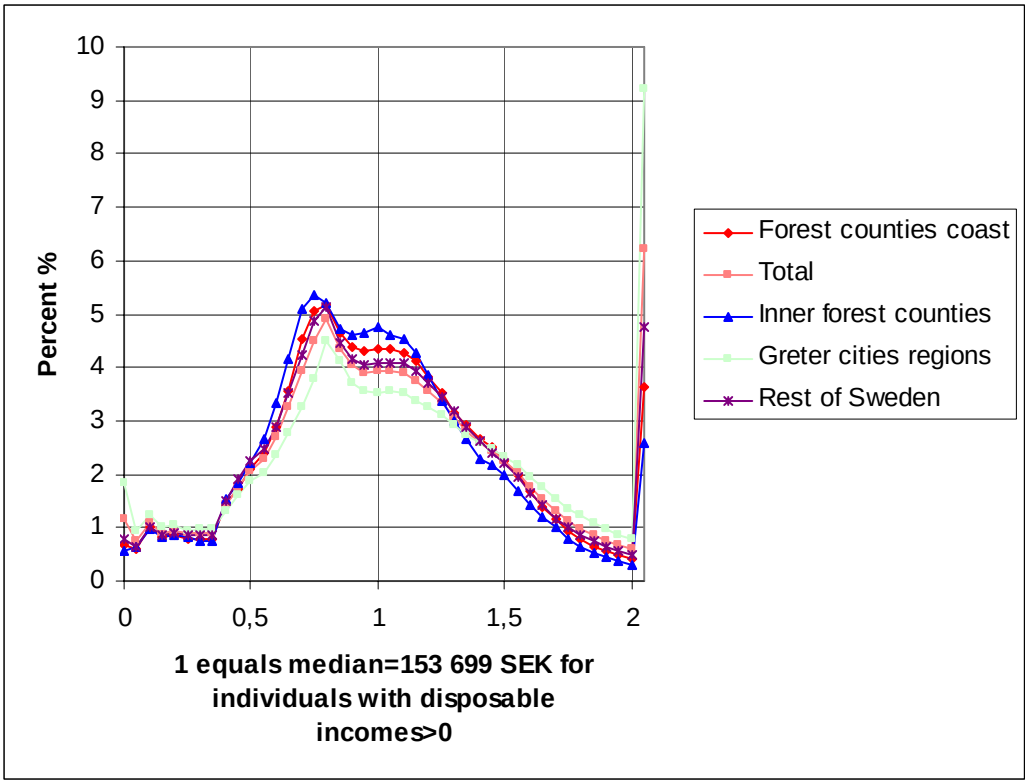


Diagram 3.3 Disposable income distribution according to National Rural Development Agency region and in total.

Diagram 3.3 shows that income distribution does not differ so greatly between regions. However, it is evident that there is a slightly greater number with high disposable income in the metropolitan regions.

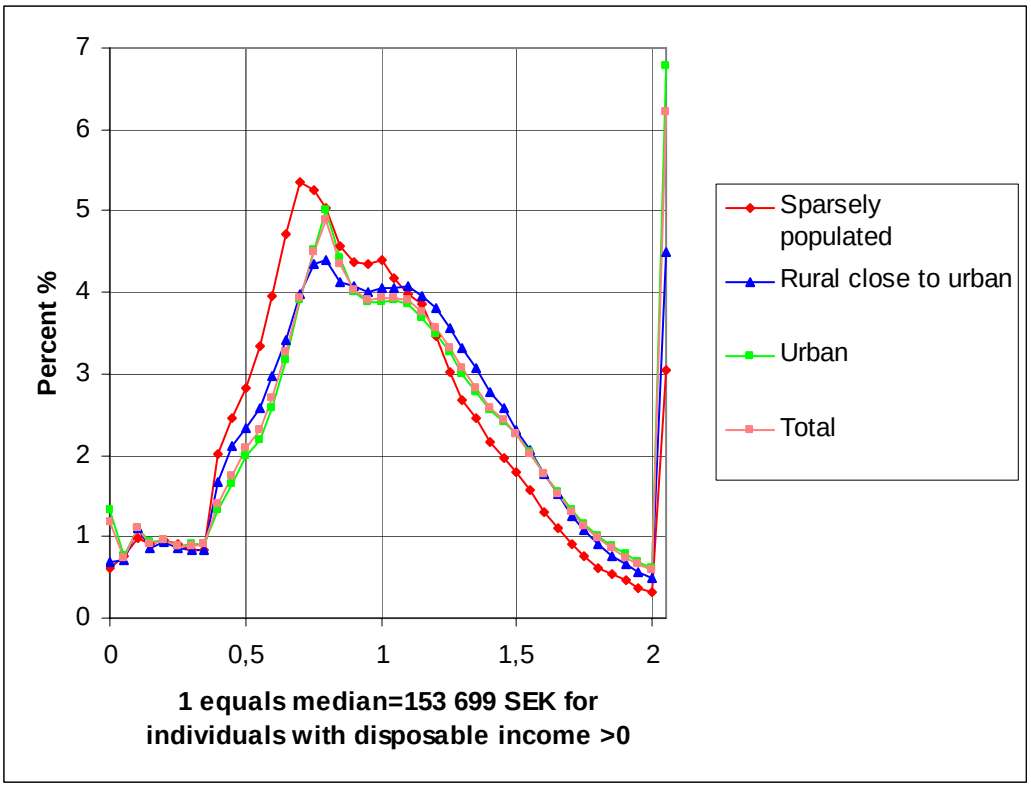


Diagram 3.4 Disposable income distribution by type of area and in total.

Although the disposable income distribution does not differ greatly between area types, it can be seen that there is a greater number in sparsely populated areas with an income below the median while the differences between urban areas and rural areas close to urban areas are less.

3.5 Persons in the lowest disposable income quartile in the Inner parts of the Forest Counties

In this section, the National Rural Development Agency's regional criterion shown in Appendix 1 is used. Table 3.1 shows that the population of the Inner parts of the Forest Counties region was almost 276 000, of which around 78 000 were in the lowest income quartile.

Table 3.1 Number of individuals per disposable income quartile and National Rural Development Agency region 2005.

	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Total
The Inner parts of the forest counties	**78 332**	77 366	73 276	46 995	275 969
Coastal parts of forest counties	293 501	300 351	296 482	232 060	1 122 394
Metropolitan regions	694 500	616 412	625 281	823 045	2 759 238
Rest of Sweden	791 214	757 710	756 845	649 774	2 955 543
	1 857 547	1 751 839	1 751 884	1 751 874	7 113 144

If we examine the group with the lowest disposable income in the Inner parts of the Forest Counties more closely, we obtain Table 3.2. In this table we have aggregated the two rural area types into one single category.

Table 3.2 Number of individuals in rural and urban areas respectively in the Inner parts of the Forest Counties.

County	Rural	Urban	Total	County share	Proportion urban
Värmland	2 325	1 134	3 459	4,4	32,8
Dalarna	4 375	8 100	12 475	15,9	64,9
Gävleborg	2 226	2 235	4 461	5,7	50,1
Västernorrland	2 336	2 686	5 022	6,4	53,5
Jämtland	12 008	16 062	28 070	35,8	57,2
Västerbotten	4 714	4 908	9 622	12,3	51,0
Norrbotten	5 339	9 884	15 223	19,4	64,9
The Inner parts of the forest counties - Total	33 323	45 009	78 332	100,0	57,5

Accordingly, more than half of the inhabitants live in urban areas according to the National Rural Development Agency's definition. Approximately 33 000 people remain outside the urban areas.

3.6 Distance to place of work in 2005

As can be seen from the map in Appendix 2 there are urban areas spread over the whole of Sweden. Therefore there are urban areas in all counties. In this section we present differences in distance to workplace for both counties and the area types to provide a possibility to compare counties and area types.

In the following two tables, a comparison is made between the distance between the home and the place of work, defined "as the crow flies" for those individuals who are employed and for whom data is available for every individual and for individuals in the lowest disposable income quartile. When we analyse the distance to the place of work, we assume that commuting to work hardly takes place over distances exceeding 300 km. We have therefore not made a detailed breakdown above this distance.

Table 3.3 Distribution of distance to place of work for all inhabitants in different counties in 2005 percent per kilometre intervals.

County	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	≥ 300	Total
Stockholm	7,1	5,8	15,8	12,0	22,0	31,0	3,3	1,3	0,2	0,3	0,3	1,0	100
Uppsala	6.6	7.8	20.0	9.8	9.8	21.9	10.4	11.3	0.7	0.3	0.4	1.0	100
Söderman-land	7,2	11,9	22,7	9,0	12,2	18,2	7,3	9,0	1,2	0,2	0,4	0,8	100
Östergötland	6.1	10.7	24.0	13.2	12.3	20.4	7.3	1.7	1.3	1.6	0.8	0.5	100
Jönköping	6.5	13.1	24.6	9.0	15.6	21.8	4.4	2.1	0.9	0.4	1.2	0.3	100
Kronoberg	7.0	12.7	25.2	11.1	9.4	23.2	5.3	2.7	0.8	1.0	0.3	1.3	100
Kalmar	8.7	13.5	23.8	8.4	12.5	21.7	4.7	2.7	0.8	0.6	1.6	1.0	100
Gotland	11.6	12.3	22.4	7.8	10.1	21.8	6.8	1.4	0.1	2.5	2.0	1.2	100
Blekinge	6.9	11.6	18.3	11.4	19.3	23.4	3.5	2.4	0.8	0.6	0.6	1.4	100
Skåne	7.7	8.6	19.9	10.4	14.3	26.7	5.5	3.5	0.4	0.3	0.6	2.0	100
Halland	8.2	8.8	18.3	9.5	14.0	26.8	7.1	3.6	1.4	0.4	0.4	1.6	100
Västra Götaland	6,9	8,7	19,1	11,2	18,9	24,1	5,2	2,8	0,7	0,3	0,7	1,4	100
Värmland	7.2	11.8	22.7	10.1	14.3	21.8	5.0	3.1	0.6	0.6	2.0	0.6	100
Örebro	6.4	11.4	24.7	12.8	12.0	22.0	4.9	1.8	0.7	2.1	0.8	0.5	100
Västmanland	6.4	10.7	27.0	12.4	12.5	17.1	5.6	5.4	1.6	0.2	0.2	0.8	100
Dalarna	7.8	11.5	23.4	11.0	13.0	21.1	4.7	2.5	1.1	1.5	1.3	1.0	100
Gävleborg	7.2	12.1	24.7	10.8	12.9	19.9	4.8	2.7	1.1	1.3	1.4	1.0	100
Västernorr-land	6,9	11,2	22,9	11,9	15,6	20,5	4,6	2,0	0,5	0,4	0,5	2,9	100
Jämtland	10.2	14.3	20.5	10.6	10.9	19.2	5.2	3.4	1.1	0.7	0.5	3.4	100
Västerbotten	7.0	13.1	22.7	11.9	11.1	21.4	4.5	2.4	1.5	0.5	0.9	3.1	100
Norrbotten	7.7	13.7	24.2	12.4	11.2	16.1	6.8	2.9	0.9	0.7	0.7	2.8	100
Total	7,2	9,4	20,3	11,1	16,1	24,6	5,1	3,0	0,7	0,5	0,7	1,3	100

We can note initially that those who live in the counties of Gotland and Värmland have the greatest proportion (2.0 percent) with between 200 and 300 km to work. These counties are followed by the county of Kalmar at 1.6, Gävleborg at 1.4, and Jönköping at 1.2. The lowest proportions are for the counties of Västmanland, Kronoberg and Stockholm at 0.2, 0.3 and 0.3 percent respectively.

Table 3.4 .Accumulated distribution of distance to place of work for all inhabitants in different counties in 2005 percent per kilometre intervals.

County	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	≥ 300
Stockholm	7,1	13,0	28,7	40,7	62,7	93,7	97,0	98,2	98,4	98,7	99,0	100.0
Uppsala	6,6	14,5	34,4	44,2	54,0	75,9	86,3	97,7	98,3	98,6	99,0	100.0
Söderman-land	7,2	19,1	41,8	50,7	63,0	81,2	88,4	97,4	98,6	98,8	99,2	100.0
Östergötland	6,1	16,8	40,9	54,1	66,4	86,7	94,1	95,8	97,1	98,7	99,5	100.0
Jönköping	6,5	19,6	44,1	53,2	68,8	90,6	95,0	97,1	98,0	98,5	99,7	100.0
Kronoberg	7,0	19,7	44,9	56,0	65,4	88,6	93,9	96,6	97,4	98,4	98,7	100.0
Kalmar	8,7	22,2	45,9	54,3	66,9	88,6	93,3	96,0	96,9	97,4	99,0	100.0
Gotland	11,6	23,9	46,3	54,1	64,2	85,9	92,8	94,2	94,3	96,8	98,8	100.0
Blekinge	6,9	18,5	36,7	48,1	67,4	90,7	94,2	96,6	97,4	98,0	98,6	100.0
Skåne	7,7	16,3	36,3	46,7	61,0	87,6	93,2	96,7	97,1	97,4	98,0	100.0
Halland	8,2	17,0	35,3	44,8	58,8	85,6	92,7	96,3	97,7	98,1	98,4	100.0
Västra Götaland	6,9	15,7	34,7	46,0	64,8	88,9	94,1	96,9	97,6	97,9	98,6	100.0
Värmland	7,2	19,0	41,7	51,8	66,1	88,0	93,0	96,1	96,7	97,4	99,4	100.0
Örebro	6,4	17,7	42,4	55,2	67,2	89,1	94,0	95,8	96,6	98,7	99,5	100.0
Västmanland	6,4	17,1	44,1	56,5	69,0	86,1	91,8	97,2	98,8	99,0	99,2	100.0
Dalarna	7,8	19,4	42,7	53,7	66,7	87,8	92,6	95,1	96,2	97,8	99,0	100.0
Gävleborg	7,2	19,4	44,0	54,9	67,8	87,7	92,5	95,2	96,3	97,6	99,0	100.0
Västernorr-land	6,9	18,1	41,0	52,8	68,5	89,0	93,6	95,7	96,2	96,6	97,1	100.0
Jämtland	10,2	24,5	45,1	55,7	66,6	85,8	91,0	94,4	95,5	96,2	96,6	100.0
Västerbotten	7,0	20,1	42,8	54,7	65,7	87,1	91,6	94,0	95,5	96,0	96,9	100.0
Norrbotten	7,7	21,4	45,6	58,0	69,1	85,2	92,0	94,9	95,8	96,5	97,2	100.0
Total	7,2	16,6	36,9	48,0	64,2	88,7	93,8	96,8	97,5	98,0	98,7	100.0

We analyse an accumulated distribution to be able to analyse how many have a shorter distance to work than 3 kilometres (i.e. walking distance) and shorter than 5 kilometres (i.e. cycling distance). The counties with the largest proportion with short distances are Gotland 46.3, Kronoberg 45.9 and Norrbotten 45.6. The counties with the lowest proportion of short distances are Stockholm 28.7 Uppsala 34.4 and Västra Götaland 34.7 percent. If we make a new calculation of the ranking for distances less than 5 kilometres then the counties of Norrbotten 58, Västmanland 56.5 and Kronoberg 56 have the highest shares and the counties of Stockholm 40.7, Uppsala 44.2 and Halland the lowest.

Let us now make a comparison with the distance of those on low incomes to their place of work.

Table 3.5 Distribution of distance to place of work for inhabitants with disposable incomes in the lowest disposable income quartiles in different counties per kilometre intervals.

	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	≥ 300	Total
Stockholm	20,3	6,6	14,3	10,4	18,3	24,1	2,6	1,1	0,2	0,3	0,4	1,3	100
Uppsala	18,1	9,4	19,6	9,2	9,9	16,7	5,8	7,4	0,7	0,4	0,8	1,8	100
Södermanland	23,8	11,8	19,9	7,2	10,4	13,5	4,1	6,0	1,4	0,2	0,7	1,1	100
Östergötland	19,6	10,9	20,6	11,2	9,5	14,5	5,5	1,7	1,8	2,3	1,7	0,9	100
Jönköping	17,5	13,0	20,5	8,1	13,8	17,2	3,3	2,0	1,4	0,8	1,7	0,6	100
Kronoberg	19,1	12,8	20,2	8,9	8,1	17,9	4,1	3,1	1,6	1,7	0,5	2,1	100
Kalmar	26,3	11,8	18,3	6,3	10,0	14,5	3,4	2,6	1,0	0,9	3,2	1,7	100
Gotland	33,3	9,9	14,6	5,1	8,2	14,1	5,0	1,2	0,3	3,9	2,6	1,8	100
Blekinge	22,7	12,7	15,7	8,7	13,8	15,5	2,3	2,7	1,3	1,1	1,0	2,5	100
Skåne	24,2	9,6	18,1	9,2	11,3	17,4	3,4	2,8	0,4	0,5	0,8	2,4	100
Halland	22,5	9,8	16,8	8,7	11,8	19,5	3,6	2,9	1,8	0,5	0,4	1,8	100
Västra Götaland	20,1	8,9	17,0	10,0	16,1	17,8	3,4	2,5	1,0	0,4	0,9	1,9	100
Värmland	23,0	12,0	18,1	7,6	10,4	16,0	3,8	3,1	1,0	1,0	2,9	1,1	100
Örebro	20,1	11,4	21,0	10,9	9,4	15,4	4,0	1,9	1,2	2,5	1,5	0,8	100
Västmanland	20,5	10,7	22,5	11,2	10,2	12,3	4,6	4,3	1,9	0,3	0,4	1,1	100
Dalarna	23,3	11,1	17,4	8,7	11,5	15,0	3,3	2,5	1,5	2,1	1,8	1,8	100
Gävleborg	26,0	10,9	18,4	8,2	9,7	14,9	3,1	2,4	1,1	1,9	1,8	1,6	100
Västernorrland	22,7	10,8	18,4	9,3	12,1	14,4	3,5	2,6	0,7	0,5	0,9	4,1	100
Jämtland	27,5	12,7	15,4	7,8	8,6	13,1	3,6	3,5	1,3	0,8	0,8	5,0	100
Västerbotten	18,2	12,6	19,6	11,2	8,8	14,3	3,2	2,6	2,1	0,8	1,4	5,1	100
Norrbotten	24,1	12,1	18,8	10,2	9,0	10,5	4,8	2,5	1,1	0,9	0,8	5,3	100
Total	21,5	9,6	17,4	9,5	13,3	18,0	3,5	2,5	0,9	0,8	1,0	1,9	100

The County of Kalmar has the largest proportion of those in the lowest disposable income quartile with the longest distance to the place of work. 3.2 percent of the inhabitants of this county have between 200 and 300 km to their place of work. The next highest proportions are in the county of Värmland at 2.9 percent and the county of Gotland at 2.6 percent. The corresponding shares in the countries with the lowest shares are the counties of Stockholm and Västmanland at only 0.4 percent.

Table 3.6 Accumulated distribution of distances to place of work for inhabitants with disposable incomes in the lowest quartile in different counties in 2005, kilometre intervals.

County	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	300-500	500-1000	≥ 1000 km
Stockholm	20,3	26,9	41,3	51,7	70,0	94,1	96,7	97,8	98,0	98,3	98,7	99,7	100,0	100,0
Uppsala	18,1	27,5	47,1	56,4	66,2	82,9	88,8	96,2	96,9	97,3	98,2	99,6	100,0	100,0
Södermanland	23,8	35,6	55,5	62,6	73,0	86,5	90,5	96,6	98,0	98,2	98,9	99,9	100,0	100,0
Östergötland	19,6	30,5	51,1	62,2	71,8	86,2	91,7	93,4	95,1	97,4	99,1	99,8	100,0	100,0
Jönköping	17,5	30,5	51,0	59,1	72,9	90,1	93,4	95,5	96,9	97,7	99,4	99,8	100,0	100,0
Kronoberg	19,1	31,8	52,1	60,9	69,0	86,9	91,0	94,1	95,7	97,4	97,9	99,8	100,0	100,0
Kalmar	26,3	38,1	56,5	62,7	72,7	87,2	90,6	93,2	94,2	95,1	98,3	99,7	100,0	100,0
Gotland	33,3	43,2	57,8	62,8	71,1	85,2	90,2	91,4	91,7	95,6	98,2	99,7	100,0	100,0
Blekinge	22,7	35,3	51,0	59,7	73,5	88,9	91,3	94,0	95,4	96,4	97,5	99,7	100,0	100,0
Skåne	24,2	33,8	51,9	61,1	72,3	89,7	93,1	96,0	96,3	96,8	97,6	98,9	100,0	100,0
Halland	22,5	32,4	49,1	57,9	69,7	89,1	92,7	95,6	97,4	97,8	98,2	99,9	100,0	100,0
Västra Götaland	20,1	28,9	45,9	56,0	72,0	89,9	93,3	95,8	96,7	97,1	98,1	99,7	100,0	100,0
Värmland	23,0	35,0	53,1	60,6	71,1	87,0	90,8	93,9	94,9	96,0	98,9	99,9	100,0	100,0
Örebro	20,1	31,4	52,4	63,3	72,8	88,1	92,1	94,0	95,1	97,7	99,2	99,8	100,0	100,0
Västmanland	20,5	31,2	53,6	64,8	75,0	87,3	91,9	96,2	98,2	98,4	98,9	99,9	100,0	100,0
Dalarna	23,3	34,4	51,8	60,6	72,0	87,0	90,4	92,8	94,3	96,4	98,2	99,6	100,0	100,0
Gävleborg	26,0	36,8	55,3	63,5	73,1	88,0	91,1	93,5	94,6	96,6	98,4	99,4	100,0	100,0
Västernorrland	22,7	33,5	51,9	61,2	73,2	87,6	91,0	93,7	94,4	94,9	95,9	98,8	100,0	100,0
Jämtland	27,5	40,2	55,7	63,4	72,0	85,1	88,7	92,2	93,5	94,2	95,0	98,0	100,0	100,0
Västerbotten	18,2	30,9	50,4	61,6	70,4	84,7	87,9	90,5	92,7	93,5	94,9	96,1	99,9	100,0
Norrbotten	24,1	36,2	55,0	65,1	74,1	84,6	89,4	92,0	93,0	93,9	94,7	95,2	98,9	100,0
Sweden	21,5	31,1	48,6	58,1	71,5	89,5	92,9	95,5	96,3	97,1	98,1	99,4	100,0	100,0

We again use the accumulated distribution to study short distances. The counties where the largest proportion in the lowest disposable income quartile have the short distances to work (less than 3 kilometres) are the inhabitants of the county of Gotland 57.8 percent followed by the county of Kalmar at 56.5 and Jämtland at 55.7 percent. Those with the lowest proportion of really short distances to work are the county of Stockholm at 41.3 percent and Västra Götaland at 45.9 percent.

The largest share with “Cycling distance” 0–5 km are in the county of Norrbotten at 65.1 percent, followed by Västmanland at 64.8 percent and Örebro at 63.3 percent. Those who have the smallest proportion with cycling distance are the inhabitants of the county of Stockholm at 51.7 percent and Västra Götaland at 56 percent.

We will now describe the distance to place of work in the lowest disposable income quartile by sex.

Table 3.7 Distribution of distance to place of work for inhabitants with disposable incomes in the lowest disposable income quartile in different.

Employed in lowest income quartile

Sex	Data lacking	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	300-500	500-1000	≥ 1000 km	Total
Man	24 362	40 840	11 377	22 312	12 918	17 751	24 965	5 363	4 059	1 415	1 190	1 589	1 995	888	67	171 091
Woman	34 098	29 987	20 162	35 076	18 498	26 150	34 275	6 103	4 219	1 489	1 291	1 687	2 244	990	70	216 339
Total	58 460	70 827	31 539	57 388	31 416	43 901	59 240	11466	8 278	2 904	2 481	3 276	4 239	1 878	137	387 430

Km distance, distribution

Sex	Data lacking	0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	300-500	500-1000	≥ 1000 km	Total
Man	14,2	23,9	6,6	13,0	7,6	10,4	14,6	3,1	2,4	0,8	0,7	0,9	1,2	0,5	0,0	100
Woman	15,8	13,9	9,3	16,2	8,6	12,1	15,8	2,8	2,0	0,7	0,6	0,8	1,0	0,5	0,0	100
Total	15,1	18,3	8,1	14,8	8,1	11,3	15,3	3,0	2,1	0,7	0,6	0,8	1,1	0,5	0,0	100

Km-distance, distribution, excluding missing

Sex		0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	300-500	500-1000	≥ 1000 km	Total
Man		27,8	7,8	15,2	8,8	12,1	17,0	3,7	2,8	1,0	0,8	1,1	1,4	0,6	0,0	100
Woman		16,5	11,1	19,2	10,2	14,3	18,8	3,3	2,3	0,8	0,7	0,9	1,2	0,5	0,0	100
Total		21,5	9,6	17,4	9,5	13,3	18,0	3,5	2,5	0,9	0,8	1,0	1,3	0,6	0,0	100

Accumulated distribution, excluding missing

Sex		0	0-1	1-3	3-5	5-10	10-30	30-50	50-100	100-150	150-200	200-300	300-500	500-1000	≥ 1000 km
Man		27,8	35,6	50,8	59,6	71,7	88,7	92,4	95,1	96,1	96,9	98,0	99,3	100,0	100,0
Woman		16,5	27,5	46,8	56,9	71,3	90,1	93,4	95,7	96,6	97,3	98,2	99,4	100,0	100,0
Total		21,5	31,1	48,6	58,1	71,5	89,5	92,9	95,5	96,3	97,1	98,1	99,4	100,0	100,0

We can note that men with low disposable incomes work at home to a greater extent while women with low incomes have a shorter distance to work than men.

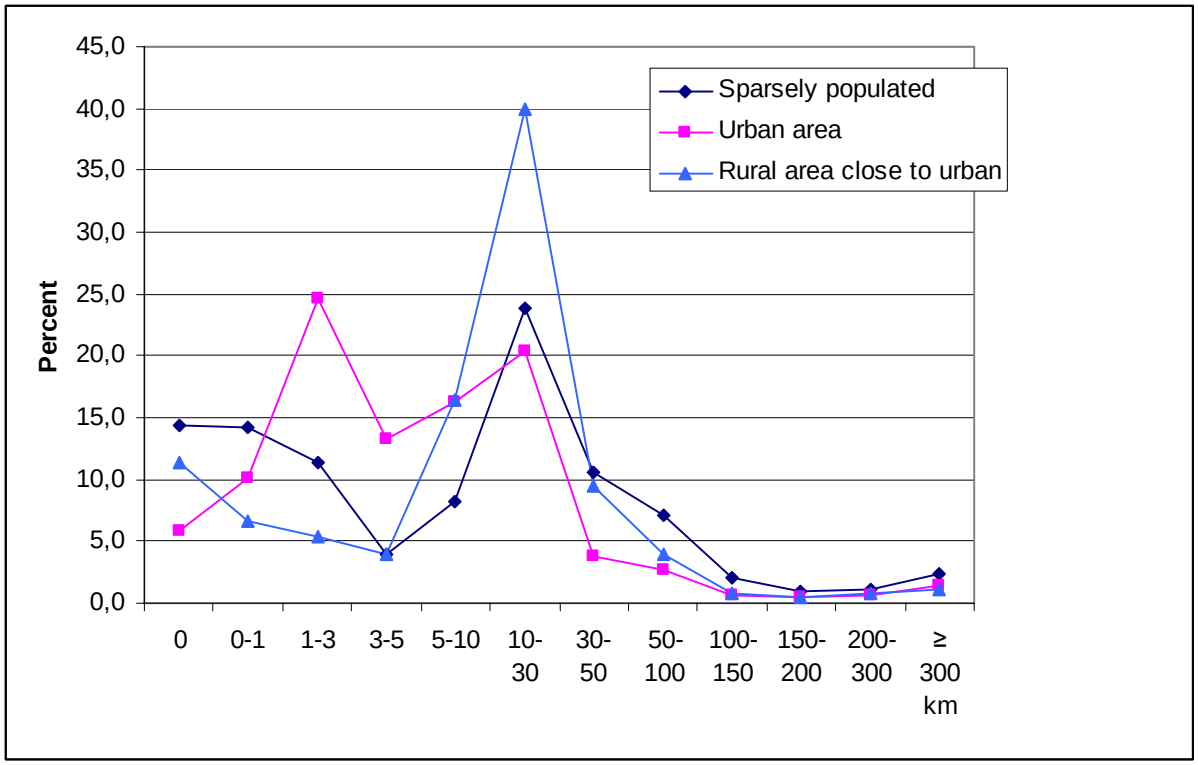


Diagram 3.5 Distribution of distance to place of work in different area types.

Diagram 3.5 demonstrates that the population in rural areas close to urban areas considerably more often have a distance to work between 10 and 30 km than do those in sparsely populated areas, 40 percent compared with 24 percent. It is more common that inhabitants of sparsely populated areas have very long distances although the difference is small.

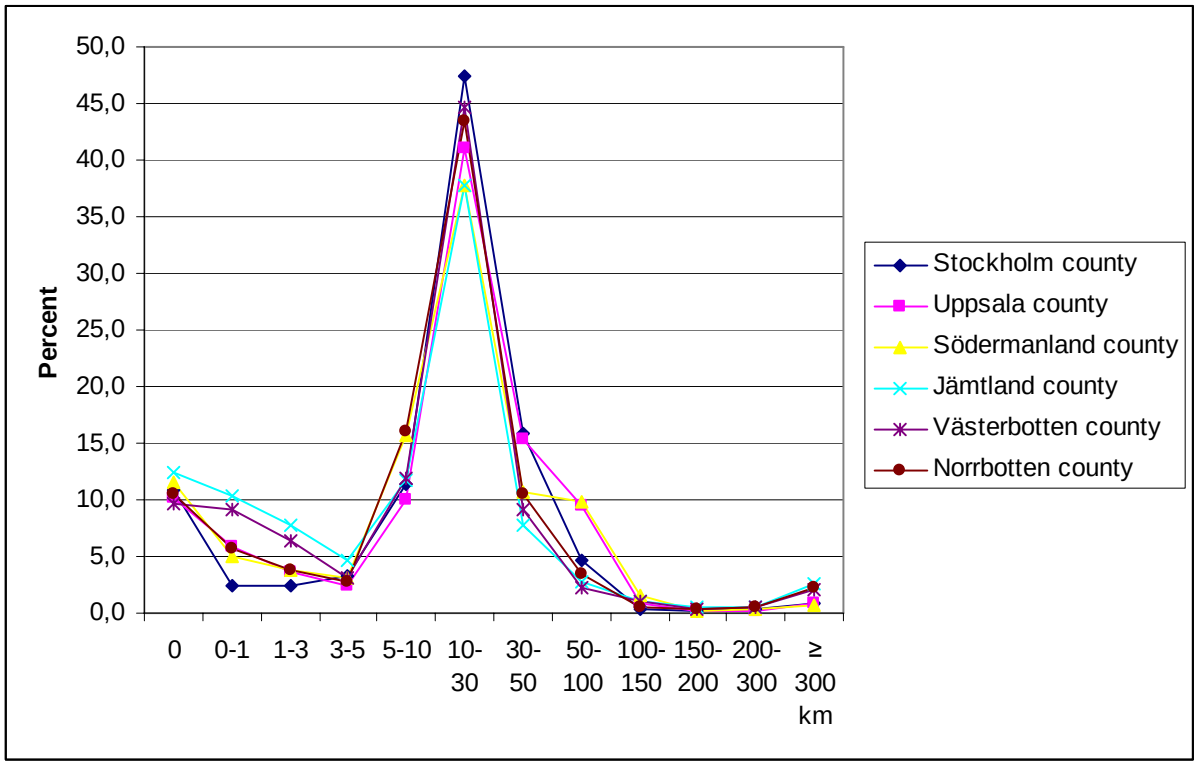


Diagram 3.6 Distribution of distance to place of work among inhabitants of rural areas close to urban areas in some different counties.

The differences between the distributions of distance to place of work seem to be small for these counties.

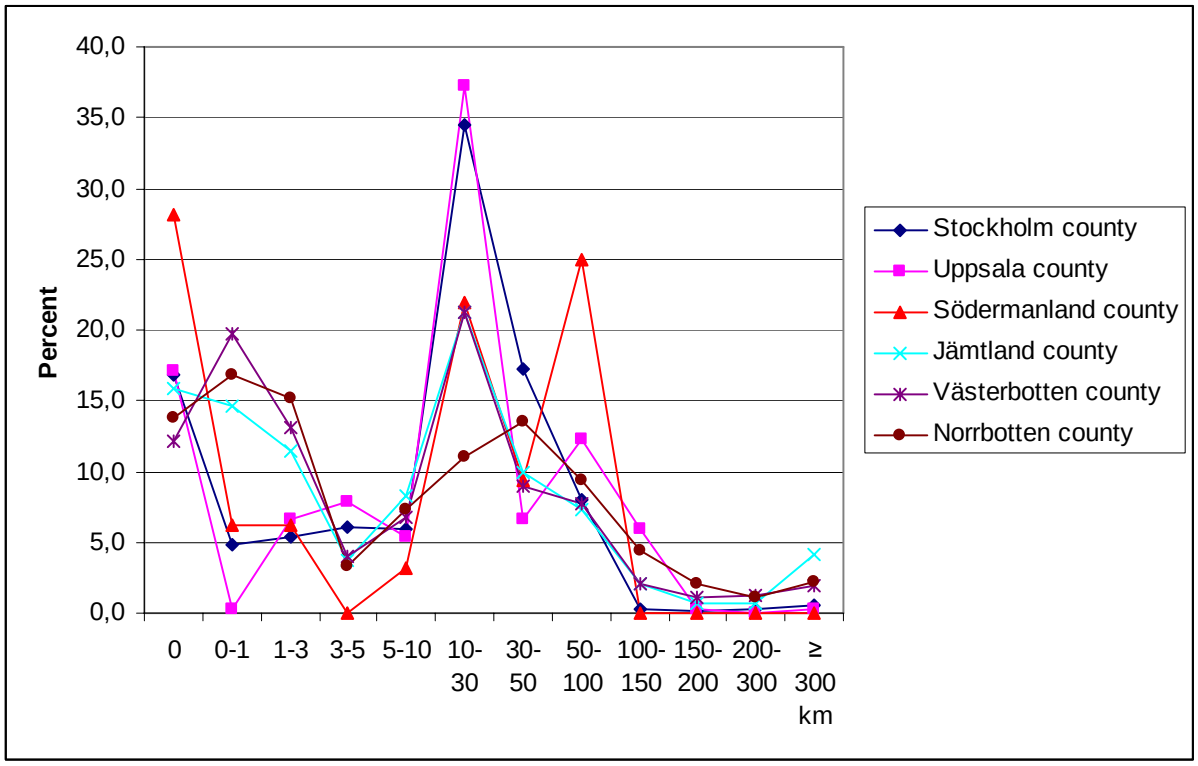


Diagram 3.7 Distribution of distance to place of work among inhabitants in sparsely populated areas in some different counties.

The distributions of distances vary between different counties considerably more for inhabitants of sparsely populated areas. In this diagram, one large difference is that inhabitants of sparsely populated areas in counties in Norrland are often closer to their work than the inhabitants of Mälardalen.

3.7 Car ownership in Sweden in 2005 by sex, disposable income quartile, area type and regions as defined by the National Rural Development Agency

In this section, we will examine more closely the distribution by income and geographic location of car ownership. Table 3.8 shows that women, regardless of disposable income, own cars to a clearly less extent than men and that individuals in the two lowest disposable income quartiles have markedly lower car ownership than in the two higher.

Table 3.8 Car ownership in 2005 in the different disposable income quartiles in percent.

	Total	Men	Women
Quartile 1	21,8	31,5	15,5
Quartile 2	41,4	58,1	29,9
Quartile 3	58,9	73,9	44,5
Quartile 4	70,1	78,1	53,0

This does not necessarily mean that women do not have access to a car. If we look at households' car ownership close to 75 percent of households have access to one or more cars. According to the Travel Survey 2005-2006 (SIKA 2007), 82 percent of men and 70 percent of women had access to a car. This means that women's access to a car is considerably more like men's than their ownership of cars. Women also have a driving licence to a great extent as shown in Vagland and Pyddoke (2006, page 22) which means that women may have access to or ability to use a car to a greater extent than they are registered as car owners.

Let us now compare the geographical distribution of car ownership. Table 9 shows that car ownership is clearly lower in than outside urban areas. However, the differences are small between rural areas close to urban areas and sparsely populated areas. To the best of our knowledge, this is the first time that this area criterion has been used to analyse car ownership.

Table 3.9 Car ownership in 2005 in the different area types in percent.

	Total	Men	Women
Urban areas	43,6	59,0	29,1
Rural areas close to urban areas	61,2	76,4	45,2
Sparsely populated areas	61,0	77,1	43,8

This pattern is repeated when we study regions as defined by the National Rural Development Agency in Table 3.10.

Table 3.10 Car ownership in 2005 in the different National Rural Development Agency regions in percent.

	Total	Men	Women
The Inner parts of the forest counties	58,4	75,1	41,6
Coastal parts of forest counties	53,6	70,9	36,6
Metropolitan regions	40,6	54,1	27,9
Rest of Sweden	50,9	67,6	34,8

The conclusion that we draw is that at this level of aggregation the great differences in car ownership depend on sex, disposable income and whether a person lives in an urban area or not. However, our data permits a considerably more detailed analysis of geographical differences.

3.8 The distribution of distances driven in 2005 in Sweden as a whole, by sex and age group

In this section, we review the use of privately-owned cars. It is important to remember that this is done by linking a vehicle to its registered owner. It is, however, important to remember that privately-owned cars are often used by others than the registered owner. However, we have no possibility of analysing this use in this survey. We will therefore only relate the distance driven to the registered owner. We will in particular focus on how long the distances driven are for the vehicles owned by individuals with disposable incomes in the lowest disposable income quartile. We can also see that relatively many of these vehicles have short distances driven. We start by looking at how car use differs depending on the type of area where the owner lives.

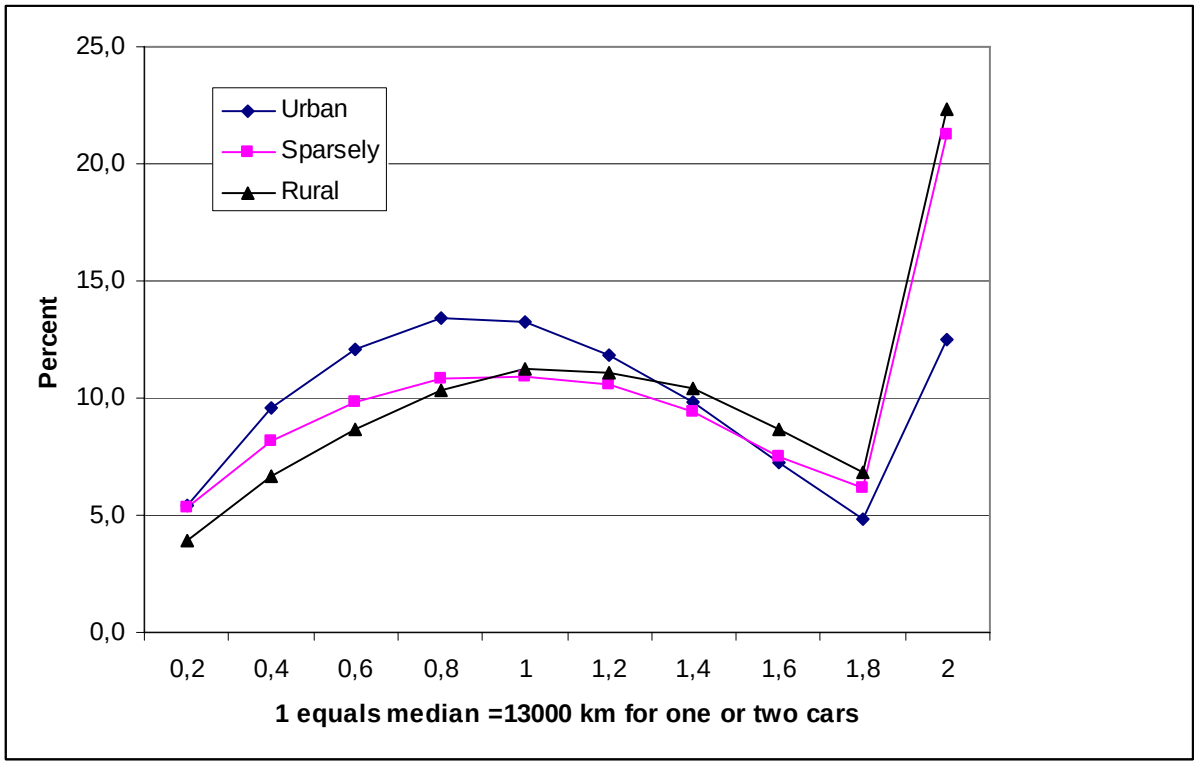


Diagram 3.8 Distribution of distance driven in 2005 according to the area where the owner lives with the median for the whole population.

In this and the following diagrams, the median for individuals' distance driven, which is 12 960 km corresponds to 1. The population consists of individuals who own a car.

We can see here that the number of inhabitants in urban areas whose car(-s) has a shorter aggregate distance driven than the median are proportionally larger than the corresponding number of individuals in rural areas, i.e. rural inhabitants' cars on average are used a bit more than urban inhabitants'. The proportion of car owners in rural areas with very long distances driven is also greater than the corresponding proportion of car owners of urban areas.

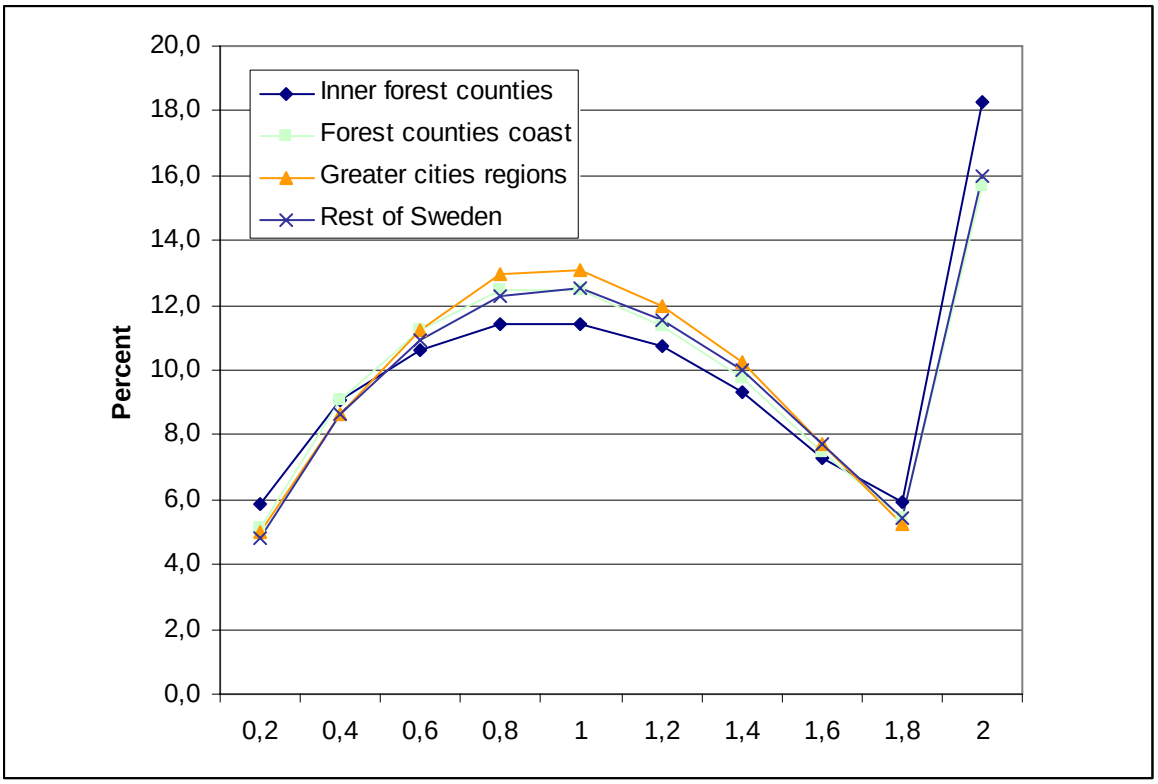


Diagram 3.9 Distribution of distance driven in 2005 according to owner's region of residence with the median for the whole population.

The differences between the distributions of distances driven are considerably less between the National Rural Development Agency regions.

We pass over now to comparing the distributions of distances driven for different disposable income groups in Diagram 3.10 below. As in the case of car ownership, use is also highly dependent on the owner's income. The differences between the two lowest disposable income quartiles are small, however. There is a considerable spread in the distance driven within the respective income group although the differences between the groups are small.

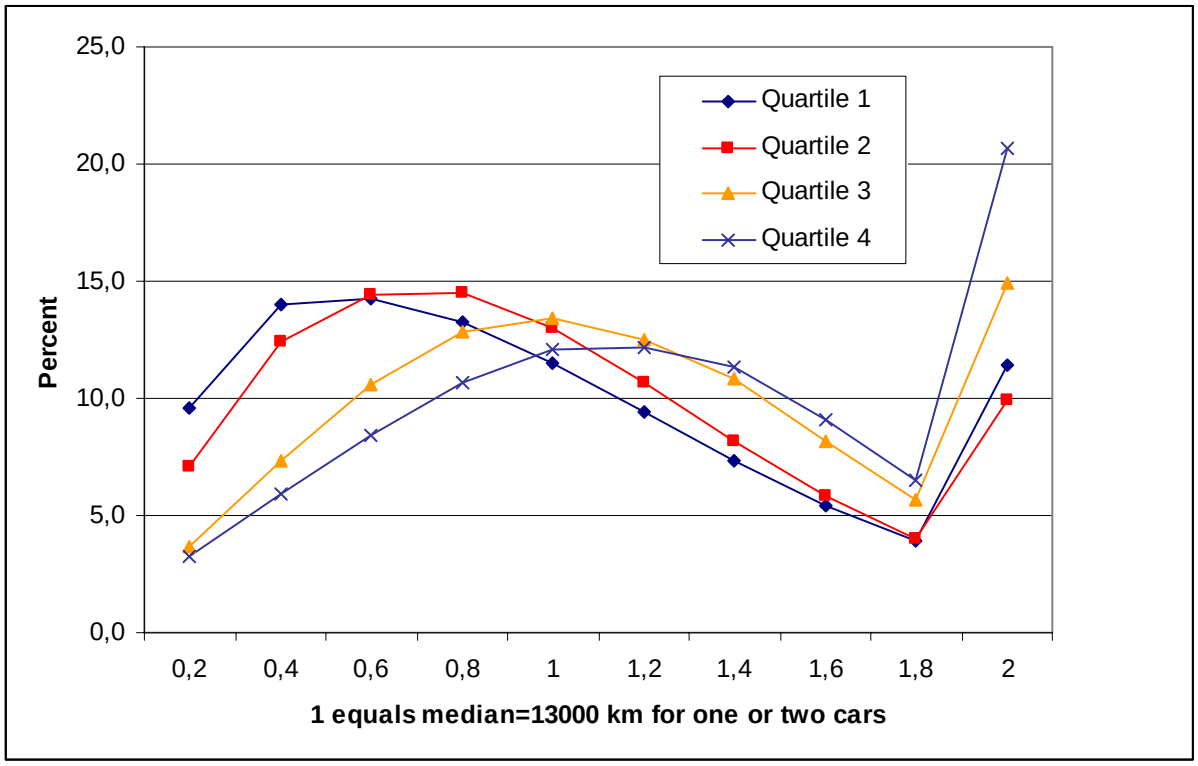


Diagram 3.10 Distribution of distance driven in 2005 according to the owner's disposable income quartiles with the median for the whole population.

We now focus on the distances driven for individuals in the lowest disposable income quartile who moreover live in the Inner parts of the Forest Counties. Diagram 3.11 shows that men in this group also use their cars considerably more than woman in the same group. We also see that those on low income use their cars clearly less than an average for the whole population.

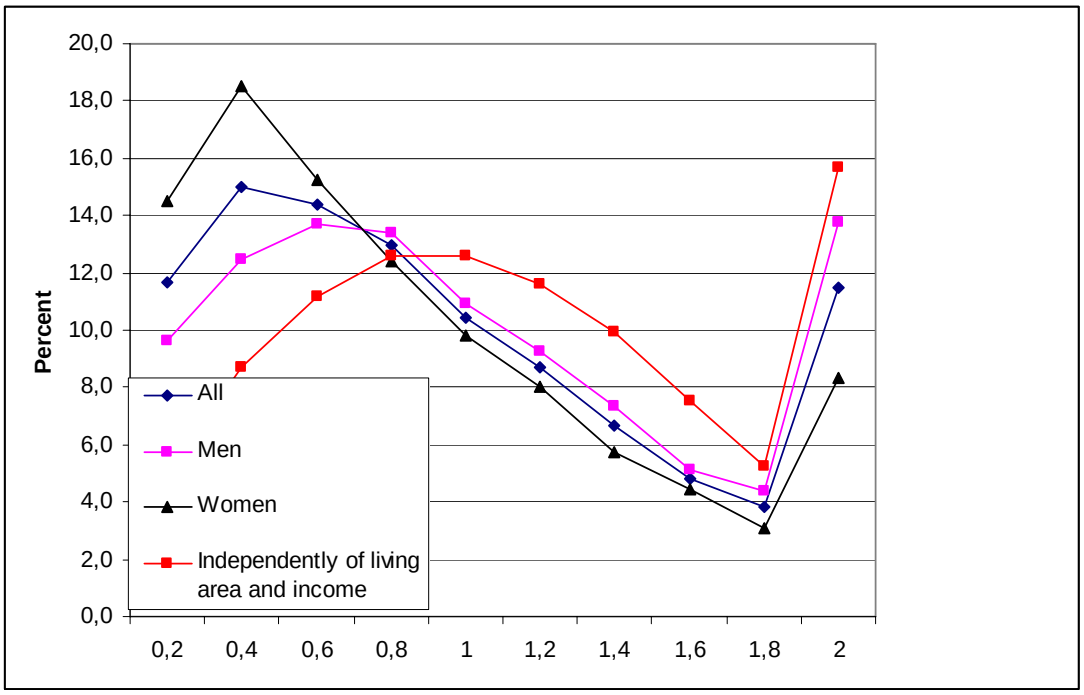


Diagram 3.11 Distribution of distance driven by sex in the lowest disposable income quartile in the Inner parts of the Forest Counties and in total.

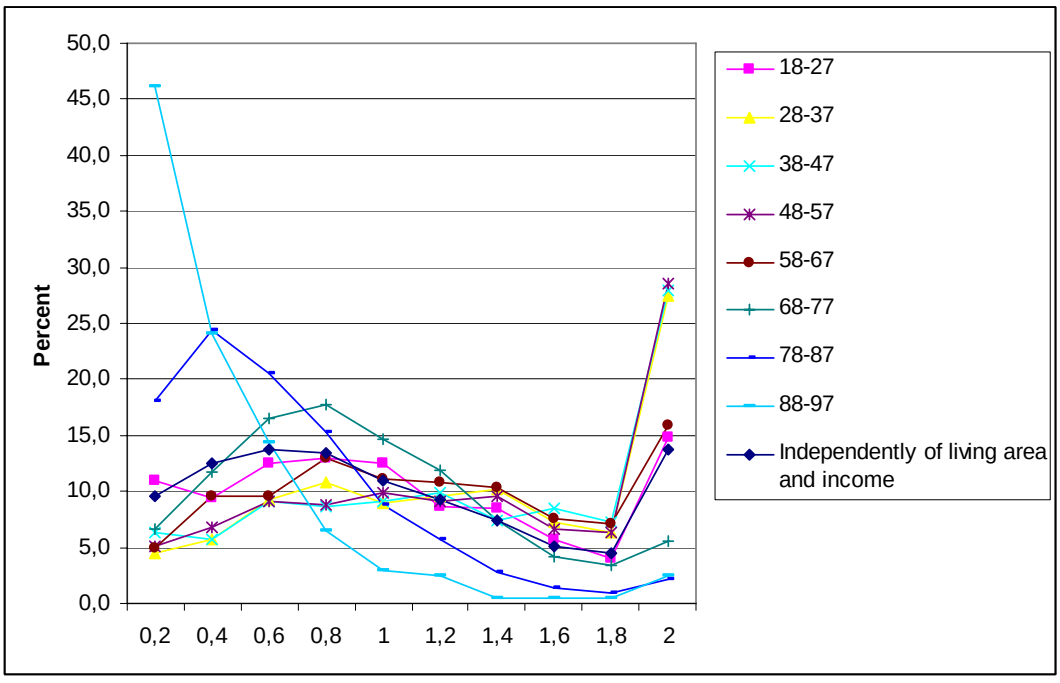


Diagram 3.12 Distribution of distance driven for vehicles owned by men in the lowest income quartile in the Inner parts of the forest counties.

We can again see that the oldest use their cars least while the youngest in this group do not deviate as much from the median.

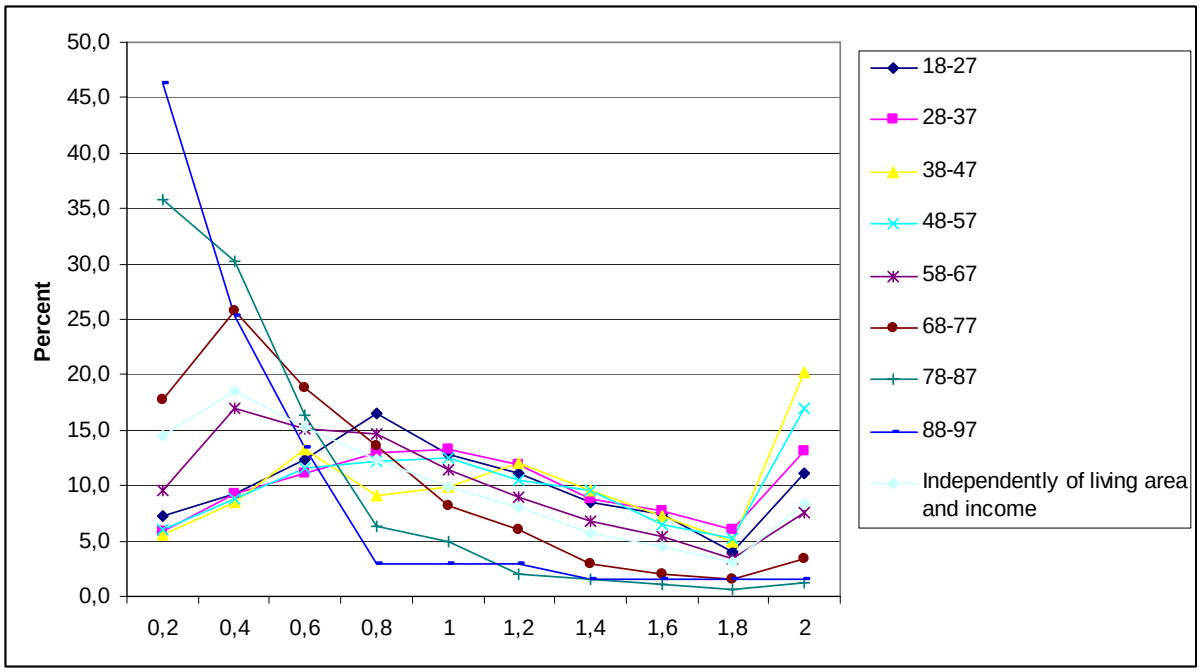


Diagram 3.13 Distribution of distance driven for vehicles owned by women in the lowest disposable income quartile in the Inner parts of the Forest Counties.

We can again see that the oldest use their cars least while the youngest of this group do not deviate so much. A comparison with Diagram 3.12 confirms that picture that women use their cars less than men.

3.9 Individuals who ceased to own a car in Sweden in 2005 (sex, disposable income quartile and type of area)

As a first step in the direction of studying the varying vulnerability of mobility, we now examine the propensity of different groups to cease owning a car. Table 3.11 shows an integrated description at a high level of aggregation. To start with, we can note that around half of all individuals over the age of 18 owned at least one car in 2005. At the end of the year, 5.4 percent of all those who were car owners in 2004 had ceased to own a car.

Table 3.11 Car ownership and the proportion ceasing to own a car in the National Rural Development Agency's area types in 2005. The proportion ceasing to own a car states how many of the car owners in 2004 who do not own a car in 2005. The whole population in 2005.

		Share of car owners per disposable income quartile				Share of car owners that cease to own a car			
Area		1	2	3	4	1	2	3	4
National		21,8	41,4	58,9	70,1	9,2	6,7	4,8	3,8
Urban		17,5	36,2	54,3	67,1	11,0	7,5	5,3	4,1
Rural close to urban		34,9	58,7	73,0	81,3	6,6	5,0	3,6	2,9
Sparsely populated rural		36,0	60,3	72,9	79,8	5,6	4,3	3,3	2,9
Urban	Men	25,2	52,7	69,9	75,7	11,0	6,2	4,2	3,6
Rural close to urban	Men	50,7	74,7	84,9	86,2	5,9	3,8	2,7	2,6
Sparsely populated rural	Men	53,6	75,4	83,9	85,3	5,1	3,3	2,6	2,5
Urban	Women	12,4	25,2	40,2	50,0	10,9	9,5	7,1	5,7
Rural lose to urban	Women	25,1	46,7	59,6	67,5	7,6	6,4	5,1	4,1
Sparsely populated rural	Women	24,0	45,8	59,2	65,3	6,5	5,7	4,6	4,3

If we consider different income layers, the proportion ceasing to own a car varies strongly. The probability of ceasing to own a car in the lowest disposable income quartile between 2004 and 2005 was more than twice as great as the probability in the highest disposable income quartile,

Let us now compare the differences between urban and rural areas. As we have seen earlier, the proportion of car owners is clearly greater in rural than in urban areas. The probability of ceasing to own a car is also around 40 percent higher in urban areas.

Comparing men and women, we have already noted that men own a car to a considerably greater extent than women. This applies to all income groups. Despite this, the probability of a woman ceasing to own a car is clearly higher than a man doing so.

If we link residence in sparsely populated rural or rural areas close to urban areas to low disposable income (the lowest quartile), we see that this admittedly small group has a clearly lower likelihood of ceasing to own a car than the corresponding urban resident. It is around 60 percent greater in urban areas. At the same time, it is clearly around 30 percent greater than in quartile 2.

3.10 References

Glesbygdsverket, 2007, Fakta.

Statistics Sweden, 2002, Tätorter 2000, Statistiska meddelanden MI 38 SM 0101.

SIKA, 2007, RES 2005–2006, Den nationella resvaneundersökningen, SIKA statistics 2007:19.

Vagland and Pyddoke, 2006, Hur hushållen anpassar sig till ändrade kostnader för bilinnehav och bilanvändning?, VTI report 545.

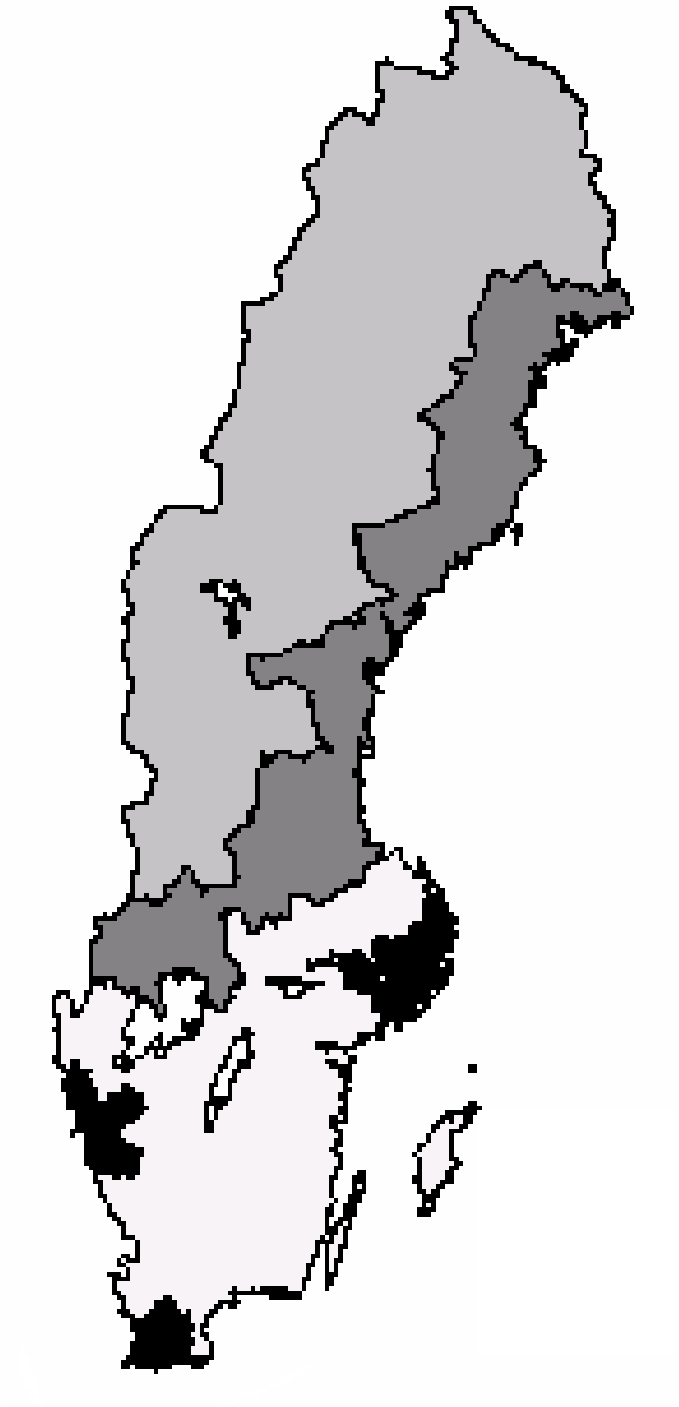
3.11 Appendix 1 National Rural Development Agency regions

Metropolitan regions – Black

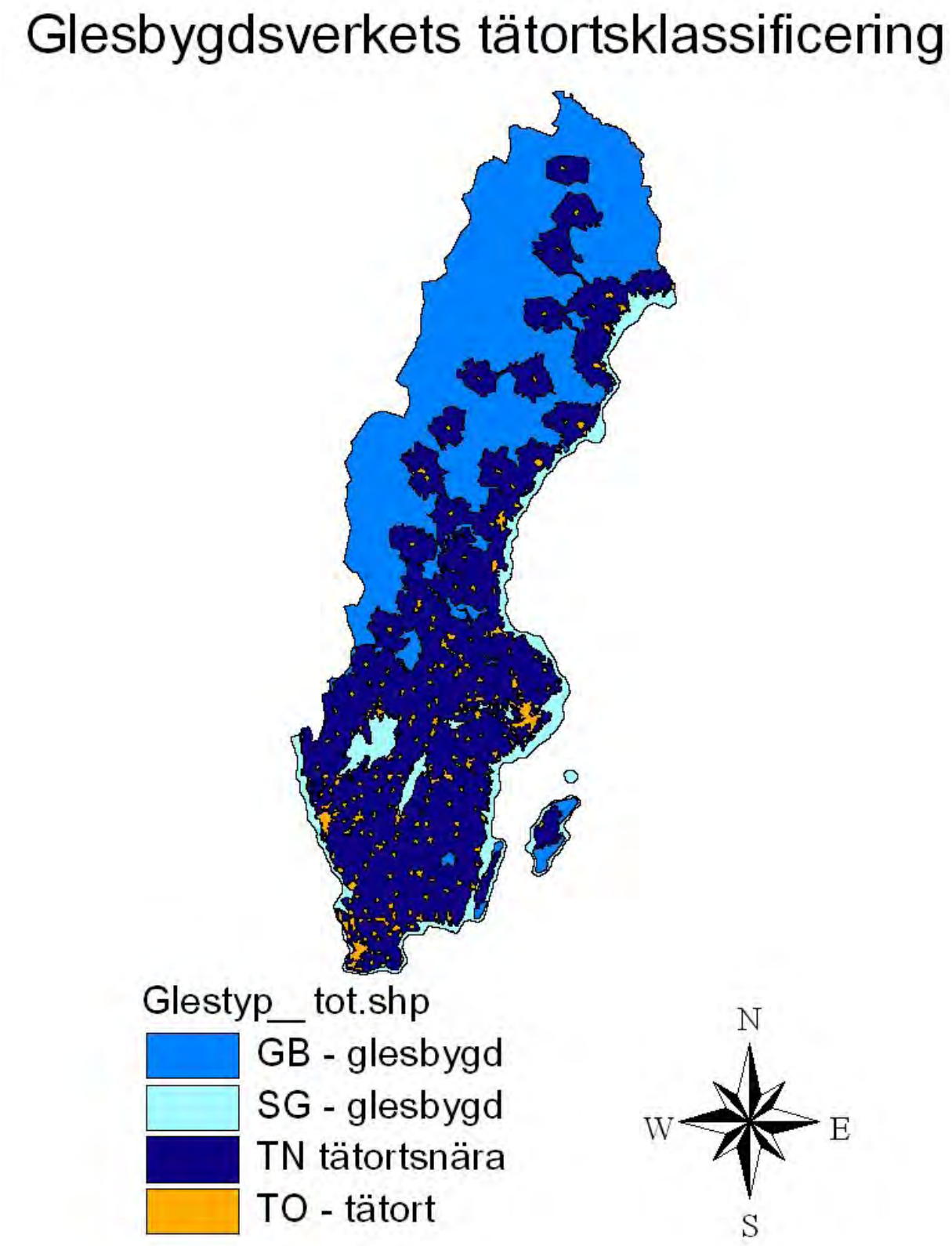
The coastal parts of parts of the Forest Counties – Grey

The Inner parts of the Forest Counties – Light grey

Others – White



Appendix 2 National Rural Development Agency's area types



Appendix 2 National Rural Development Agency’s area types

National Rural Development Agency’s classification of urban areas

Type of area

GB – Sparsely populated area

SG – Coastal/lakeside (island) rural area

TN Rural area close to urban area

TO Urban area

4 Differences in the effects of costs and income on private car use in Sweden 1999-2005*

4.1 Abstract

The objective of this paper is to analyze how the use of privately owned cars in Sweden varies across a number of background parameters, including disposable income, prices of petrol and a car purchase cost index, the number of children and the car owners' distance to work. These factors are analysed separately for men and women, individuals living in urban, rural and sparsely populated areas as well as disposable income quartiles. In particular we look at how low income car owners in rural and sparsely populated areas adapt their car use to cost and disposable income variations.

The study uses register data from the whole population in Sweden from the Swedish tax authorities for 1998–2005 as well as kilometre readings from the National Vehicle Inspection. This allows us to follow individual changes in car use over seven years as well as to contrast car use in rural and sparsely populated areas with car use in urban areas.

We find small geographical differences in the sensitivity to variations in disposable income and costs. The income elasticity of car use decreases with increasing disposable income. The lowest disposable income quartile presents an anomaly in that the income elasticity is negative. This may be a result of several possible causes, one of which is unreported income. Car use is also a bit more income elastic in rural than in urban areas. Rural inhabitants also use their cars more than urban inhabitants when they have children. On average Swedish private car use is more inert than car use in the UK with respect to changes in income and costs. The car travel elasticity with respect to petrol price is estimated to be positive, which is anomalous.

* Funding from Bisek is gratefully acknowledged. Urban Björketun VTI has handled the data, tables and diagrams and done the computational work. I am also grateful for comments received at seminars at VTI and the National Rural Development Agency. I am also grateful to Mogens Fosgerau for sources of bias, Joyce Dargay for useful suggestions, Gunnar Isacsson for sources of bias and a very thorough reading at VTI:s quality review seminar and Henrik Andersson, Gunnar Lindberg, Lena Nerhagen and Jan-Eric Nilsson for pointing to perspectives for presentation and analysis.

4.2 Introduction

An increasing interest in the distribution of car use in Sweden has prompted this study. While the original interest may have focussed on the dependence on cars of low income earners and individuals living in rural areas, the results of this paper are also helpful for understanding the distributional consequences of impending climate policies in the form of increases in fuel taxes.

The objective of this paper is to use register data to analyze the utilization of privately owned cars in Sweden with panel data methods, and in particular how low income earners in rural areas use their cars. We also examine the effects of disposable income, car purchase costs, the price of petrol, the number of children, the distance to work and car use the previous year on car use. These effects are analyzed separately for sex, area type and disposable income quartiles.

There have been some studies on car use or car travel with panel data methods in the international research literature, but none in Sweden. This is the first study to use register data from the whole population and all privately owned cars in a country. From the years 1998 to 2005 we have data for all adult individuals in Sweden. These are associated with privately owned cars. This implies for example, that we have data from approximately 3,4 million car owners owning 4,4 million cars in 2005. For each year we also have the yearly car use calculated from odometer readings from all cars that were subject to the mandatory vehicle inspection. We therefore have a panel that contains approximately 3,4 million times 8 individual observations of car use. This means we have the, by far, largest panel data set ever to have been assembled to examine car use.

Previous studies on car travel

There are broadly four categories of empirical analyses of car travel. The first category is studies analyzing the sensitivity of car travel to fuel price changes. There have been several such studies. Many of these analyse car travel and fuel demand on an aggregate level. A related topic is price elasticity of fuel demand and transport demand, which we will not comment further on here. The second category is descriptions of car use based on travel survey data. The third category is analyses of travel demand models. Such models are frequently based on cross sectional data from more than one time period. Fourthly there are panel data approaches to model individuals or households adaptation in car ownership and car travel.

Most of what we know about car use comes from the first three categories of data and modelling. This is true also for Sweden where both the national travel surveys and household expenditure data have been important sources of information. The travel surveys have also been used for travel demand modelling. Both the travel surveys and household expenditure data, however, suffer from an important drawback in that there are few observations of car use in rural and sparsely populated areas. The desire to provide a more reliable data set for rural car users has been a central motive for constructing the data set for this study.

In this perspective the availability of register data in Sweden was seen as a possibility. We also wanted to explore the expanded possibilities of analysing determinants of car ownership provided by panel data methods compared to the potential of travel survey and travel demand models. Furthermore a recently developed geographical criterion allowed us to use a sharper distinction of rural and urban inhabitants than earlier studies.

An important advantage of panel data is that this allows for the study of how individuals or households adapt to changing conditions over time as compared to cross sectional studies where inferences are drawn from the differences between individuals. With observations from several years for each individual in the panel it becomes possible to study the effects from more than one year on the current year. In this study we have limited the study of dynamics to the effect of one previous year.

We consider the following facts and relationships about car ownership and car use in Sweden to be well known through travel survey studies (Riks/RVU) and the Swedish car ownership model (Matstoms, 2002). The inhabitants in urban areas to a lesser degree own cars than inhabitants in rural areas (Matstoms, 2002 pp. 80–87). High income earners are more likely to be car owners than low income earners (Vagland and Pyddoke, 2006 p. 25). Men own cars to a larger extent than women (Matstoms, 2002 p. 50) but this difference has been decreasing.

The use of cars is also related to geography, disposable income and sex. Inhabitants in metropolitan areas tend to travel less by car on average than rural residents. Furthermore, high income earners use their cars more than low income earners (Vagland and Pyddoke, 2006 p. 33). Men drive their cars more than women (Vagland and Pyddoke, 2006 p. 20).

There is also a systematic relationship between, on the one hand, area of residence, income and sex, and on the other hand, the distance to the individual's workplace. In Sweden inhabitants of smaller and medium sized urban areas tend, on average, to have shorter distances to work than inhabitants of the metropolitan areas. Rural residents tend, on average to have the longest distances to work. There is however a larger variance in the distance to work in rural areas as many rural residents have their work at home or close to home. Longer distances to the workplace are also correlated with higher income. This is particularly so for men, and women's workplaces are generally closer to home in Sweden (Krantz, 1999).

More long term analyses with pseudo-panel or panel data in the UK have yielded some further insights into the use of cars. These studies have mainly relied on using household expenditure data. One of the most recent Dargay (2007) uses the UK Family Expenditure Survey from 1975–1995 thereby containing approximately 7200 times 20 household observations. Given the large increase in the number of privately owned cars since the 1950-ties it comes as no big surprise that later generations use cars more than earlier generations. But it has also been shown that car use increases over the lifetime, peaks around the age of 50, and declines after that (Dargay and Vythoulkas, 1999 and Dargay, 2007). This pattern follows that of household income.

Dargay also finds "some indication that the relationship between income and car travel is not symmetric" (Dargay, 2007 p. 959). The hypothesis is that car travel will adapt faster to income increases than to income decreases. She also finds that car travel is sensitive to cost variations, but only weakly so. Car travel is found to be more sensitive to car purchase cost than to fuel prices.

That car use is not so sensitive to fuel prices is not really surprising as car fuel constitutes a small fraction of household expenditure (Vagland and Pyddoke, 2006 and Gray, Farrington, Shaw, Martin and Roberts, 2001). But a very small fraction of low income earners use their cars really much. For many low income earners the sacrifices they may have to do, to be able to use their cars may therefore be substantial.

Dargay and Hanly, 2004 also look into the influence of geographic location on car use and find that population density is a strong factor determining car use in the UK. They also find that the proximity of local service, bus stops as well as frequency of services also has an impact on car use.

In Sweden there has been a long lived perception that inhabitants in sparsely populated areas in particular in the north of Sweden are more dependent on their cars than inhabitants in the southern parts. We may conceive of several ways to quantify such a larger degree of dependency. It could manifest itself in larger car use (longer driving distances), more car ownership and a smaller sensitivity to income and price changes. A lower sensitivity for price and income changes could indicate less availability of attractive substitutes. On the other hand, sensitivity to income could be considered to be asymmetric and with larger increases in car use when income increases than decreases when income decreases. Furthermore these factors may be stronger for low income earners in sparsely populated areas.

Panel data approaches to modelling car use

Dargay (2007) seems to be among the first papers to directly analysing car travel at household level with panel data methods. Other early attempts at analysing car use with panel data methods include de Jong (1990), Rouwendal and de Vries (1999) and Bjørner (1999).

Dargay (2007) uses data from the UK Family Expenditure Survey which provides a random sample of around 7200 households a year since the 1960s to construct a pseudo-panel. Data from 1975 to 1995 is used. This involves construction of cohorts by using the year of birth of the household heads and using 5 year bands. Car ownership can be taken directly from the data but car travel must be constructed. This is done by using expenditures on fuel, fuel prices as well as average fuel efficiency for the car stock.

Dargay models the households desired car travel for a cohort *i* in period *t* as a function of disposable income, number of adults of driving age and the number of children per household in the cohort, an index of real car purchase price including both new and second hand cars, real per-kilometre fuel price, a cohort specific effect and an adjustment lag.

The most important results from our perspective are the following. The elasticity of car travel with respect to increasing income is significantly and substantially larger than the elasticity with respect to decreasing income. Prices for fuels and cars are found to have negative effects on car travel. Car travel is found to be more sensitive to car purchase costs than to fuel costs. An increase in the number of adults in a household is estimated to increase car travel by a third, while an additional child reduces it with around 10 percent. Car travel is found to be strongly susceptible to habit formation and resist change. The estimated effect of lagged car travel is estimated to be relatively swift with 75 percent occurring within a year. Dargay does not, however, distinguish or study sex differences or differences in car use depending on the area types we use.

The most important differences between our analysis and Dargay's are the following. As we have much more data we may divide our data into many parts and estimate separate models. We therefore distinguish the differences in the use of cars owned by sex, disposable income and geographical area type. Dargay also analyses the effects of income but with a specification that economizes on the number of observations. This

also brings extra information on the asymmetry of adaptation to increases and decreases in income. This has not been done in the present study.

In Sweden there is no joint taxation of spouses or of individuals sharing household. Therefore there are only partial register data on which adult individuals that share household. In this study we have neither acquired nor used this information. This may be an important limitation since previous work (e.g. Dargay, 2007) demonstrates the importance of household size and in particular the number of employed adults for car use. The reason for this choice was that we would not have been able to completely map all households in Sweden.

In shared households the income of one household partner obviously may have an important effect on joint income and therefore on other household members consumption. We can obviously not study this effect.

4.3 The data

When choosing the data to estimate a model for Sweden we primarily sought data that resembled that used by Dargay (2007), and preferably more detailed or exact data.

For each privately owned car we have the yearly car use registered from odometer readings by the National Vehicle Inspection. We use data from 1998 to 2005. There are however some qualifications that must be known about the kilometre readings.

The first qualification is that this data has been created with the primary purpose to calculate the total annual vehicle use in Sweden. Therefore Statistics Sweden has applied estimated kilometre measures for those cars for which there are no vehicle inspections done, like for example on cars during the first three years of the cars life. We have not received a key to which car use numbers that are model generated. As we have such a large number of real observations, we have chosen to eliminate model generated observations as far as we were able to identify them. This has two important consequences. First our data does not cover new cars. We discard only those observations concerning an individual that pertain to years where the individual owned a new car. To the extent that new cars are used systematically differently than older cars this may introduce a bias.

The second qualification is that we can not distinguish who actually drove the observed distance implied by the kilometre reading. There are several reasons for this. One reason is that when a car changes owner during the year, the previous owners' car use that year will be associated with the owner in December. Another is that in many cases cars are owned by one family member whereas the car is also used by further members. This is an important limitation since previous work (e.g. Dargay and Hanly, 2007 and Dargay, 2007) demonstrates strong household size effects on car ownership and car use.

Statistics Sweden has two partial measures of possible household links. One is individuals who are married and the other is adult individuals living together with children. These measures do, however, provide only uncertain and partial links between individuals in households. At the initiation of this study the choice was therefore made to exclusively use data on individuals. Swedish travel surveys also indicate that women have access to cars to a much larger extent than they own cars SIKA (2007). In this study we disregard this complication and concentrate the study on how car use varies with the owner's residential location, sex and disposable income.

Each privately owned car is therefore associated with an individual (and not a household). The data on individuals, which was provided by Statistics Sweden, are the official records kept by the Swedish tax authorities. We therefore use yearly data on each individual in Sweden over the age of eighteen from 1998 to 2005. For each individual and observation we have sex, disposable income, the number of children (of all ages) living with the individual, the location of the home, the location of the workplace and the status of occupation. All these values are recorded in December each year. These factors are analysed separately for men and women, the three area types and finally the four disposable income quartiles of the individual in the particular year. These properties define 24 separate panels.

As we shall comment on later, there is for some individuals a discrepancy between reported income and true income. This problem has also been observed in the Swedish household expenditure panel (Hushållens utgiftsundersökning HUT), where a sizeable number of households in the lowest income quartile report larger expenditures than disposable income. Although this problem has been noted by Statistics Sweden we know of no systematic attempts to analyse this phenomenon in Sweden. This discrepancy between reported and true income may appear as more car use than for individuals who report the same but true income, and therefore is likely to induce bias in the estimates of income elasticity.

In this study we have used a new geographical criterion developed by Glesbygdsverket (the National Rural Development Agency). According to this criterion habitation is separated in three groups, individuals living in: *urban areas* with more than 3000 inhabitants, *rural areas close to an urban area* with more than five but less than 45 minutes driving distance from the nearest urban area and *sparsely populated areas* with more than 45 minutes drive from the nearest urban area. The sparsely populated areas are found almost exclusively in the northern parts of Sweden.

The values for fuel price used are the yearly averages for petrol provided by the Swedish Petroleum Institute (SPI). These values have been deflated by Statistics Sweden's Consumer price index (CPI). As petrol and diesel prices are highly correlated we have not used diesel prices. The car purchase cost index used is a subindex to Statistics Sweden's CPI. This in turn is constructed by subindexes for new and used cars. It is not obvious that we should use both prices of new and used cars for our model, as we have no observations of new cars. We however assess that the prices of new cars may also reflect on the perceptions of the alternative costs of using a used car. The car purchase cost is also deflated by the CPI. The yearly averages of petrol price and car purchase price of course suppress all the variation during the year and in geography.

The distance to work is calculated as the direct distance between the location of the individual's home and her workplace in December. This also of course suppresses any change that may have taken place during the year.

Some descriptive observations

As an indication of the number of individuals in the data set and the different area types we give the numbers for 2005. In this year there are 7,113 million individuals in the data set. Of these 5,45 million lived in urban areas, 1,51 million in rural areas close to urban areas and 0,12 million in sparsely populated areas. Of these inhabitants 2,4 million, 0,9 million and 0,07 million respectively owned cars. After elimination of

observations with model generated car use and negative disposable income, we use about 2,4 million observations per year.

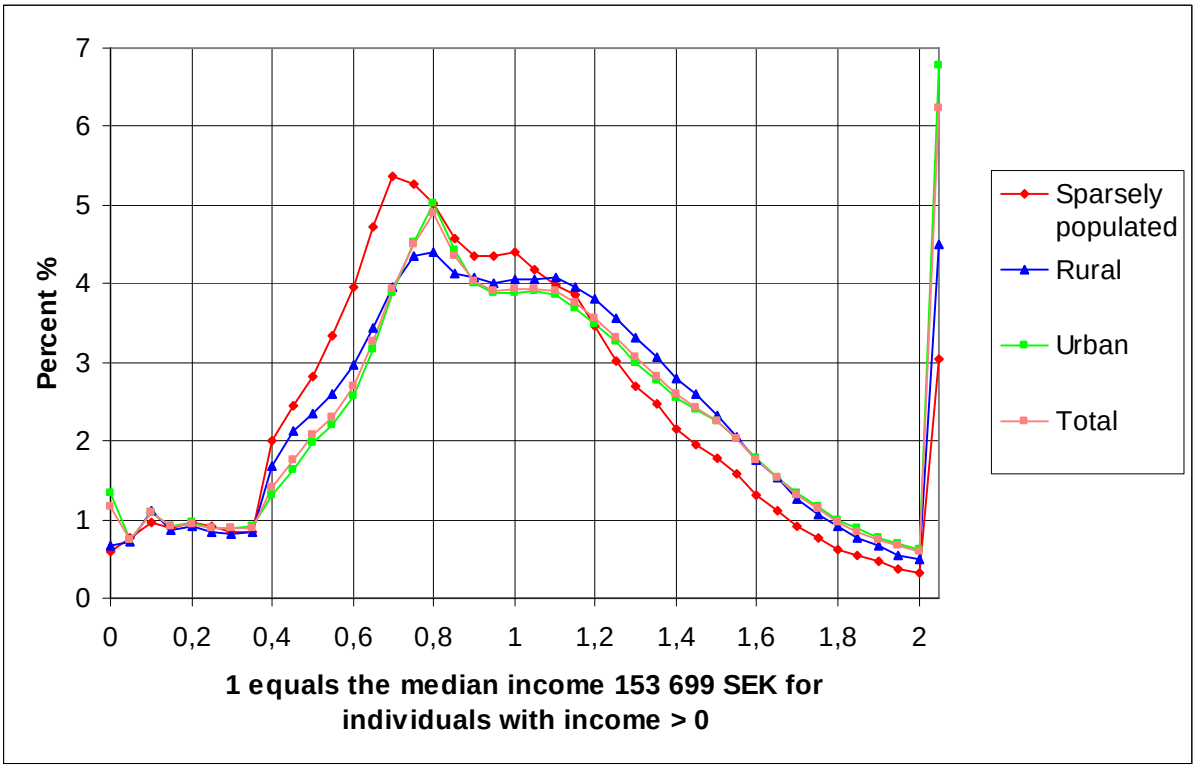


Diagram 4.1 Disposable income distribution in different area types.

In Diagram 4.1 income distributions in the area types and the total country are given. The densities beyond the double median income are given as one mass point. There seems to be small differences in income distribution between the area types. The most distinctive difference is the difference between sparsely populated areas and the other areas. In the sparsely populated areas there are slightly more inhabitants with lower than median disposable incomes and slightly fewer inhabitants with higher than median incomes than in the other area types. This may partly be explained by the fact that there are more elderly inhabitants in the sparsely populated areas.

Car ownership

In the total population of adults 48 percent owned cars in 2005. The sexes have very different car ownership, 63 percent of the men are car owners and 33 percent of the women. This may be compared to the number of households that say they have access to at least one car which was 75 percent in the travel survey data from 2005/2006 (Riks/RVU). Car ownership is strongly correlated with disposable income and sex which may be seen in the Table 4.1 and 4.2.

Table 4.1 Individual car ownership in Sweden 2005 for disposable income quartiles, percent.

	Total	Men	Women
Quartile 1	21,8	31,5	15,5
Quartile 2	41,4	58,1	29,9
Quartile 3	58,9	73,9	44,5
Quartile 4	70,1	78,1	53,0

Car ownership is also very dependent on where the individual lives. The most marked differences are between urban and rural areas.

Table 4.2 Individual car ownership in Sweden 2005 in the three studied area types.

	Total	Men	Women
Urban areas	43,6	59,0	29,1
Rural area close to urban areas	61,2	76,4	45,2
Sparsely populated areas	61,0	77,1	43,8

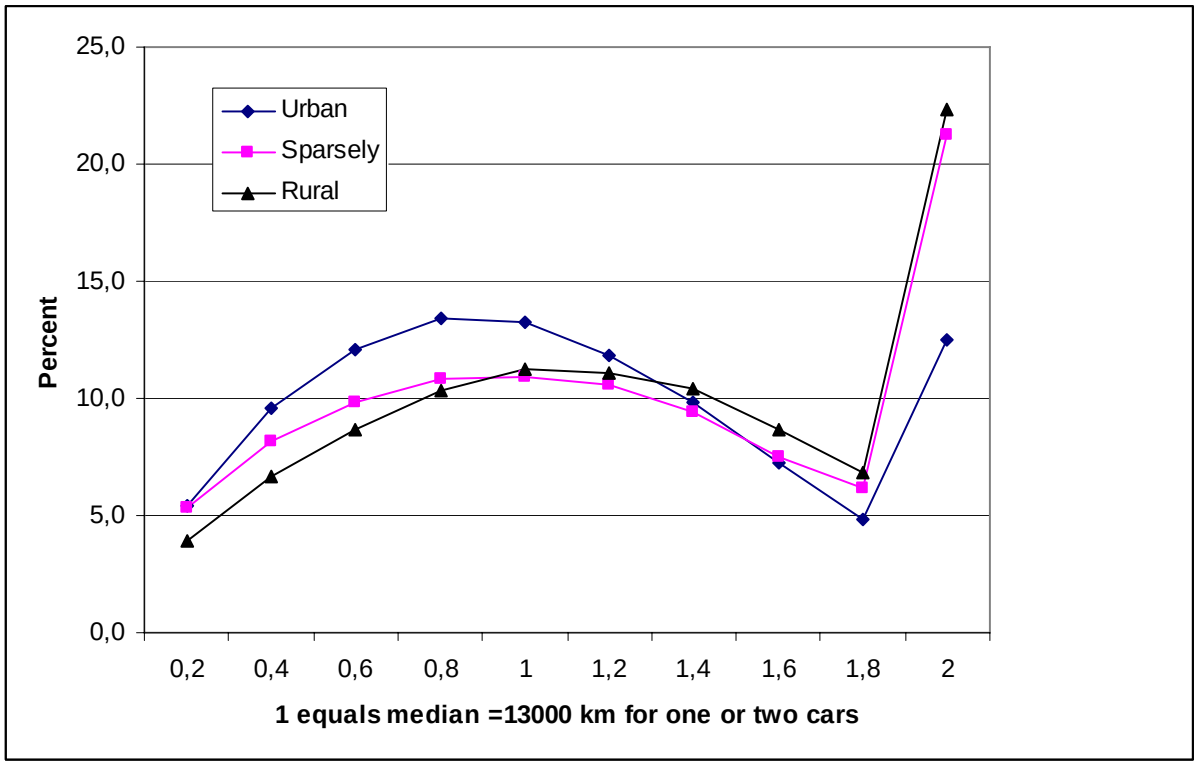


Diagram 4.2 Distribution of yearly car use, population median equals 13000 kilometres.

In Diagram 4.2 we present the distribution of the use of individual car owners' cars. In the diagram 5 the number 1 represents the median of summed car use, that is 13000

kilometres. We have chosen not to give the whole scale of driving distance so the last point represents the total frequency in the tail of larger car use numbers.

By and large, the distribution of the use of cars owned by residents in rural areas is similar to that of residents in urban areas. The main difference is that that the use of cars owned by urban inhabitants which is below the median is a larger share of the population than in the whole car owner population and that car use above the median is a smaller share. For the residents in the rural areas the opposite is true. In particular there is a small group in the rural areas that use their cars really much.

Consequently the most important differences in car use between urban and the two kinds of rural areas are that more individuals own cars in rural areas and a few of them use their cars really much.

During the period for which the models are estimated, 1999 to 2005, the central variables developed like follows. The use of privately owned cars in the population we study increased by 3.5 percent on average. If we look at all cars the use increased with 7.2 percent. The commercial use of cars therefore grew much faster than the private use of cars. Real petrol prices increased with 22 percent and average real disposable income in the studied population increased with 14 percent. Given that fuel expenditures are between 5 and 10 percent in 2005, a 22 percent price increase would imply a cost increase of 1.1 and 2.2 percentage points of real disposable income.

4.4 The model

The objective for our modelling has been to formulate a model as close as possible to that of Dargay (2007) so as to provide a possibility to compare the results. At the same time we wanted to use our large data set to analyse the small but politically important group of car users residing in sparsely populated areas, which are considered to be particularly car dependent.

Dargay tested several models and we chose the model that fitted UK data the best. This is done by applying the following model.

$$\sum_{f=1}^{n} k_{itf} = a + b\ln I_{it} + cC_{it} + dDi_{it} + eP_{Ft} + fP_{Vt} + g\sum_{f=1}^{n} k_{i,t-1,f} + hKPM_{t-1} + mD_i + \varepsilon_{it}$$

Here, k_{itf} represents the sum of yearly car use calculated from odometer readings for each car *f* owned by an individual *i* in year *t*. I_{it} is individual *i*'s real disposable income in year *t*, C_{it} is the number children living in the home of the individual *i* in year *t*, Di_{it} is the distance to the individual *i*'s workplace in year *t* (if the individual is employed or self-employed), P_{Ft} is the yearly value of the real price of petrol, P_{Vt} is the yearly value of the real car purchase price, $\sum_{f=1}^{n} k_{i,t-1,f}$ is the yearly car use numbers calculated from odometer readings for the previous year, *KPM* is a dummy for the case where the odometer readings for the previous year is not available and D_i is an individual specific effect.

This model is estimated separately for the following 24 groups. The observations of individuals are separated in men and women. The individuals of these groups are allocated to three groups by type of area of residence: urban area, rural area close to urban area and sparsely populated area. The individual observations are furthermore grouped by disposable income quartiles.

The estimated coefficients of this model may be interpreted as short term effects and short term elasticities may be calculated from them. The coefficient *g* indicates how much of a long run adaptation to a change that may take place in one period. In other words 1-*g* gives the proportion of the long run adaptation that takes place in the first stage. In the longer run 1/(1-*g*) times the short run elasticity gives the long run elasticity.

4.5 Estimation methods and results

The twenty-four models were estimated with the SAS Institute program PROC MIXED, which allows for maximum likelihood estimation using fixed effects for the individuals. This implies that we have used an unbalanced panel. We have used fixed effects to control for unobserved heterogeneity. In Table 4.5 we present the estimation results for the 24 models while tables 4.3 and 4.4 summarises short and long term income elasticities, respectively.

The coefficient for car use the previous year, or the inertia coefficient, is slightly higher in sparsely populated areas than in urban areas. It is however larger in Sweden (between 0,3 and 0,5 and a weighted average of 0,36) than the number found for UK 0,25 by Dargay (2007). This implies that long term elasticities are 1.56 times higher than the short run elasticities whereas they are only 1.33 times higher in the UK. Introducing the lagged car use variable inevitably comes with the risk of bias and inconsistency if there is correlation between the lagged car use and the error term. This could be avoided if we use a good instrumental variable for the lagged car use. This has neither been tested nor tried in this paper.

The short run income elasticities reported in Table 4.3 are based on the quartile medians of disposable income and car use numbers[11]. The estimated signs for low income earners are counter to what we expect on theoretical grounds and from previous studies. For low income earners of both sexes and in all area types the income coefficient has the "wrong" sign. Our assessment is that there may be several sources of this fact. One may be attributed to the fact that many low income earners have incomes that are not reported. Another is that low income households may share the use of their cars more. If

[11] The elasticities are calculated as point elasticities at quartile income medians for car use medians. Using the definition of point elasticity

$$E = \frac{\partial \Sigma k}{\partial I}\frac{I}{\Sigma k} \text{ and } \quad \frac{\partial \Sigma k}{\partial I} = \frac{b}{I} \text{ gives } \quad E = \frac{b}{\Sigma k}$$

This shows that this functional form imposes an elasticity that is inversely proportional to income within the interval for which it is estimated.

Car use medians in the respective income quartiles, kilometres

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Car use medians	1 026	1 075	1 351	1 522

Disposable income quartile medians

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Income medians	87 407	132 643	180 409	252 768

two or more individuals share household and car, the car use of the individual registered as the owner of the car is overestimated.

A third factor that may contribute to the anomaly, is if low income earners frequently buy used cars from users that use their cars much. In such cases the low income earners car use will be overestimated. We, therefore, do not believe that this is an accurate reflexion of the true income elasticities. If the low income earners would follow the pattern of the other income groups we would expect their income elasticity to be larger than that of quartile 2.

Except for the lowest income earners we find the following pattern of income elasticities. Car use is more income elastic in sparsely populated areas and decreases with higher income. This contradicts the hypothesis in the Chapter 2 introduction that car use with respect to income would be smaller for low income earners. On the contrary it appears as if there is a strong preference for mobility with cars that manifests itself with growing income in the lower income quartiles. At the same time, an increased car use associated with higher incomes seems to be associated with decreasing marginal benefit in the higher income quartiles as the income elasticities decrease with income.

Table 4.3 Short term income elasticities of car use.

	Sparsely populated areas				Rural area close to urban areas				Urban areas			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Men	-0,04	0,49	0,40	0,01	-0,03	0,48	0,35	0,02	-0,02	0,28	0,29	0,01
Women	-0,02	0,43	0,28	0,02	-0,02	0,39	0,25	0,03	-0,02	0,25	0,15	0,02

Table 4.4 Long term income elasticities of car use.

	Sparsely populated area				Rural area close to urban areas				Urban area			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Men	-0,06	0,77	0,63	0,02	-0,05	0,76	0,54	0,03	-0,04	0,44	0,46	0,02
Women	-0,03	0,66	0,44	0,04	-0,04	0,62	0,39	0,04	-0,03	0,39	0,23	0,03

The long term elasticities[12] in Table 4.4 are all clearly lower than the long run elasticity found in Dargay 2007 for a similar specification which was 1,02.

It may of course be possible that income elasticities are smaller in Sweden than in the UK. There may also be a number of bias sources. If the car use has not been correctly attributed to an individual this may cause overestimation of the individuals car use. Two possible reasons for this are that the car is used by other household members and that the car has changed owner. The first may be more likely in low income households. The second is likely if low income households on average buy cars from households that use their cars more. If there is measurement error in the measurement of disposable income

[12] The long term elasticities are calculated by multiplying the short term elasticity by 1/1-g.

this may cause attenuation bias. In particular if the coefficient is positive the estimated coefficient will tend to be an underestimation (and if the coefficient is negative the estimated coefficient will be closer to zero than the true coefficient). We know that many low income households have larger expenditures than disposable income. This may also contribute to that the estimated elasticities may be smaller than the true elasticities. These sources of bias may disturb other estimates of coefficients also.

Table 4.5 Estimation results for basic models – the unit used is 10 kilometres

	Sparsely populated areas				Rural areas				Urban areas			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Quartile 1	Quartile 2	Quartile 3	Quartile 4
	1136,2	-6101,1	-5902,7	? 466,3	897,9	-5923,8	-5154,4	37,3	809,4	-3251,9	-4293,9	274,2
n of disposable income	-38,0	530,0	541,1	? 17,0	-34,4	520,9	470,3	32,3	-23,3	304,1	397,2	16,4
to work	0,6	0,4	0,5	0,5	0,8	0,8	1,0	0,7	0,4	0,6	0,7	0,6
hase cost ind.	? 0,8	6,4	? 2,1	? -0,2	1,7	6,5	3,9	2,6	2,1	4,5	2,2	1,6
ce	? -3,4	8,2	23,9	53,7	14,4	4,8	18,3	50,0	12,4	? 0,8	19,4	41,2
meters t-1	0,4	* 0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,3
of children	130,1	119,1	85,0	90,8	139,1	142,8	84,5	80,9	104,8	130,5	76,1	63,6
t-1 missing	114,6	1161,9	** 533,8	850,2	46,9	457,0	427,6	335,7	91,4	386,3	285,8	172,0
of observations used	54 624	78 651	69 735	47 040	464 671	678 644	929 131	966 955	760 832	1 683 007	2 408 521	3 503 488

	Sparsely populated areas				Rural areas				Urban areas			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Quartile 1	Quartile 2	Quartile 3	Quartile 4
	661,7	-5197,5	-4123,4	? -390,2	725,3	-4676,0	-3666,3	? 117,5	717,1	-2702,6	-1704,0	532,2
n of disposable income	-20,1	457,0	380,7	? 35,1	-25,3	424,1	341,8	39,0	-22,6	266,6	197,2	25,2
to work	0,6	0,7	0,6	0,7	0,8	1,0	1,1	0,9	0,5	0,6	0,7	0,7
hase cost ind.	** 3,1	*** 4,3	? 0,6	? -0,4	** 1,5	3,9	2,0	** -1,6	1,6	2,1	** -0,5	-3,2
ce	*** -7,3	*** 15,9	36,5	87,5	17,1	17,1	35,7	62,7	10,8	9,1	20,7	35,1
meters t-1	0,4	0,4	0,4	0,5	0,4	0,4	0,4	0,4	0,3	0,3	0,3	0,3
of children	141,8	112,5	84,7	78,6	141,3	108,6	71,3	73,3	122,3	108,0	72,7	61,9
t-1 missing	*** 103,3	*** 573,4	? 424,3	? 621,7	98,5	456,4	365,3	326,8	120,3	365,1	284,6	243,1
of observations used	32 175	41 270	37 319	17 197	335 240	505 236	549 083	324 292	560 146	1 090 394	1 423 046	1 254 123

All unmarked coefficient estimates have large t-values. ? Indicates not significant, *** indicates significant at 1 percent level, ** at 5 percent and * at 10 percent. Red figures denote wrong sign.

One additional child increases an individual's car use with between 600 and 1400 kilometres, or between 4 and 14 percent (calculated as fractions of the median car use in each disposable income quartile), more for low income earners and less for high income earners. This contrasts with Dargay's findings, where one further child reduces car use by around 10 percent. A possible explanation for this difference may be a difference in the definition of child. The Swedish definition is without restriction in the child's age. In the UK it appears as it may mean child under the age of 18 years.

An extra 10 kilometres to work increases yearly total car use between 4 and 10 kilometres which is neligible. Our interpretation to this result is that most of the commuting is captured through the income and inertia effects. For many long distance trips to work it may also be the case that car is not used. Dargay (2007) does not have this variable.

The estimated coefficient for petrol price is positive, implying that individuals drive more when petrol prices increase. The average value of the car use elasticity with respect to fuel price, calculated for population quartile medians for car use and a petrol price of 11 SEK, is 0.22. This obviously deviates from the theoretical prediction and from the empirical results in a large number of studies. A previous study of Sweden Jansson and Wall (1994) found a short term elasticity of -0,2 and a long term elasticity of -0,3. Dargay's (2007) results imply a short term elasticity of -0,18. In the surveys of Graham and Glaister (2002) and Jong and Gunn (2001) average values from a large number of studies of car use elasticities with respect to petrol price are given as: short term -0,16 and long term -0,26. The standard error of the latter estimates is in the magnitude of two thirds of the estimates.

There are several possible sources of bias that may influence the estimates of the petrol price coefficient. We have tested a number of such hypotheses in a model with all our data, but without the fixed effects. Among the alternatives were:

- a model without the lagged car use
- a model with differenced car use, income and prices, distance to work and car use the previous year
- a model with a variable consisting of the petrol price divided by the individuals disposable income
- a model excluding the decile with largest car use
- a model including the individuals wealth and the interest rate

None of these models yielded a negative coefficient for petrol price.

There are also a number of possible reasons for this result that we have not yet tested. First we want to emphasize that the fact that we use only seven observations of yearly petrol price averages (and car purchase cost index) creates a bias in the estimated variances of the coefficient estimates leading to an underestimation of the variances (showed by Kloek, 1981 and Moulton, 1990). There are some suggested methods for correcting such bias (Petersen, 2006 and Donald and Lang, 2007) that have not been possible to include within the scope of the present study. This bias implies that the estimate for the petrol price coefficient may not be significant. Secondly, the sources of bias mentioned for the income estimates may apply here also.

Aggregate models

As a further test of the hypothesis that Swedish data with other specifications could yield negative price elasticities, two simple models of aggregate and average data for the studied population have been tested. In Table 4.6 we present a model using 7 observations from 1999 to 2005 of aggregate car kilometres, average disposable income for the whole population and petrol price.

Table 4.6 Model of aggregate car kilometres for 1999–2005.

	Estimate	Standard error	t-value	Pr > |t|
Constant	25311,53	5876,97	4,3	0,02
Average disposable income	186,0	60,04	3,1	0,05
Petrol price	-867,2	244,8	-3,5	0,04
Car use the previous year	0,27	0,2	1,2	0,31

Assume a price increase for petrol by 1 SEK in 2005, when it was 10 SEK. This would reduce car kilometres with 867 million, that is 1.4 percent. This implies that the elasticity of car use with respect to petrol price is -0,14, which is close to the number found from earlier Swedish studies.

In Table 4.7 the estimations of a slightly different model are presented. Rather than using average disposable income for the whole population, this model uses 7 observations from 1999 to 2005 of average disposable income for our population of car owners, and instead of aggregate car use, we use the average car use in our population of car owners. In this model the elasticity of car use with respect to petrol price is -0.27.

Table 4.7 Model of average car use in our data.

	Estimate	Standard error	t-value	Pr > |t|
Constant	867,7	123,9	7	0,002
Average disposable income	5,2	1,3	3,97	0,017
Fuel price	-40,1	15,0	-2,67	0,056

Both these aggregate models therefore generate elasticities for car use with respect to petrol price in the same magnitude as earlier studies. The collected evidence from earlier studies suggest that the car use elasticity with respect to petrol price is in the magnitude of -0.2. Our overall assessment of the aggregate car use elasticity with respect to petrol price was the same in Sweden between 1999 and 2005 as before. In view of the fact that our results are anomalous we do not consider them as ground for changing the overall assessment that the aggregate car use elasticity is in the magnitude of -0.2.

The estimated coefficient for the car purchase cost index is positive for most groups, implying that individuals drive more when the cost for cars increases. We assume that increasing car prices increase the car owners' perception of the costs of driving a car. In

theory increased car purchase costs should decrease car use. The estimated coefficients for car purchase cost index have large variances, in spite of the fact they have not been corrected. This is less surprising for two reasons. The first is that this index may be far from the purchase cost of an individual car. The second is that the aggregate turnover of cars is not large. In 2007 there were 4,2 million cars in Sweden, 0,24 million were scrapped and 0,34 million new cars were registered. This implies that the turnover of the car fleet in terms of new cars was 8 percent. Therefore the purchase price of cars has a direct influence on only a very small proportion of car owners a given year. Dargay (2007), however, finds the right sign and significant estimates for this coefficient.

4.5.1 Overall patterns of the results

Car use in urban compared to rural areas

Car use is more income elastic in rural than in urban areas. The effect of the distance from home to work on car use is also largest in rural areas close to urban areas and smallest in sparsely populated areas with urban areas in between. The effect of the number of children on car use is larger in rural areas than in urban areas.

Car use in sparsely populated areas

Comparing car use in sparsely populated areas to car use in rural areas close to urban areas, we find small differences. The most marked difference is that car use in the middle quartiles is a bit more income elastic in the sparsely populated areas than in the rural areas. Furthermore the number of children has slightly larger effects on car use in the sparsely populated areas than in the rural areas. On the other hand, the distance from home to work has a larger effect on car use in the rural areas close to urban areas than in sparsely populated areas.

Women and men

Although there are large differences in the degree to which women and men own cars, the differences in car use given that an individual owns a car are small. This can be seen from the small differences in the estimated car use functions. For the two middle quartiles men’s car use is more income elastic. Women’s car use on average is a bit more sensitive to the distance from home to work.

The lowest income earners in rural and in urban areas

The inertia of low income earning women’s car use is stronger in rural areas than in urban. The car use of low income earning rural inhabitants is a bit more sensitive to the number of children.

4.6 Conclusion

A main objective of this paper has been to asses how low income car users in rural and sparsely populated areas adapt their car use to cost and income changes. Generally we find small geographical differences in the sensitivity to changes in disposable income and cost. The estimated income elasticities decrease with increasing disposable income. This may indicate that there is some saturation in car use occurring when disposable income increases. The estimates for income elasticities appear to be reasonable (except for the lowest disposable income quartile) and are based on observations from all individuals. The estimated car use elasticities with respect to income are smaller than those found for the UK.

The models for the lowest disposable income quartile have negative elasticities for car use with respect to disposable income. This would imply that increases in disposable income would lead to reduced car use for the lowest income group.

A possible reason for this anomalous result may be that low income households share their car use more. Another possible reason may be that there is a negative correlation between reported disposable income and unreported income in this quartile. It is well known from household expenditure surveys in Sweden that households in the lowest disposable income quartile frequently have expenditures that are above the households reported disposable income. A third possible reason may be that low income individuals frequently buy cars from users who used their cars more and that this leads to an overestimation of low income earners' car use.

The estimated car use functions also indicate different responses depending on if the subject lives in a rural area or in an urban area. Car use is more income elastic in rural than in urban areas. This indicates that the car use of rural inhabitants with low disposable incomes is more restricted than is the car use of urban inhabitants with the same disposable income. A possible interpretation of this is that the car use of rural inhabitants and hence their mobility is more vulnerable to income changes than that of urban inhabitants.

The effect of distance from home to work on car use is also largest in rural areas close to urban areas and smallest in sparsely populated areas with urban areas in between. The effect of the number of children on car use is larger in rural areas than in urban.

The effect of lagged car use, inertia, is larger than the estimated effect for households in the UK. This implies that it takes longer time for Swedish car users to adapt to changes in costs and income, than in the UK.

The responses in car use of women and men to income differ little. Men's car use is slightly more income elastic in the two middle quartiles. Women's car use on average is slightly more sensitive to distance from home to work.

Our estimates suggest that the car use's fuel price elasticity is positive for most quartiles. We do not, however, believe that increased fuel prices lead to increased consumption of car travel *ceteris paribus*. With a better measure of disposable income this could hopefully be remedied. Such a better measure could be provided by linking individuals in the same household. The estimates of the coefficient for car purchase cost index are positive also. Both these results thereby contradict theoretical predictions and contrast with Dargay's (2007) findings for households in the UK.

More children increases car use, more for low income earners than for high income earners. This also contrasts with Dargay's findings for households in the UK, which is

that children reduce car use. This may be an effect of adult children not counting as children in the UK.

Combining these observations we may formulate the following conclusions about low income car users in rural areas. This group owns cars to a lesser degree than those with higher incomes in rural areas but more than the corresponding inhabitants in urban areas. Except for the lowest income earners, it appears that low income earners' car use is more income elastic. This implies that low income earners want to use their cars considerably more if they receive higher incomes.

Our estimations of coefficients for petrol price and car purchase cost do not yield the theoretically predicted signs. Comparing with estimations for aggregate car use and other studies, and in view of the fact that our results are anomalous we do not consider them as ground for changing the overall assessment that the car use elasticity is in the magnitude of -0.2.

The policy implications of, for example, increasing petrol taxes are that households will initially mostly absorb price increases by not increasing other forms of consumption. In a longer perspective increased petrol prices is likely to impact on the choice of car type. We may also conclude that in a majority of the population there is still a strong preference for increasing car use when disposable income increases.

The car use patterns for sparsely populated areas do not differ much from other rural areas. Therefore, in contradiction to popular beliefs, policies specially directed at subsidising the car use of inhabitants in sparsely populated areas in general, do not seem to be called for. The lack of mobility in terms of car use seems to be a problem primarily for the lowest income group.

The distributional consequences of increased petrol prices will thus be fairly even among car owners in different area types but will hurt low income car owners more as they frequently use a larger share of their disposable income for fuel expenditures. Any remedies against increases in fuel prices motivated by distributional concerns should therefore target income rather than where people live.

Further research

This paper should be seen as a first step in the analysis of socioeconomic and geographical differences in Swedish car use. As we have a uniquely rich data set this opens a potential for further detailed analysis of car use in different social groups as well as geographical areas. In this paper we have begun this process.

The most interesting development that we foresee is to connect individuals in the same households. This would allow a more accurate mapping of the income and cars that individuals can utilize. It may also reduce the bias in the estimation of the influence of disposable income on car use and hopefully also on estimation of the influence of petrol price and car purchase cost.

There is also a selection issue in the sense that some individuals may seek to acquire the right to use a car provided by their employer. This may be particularly attractive for self-employed individuals. If the individuals that use their cars the most get cars from their employers they do not appear in our data set. This may also create a bias. A possible further extension to our models could be such selection models.

4.7 References

Bjørner, Thomas Bue, 1999, Demand for Car Ownership and Car Use in Denmark: A Micro Econometric Model, International Journal of Transport Economics, Volume 26, No 3, sidorna 377–95.

Dargay, Joyce, 2007, The effect of prices and income on car travel in the UK, Transport Research Part A, Volume 41 pp. 949–960.

Dargay, Joyce and Hanly, Mark, 2004, Land use and mobility, Paper presented at World Conference on Transport Research.

Dargay, Joyce and Hanly, Mark, 2007, Volatility of car ownership, commuting mode and time in the UK, Transportation research Part A, Volume 41, pp. 934–948.

Dargay, J. and Vythoulkas, P., 1999, Estimation of dynamic car ownership model: a pseudo-panel approach. Journal of Transport Economics and Policy 33 (3), 283–302.

Farrington, Gray, Martin and Roberts, 1998, Car Dependence in Rural Scotland: Challenges and Policies, Scottish Office Central Research Unit. HMSO, Edinburgh.

Graham, D. and Glaister, S., 2002, Review of income and price elasticities of demand for road traffic, Center for Transport Studies, Imperial College of Science London.

Gray, D.; Farrington, J.; Shaw, J.; Martin, S.; Roberts, D., 2001, Car dependence in rural Scotland: Transport policy, devolution and the impact of the fuel duty escalator, Journal of Rural Studies 17, No 1, pp. 113–125.

Jansson J.-O. and Wall, R., 1994, Bensinskatteförändringars effekter, Rapport till Expertgruppen för Studier i offentlig ekonomi.

Jong, G.C. de (1990) An indirect utility model of car ownership and private car use, European Economic Review, 34, pp. 971–985.

Jong, G.C. de and Gunn, H., 2001, Recent evidence on car cost and time elasticities of travel demand in Europe, Journal of Transport Economics and Policy 35. pp. 137-160.

Krantz, L.-G., 1999, Rörlighetens mångfald och förändring, Befolkningens dagliga resande I Sverige 1978 och 1996, Meddelanden från Göteborgs universitets geografiska institutioner, Serie B, Nr 95, Handelshögskolan vid Göteborgs universitet.

Matstoms, P., 2002, Modeller och prognoser för areaalt bilinnehav i Sverige. VTI rapport 476.

Petersen, M., 2006, Estimating standard errors in finance panel data sets: Comparing approaches. Kellogg Finance Department Working Paper, 329.

Rouwendal, J. och de Vries, F., 1999, Short term reactions to changes in fuel prices - a panel data analysis, International Journal of Transport Economics, 3 Volume 26, sidorna 331–350.

Riks-RVU/RES 1994–2001.

SIKA 2007, RES 2005–2006.

Vagland, Å. and Pyddoke, R., 2006, Hur hushållen anpassar sig till ändrade kostnader för bilinnehav och bilanvändning? VTI rapport 545.

5 A dynamic model of individual private car ownership in Sweden 1996–2005*

5.1 Abstract

This paper presents estimations of models for individual private car ownership in Sweden. We use register data of all adult Swedes 1996–2005. A central objective is to compare the sensitivity of urban and rural inhabitants with respect to the sensitivity of their car ownership to income and cost changes. The central result in this paper is that Swedish car ownership is very resistive to change. The dominant factor for car ownership is the status of the previous year's car ownership. Rural car owners are only slightly less likely than their urban counterparts to cease their car ownership and slightly more likely to increase it. Young and pensioned car owners are more likely to cease their car ownership. This probability is also larger for women than for men. Men are also significantly more likely to acquire a car when owning no car than women, and this likelihood is larger for men in rural areas. Variations in income are estimated to have a negligible effect on car ownership. Some of the estimated effects of the economic variables do not have the right sign. The effect of increase in petrol price reduces the probability of owning no (which is unexpected) or one car (expected) and increases the probability of owning two cars (which is unexpected). An increase in the car purchase cost index has the expected sign for urban inhabitants but not for rural inhabitants. Having children has the expected sign but a small impact on car ownership. The distance to work has no effect on car ownership.

* Funding from Bisek is gratefully acknowledged. Urban Björketun VTI has handled the data, tables and diagrams and done the computational work. I would like to thank the participants at VTI:s seminar the 18 june 2008 for comments and suggestions. I would also like to thank Mogens Fosgerau for suggestions on bias sources, Joyce Dargay for useful suggestions, Gunnar Isacsson for suggestions on bias sources and a very thorough reading for VTIs quality review seminar and to and Henrik Andersson, Gunnar Lindberg, Lena Nerhagen and Jan-Eric Nilsson for pointing to important perspectives for presentation and analysis.

5.2 Introduction

In countries like Sweden for a part of the population which inhabit sparsely populated areas, the car is almost indispensible for social and cultural life. This is indicated by the fact that the inhabitants in these areas to a larger extent own cars than people living in urban areas. Several studies have also shown that the rise in income has spread car ownership in groups who previously did not own cars.

The objective of this paper is to update descriptive statistics on how frequently car ownership ceases in different socioeconomic groups in different geographic area types, particularly in rural areas, and to look further at determinants of car ownership. In particular we want to know the significance of income and motoring costs for car ownership in Sweden. Finally, determinants of car ownership in Sweden are compared with the corresponding determinants in the UK.

Based on travel survey studies the following facts about car ownership in Sweden are taken to be well known. Inhabitants in urban areas own cars to a lesser degree than inhabitants in rural areas (Matstoms, 2002 pp. 80–87). High income earners are more likely to be car owners than low income earners (Vagland and Pyddoke, 2006 p. 25). Men own cars to a larger extent than women (Matstoms, 2002 p. 50) but this difference has been decreasing.

Swedish car ownership and car acquisition has been thoroughly modelled by Matstoms et al. (2002). The study used a dataset of all adult Swedes from 1980 to 1995, and the purpose was primarily to create a robust forecasting model for probabilities of entry into, and exit from car ownership from one year to another. These probabilities were modelled for a large number of subgroups of the population, for instance according to sex, geographic area and age. Although the study's purpose was not primarily to develop an analysis of determinants of changes in car ownership a selective analysis was nevertheless presented.

Matstoms argues that age and income are decisive factors behind both entry and exit from car ownership in this period. He also argues that it is harder to model entry than exit. Exit seems to be a more inert process driven primarily by age and the type of area in which the individual lives. Entry declines with age. In the 1980-ties entry was largest at the ages of 20–24 years. Over that age entry declined with age. The young were shown to be most likely to acquire a car but many individuals in this age also ceased to own cars. In sparsely populated areas this acquisition likelihood was found to be larger. Matstoms however finds that entry has been declining in the youngest group during the 1990-ties for both men and women.

Higher petrol prices were shown to have a negative effect on entry to car ownership for several groups. The price variable was however eliminated when found not to be significant for many groups in a first round of analysis. Petrol price appears to have a stronger effect on entry in large urban areas than in rural areas. The income elasticity of entry was largest in the youngest group. For the older groups the correlation between income and entry was significantly lower. Women's entry was more income elastic than men's. The Matstoms research group also tried to find geographical differences but found no distinct variables for explaining these.

In contrast to the entry function the exit function is u-shaped with respect to age. The exit propensities are largest for the youngest and oldest individuals. For the years in between the variation is significantly smaller. This is the same for both men and

women. The form of the exit function does not change much during the 1980 to 1995 period.

In the international literature on determinants of car ownership there has been a development towards using household expenditure data and panel data modelling for exploring the determinants of car ownership. In this study the desire to explore rural car ownership precluded using Swedish household expenditure data as these datasets are thin in rural areas. Instead the availability of register data in Sweden was seen as a possibility. We also wanted to explore the expanded possibilities of analysing determinants for car ownership provided by panel data methods compared to the forecast models used by Matstoms. Furthermore a recently developed geographical criterion allowed us to use a sharper distinction between rural and urban inhabitants than earlier studies.

There have been some studies on car ownership adapting panel data methods in the literature. They have all emphasized the importance of past car ownership for predicting current car ownership. It has also been stressed that if state dependence (previous car ownership) is included in a model there is a risk that unobserved heterogeneity among the households may cause a bias in the estimate of state dependence. This risk was elaborated in a paper by Kitamura and Bunch (1990).

The present paper makes use of a modelling approach developed by Dargay and Hanly in a series of papers. They have worked with household data from the British Household Panel Survey. In Dargay and Hanly (2000b) they tried a new modelling approach when they utilized an ordered-probit specification, using 1993–1996 data to examine the issue of state dependence versus unobserved heterogeneity. In Dargay and Hanly (2000b) dependence on past experience were incorporated by including lagged car ownership and unobserved heterogeneity was specified as a random effects model with two alternative formulations. The results supported the importance of state dependence. In the two tested specifications of models taking account of state dependence, heterogeneity was not found to be significant.

Two different specifications of state dependence were estimated by Dargay and Hanly (2000b): in the first the number of cars owned in the previous year was used, and in the second dummies for a lagged car ownership were used. Including state dependence improved the fit of the model considerably, but the particular specification made less difference. The car dummy specification indicated some saturation, the more cars a household owns, the less likely it is to acquire additional cars.

The most important results in Dargay and Hanly (2000b), were the influence of the following factors for the households car ownership:

- previous car ownership (state dependence) has strong positive effects
- the number of adults in the household who are employed has large effects
- whether or not the household head is a pensioner has effect
- the type of area where the individual lives also has effect
- income has a significant effect.

In Dargay and Hanly (2007) the analysis is further developed and two questions are studied. The first is the extent to which household car ownership and the individuals' commuting behaviour vary over time. For this purpose they analyse changing household

structure, employment status, moving house and change of employer. The second is to estimate the effects of various determinants of car ownership at household level.

The first question is answered by a set of tables describing how household car ownership is adapted to changes in employment, housing, number of household members and form of commuting. The second question is answered by estimation of a dynamic ordered probit model using data from 1991 to 2001.

Dargay and Hanly (2007) find that the strongest factor for reduction of car ownership is that an adult member leaves the household. They also find that on average the number of households that increase their car ownership is larger than the number of households that reduce it. About 25 percent of the households either move house or change employment. Both unemployment and retirement lead to reductions in car ownership, unemployment the most.

The modelling analysis demonstrated a significant inertia of the current level of car ownership. The heterogeneity is also found to be significant, meaning that there are unobserved differences between households that influence car ownership. Furthermore, household car ownership increases with income, number of adults in household, the number of employed and the number of children while it decreases with purchase costs and population density and is lower for pensioner households and women. The number of full-time working adults has a stronger effect than part-time workers which has stronger effect than the number of children.

Dargay and Hanly (2007) also find that car purchase costs have a strong negative impact on car ownership. None of the other cost measures were found to have significant effects. In the 2007 model the specification implies that the impact of the state variable is the same for all ownership levels, meaning that the inertia factor is the same irrespective of the previous year's ownership level.

It is also well known that the proportion of car owners (households) that cease their ownership each year is small (Matstoms, 2002 and Dargay and Hanly, 2007 p. 938). As the car is so important for mobility, rising costs for car ownership and car use as well as loss of job opportunities or income, poses significant threats to household mobility to particularly vulnerable individuals and households. In this study we therefore look at the impact of cost and disposable income changes on car ownership in Swedish data.

In the present study we have tried to implement as much as possible from the model from Dargay and Hanly (2007) to a set of Swedish data. The most important difference between our model and data and Dargay and Hanly (2007) is that we have data on individual level and therefore model individual car ownership whereas they have data on household level and therefore model household car ownership.

Compared to Dargay and Hanly (2007), this study has more data on individual car ownership as we have data from nearly the whole adult population. Therefore we have substantially more observations of rural households. We also have a new geographical criterion, making it feasible to distinguish between urban, rural and sparsely populated areas. We can therefore look more closely at the differences in car ownership depending on sex, socioeconomic status and residential area. Consequently we may model rural car ownership. We also have data for ten more years than Matstoms. These years cover a period with large increases in real disposable income and petrol prices.

5.3 The data

When choosing the data for our model we primarily sought data that resembled the data used by Dargay and Hanly (2007), and we used register data whenever these where applicable. This allows us to examine rural car ownership more closely. The data, which was provided by Statistics Sweden, are the official records kept by the Swedish Tax authorities. We therefore have yearly data on each individual in Sweden over the age of eighteen from 1980 to 2005. In the present estimations of car ownership only 1996 to 2005 data are used since a previous study (Matstoms, 2002) has studied the period 1980–1995.

For each individual we have age, sex, disposable income, children (of all ages) living with the individual, the location of the home, the location of workplace, the number of children and the number of privately owned cars. The disposable income is a concept defined by Statistics Sweden including a wide range of incomes and transfers net of tax payments. We also use real yearly average petrol prices from Svenska Petroleum Institutet and a car purchase cost index from Statistics Sweden. Individuals who exclusively have driven cars provided by their own firm or their employers, even for private use, do not count as car owners, i.e. they are no included in the analysis.

An important limitation is that register data indicating if individuals are connected by living in the same household are generally not available, and the partial information that does exist was not included in our dataset. Therefore we can not model the significance of household income or the number of household members for car ownership. By using individual income and car ownership we take the risk of using an irrelevant measure of income, thus creating problems associated with measurement error in income. This limitation can be seen from previous work (Dargay (2007) and Dargay and Hanly (2007)) which demonstrate strong household size effects on car ownership and car use. Statistics Sweden does have two partial measures of possible household links. One is which individuals who are married and the other is adult individuals living together with children. These measures do, however, provide only uncertain and partial links between individuals in households. At the initiation of this study the choice was therefore made to exclusively use data on individuals.

A second limitation is that expenditure data may be more accurate than income data collected from tax authorities. We know that in particular some low income households, that participate in household expenditure surveys report larger expenditures than disposable income (Vagland and Pyddoke (2006)) and we cannot exclude that there may be such errors in the higher income groups. Such measurement errors in disposable income could generate bias in estimates.

A third limitation is that we do not have information about if the individual has access to a car owned by his own firm or his employers firm. There is a partial measure of this also in the sense that individuals who declare that their employer supply them with a car are recorded. If the individual has declared herself as having a car provided by her employer, we may assess how many individuals have exclusively their own cars. For cost reasons we chose not to acquire this information. Ideally we would also like to associate car ownership with access to public transport. There are however no such data available.

The area of residence is classified into three types according to a new criterion developed by Glesbygdsverket (the National Rural Development Agency): individuals living in *urban areas* with more than 3000 inhabitants, in *rural areas close to a urban*

area with more than five but less than 45 minutes driving distance from the nearest urban area and in *sparsely populated areas* with more than 45 minutes drive from the nearest urban area. The sparsely populated areas are found almost exclusively in the northern parts of Sweden.

In 2005 there were 7,113 million individuals in the data set. Of these 5,45 million lived in urban areas, 1,51 million in rural areas close to an urban area and 0,12 million in sparsely populated areas. Of these there were totally 3,4 million car owners, 2,4 million living in urban areas, 0,9 million in rural areas close to an urban area and 0,07 million in sparsely populated areas.

Diagram 5.1 presents income distributions for individuals above 18 years of age with a positive income, by area types and for the country. The density beyond the double median income is represented by one mass point. The most distinctive difference between the area types is that in the sparsely populated areas there are slightly more inhabitants with lower than median disposable incomes than in the other area types. This may partly be explained by the fact that there are more elderly inhabitants in sparsely populated areas.

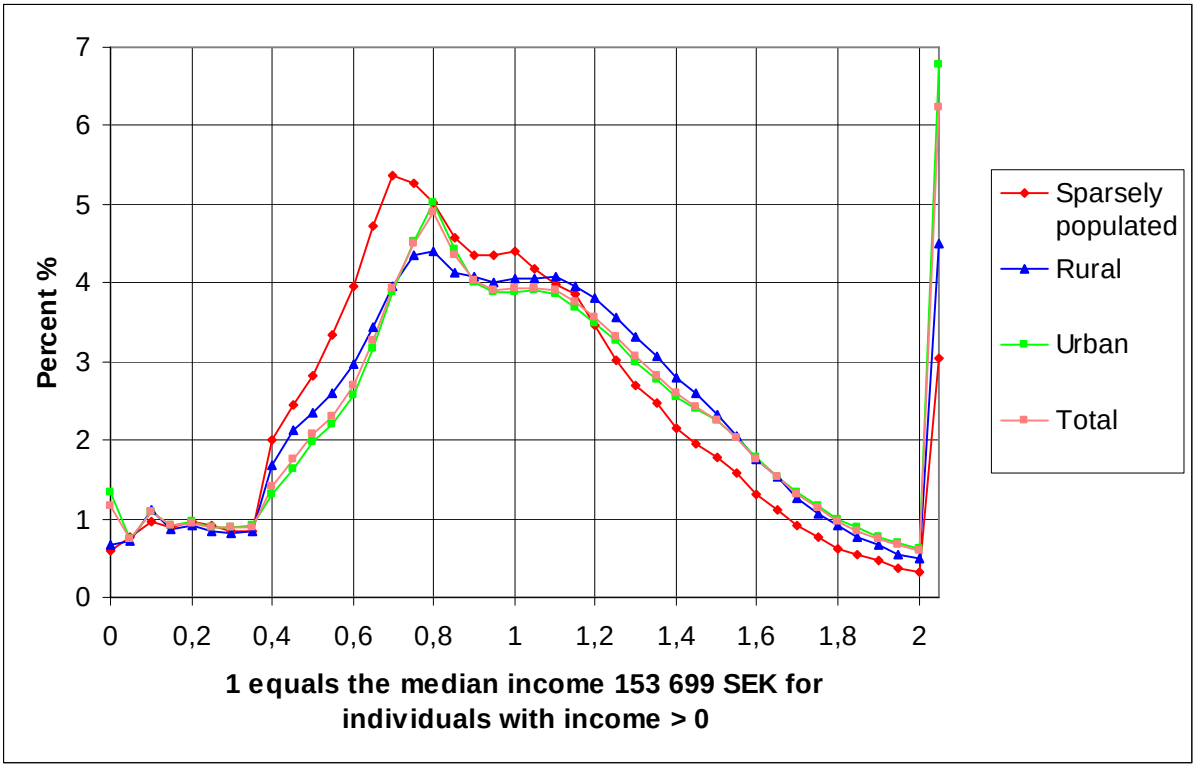


Diagram 5.1 Disposable income distribution in different area types.

Car ownership

In the total population of adults 48 percent owned cars in 2005. The sexes have very different car ownership, 63 percent of the men are car owners and 33 percent of the women. This may be compared to the number of households that say they have access to at least one car which was 75 percent in the travel survey data from 2005/2006 (Riks/RVU). Car ownership is strongly correlated with disposable income and sex which may be seen in the Table 5.1 and 5.2.

Car ownership is strongly correlated with disposable income and sex which may be seen in the following tables.

Table 5.1 Car ownership in Sweden 2005 for disposable income quartiles, percent.

	Total	Men	Women
Quartile 1	21,8	31,5	15,5
Quartile 2	41,4	58,1	29,9
Quartile 3	58,9	73,9	44,5
Quartile 4	70,1	78,1	53,0

Table 5.2 Car ownership in Sweden 2005 in the three studied area types.

	Total	Men	Women
Urban area	43,6	59,0	29,1
Rural area close to urban area	61,2	76,4	45,2
Sparsely populated area	61,0	77,1	43,8

Table 5.3 The share of car owners 2005 and car owners 2004 that ceased to own a car in 2005.

		Share of car owners per disposable income quartile				Share of car owners that cease to own a car			
Area		1	2	3	4	1	2	3	4
National		21,8	41,4	58,9	70,1	9,2	6,7	4,8	3,8
Urban		17,5	36,2	54,3	67,1	11,0	7,5	5,3	4,1
Rural		34,9	58,7	73,0	81,3	6,6	5,0	3,6	2,9
Sparse		36,0	60,3	72,9	79,8	5,6	4,3	3,3	2,9
Urban	Men	25,2	52,7	69,9	75,7	11,0	6,2	4,2	3,6
Rural	Men	50,7	74,7	84,9	86,2	5,9	3,8	2,7	2,6
Sparse	Men	53,6	75,4	83,9	85,3	5,1	3,3	2,6	2,5
Urban	Women	12,4	25,2	40,2	50,0	10,9	9,5	7,1	5,7
Rural	Women	25,1	46,7	59,6	67,5	7,6	6,4	5,1	4,1
Sparse	Women	24,0	45,8	59,2	65,3	6,5	5,7	4,6	4,3

In Table 5.3 we tabulate car ownership by sex, area type and income quartile and add the proportion that cease their car ownership. In some groups there are a significant number of individuals that cease to own a car. Women are much more likely to cease their car ownership than men. For three reasons, this does not necessarily mean that the individual ceases to have access to a car. Firstly, the individual may be part of a household where another individual owns a car. Secondly and thirdly, the individual

may receive access to a car owned by his own firm or by his employer. The change of car ownership may therefore result from a change in the number of adult members of the household, a change of income or the individual receiving an employer owned car. In addition to these reasons the individual may change home or work.

5.4 The model

In this paper we use an ordered probit model to represent the choice of level of car ownership. We use data from 1996 to 2005 to estimate a dynamic car ownership model that incorporates state dependence in the form of lagged car ownership.

The dependent variable is the number of cars recorded to be owned by the individual in each year. This variable can take on one of four values: 0, 1, 2 or 3 or more cars. The dynamic element is incorporated by including the number of cars owned by the individual the previous year. This implies that the car ownership in the current period is influenced by the car ownership the previous year.

The further explanatory variables in the model are sex, disposable income, the number of children, distance to workplace, petrol price, car purchase cost index and age dummies for young individuals 18–24 and for individuals elder than 67 years.

A probit model uses a latent variable y* defined as

$y^* = \mathbf{X}\,\mathbf{a} + e$

where **X** is a vector of independent explanatory variables, **a** is a vector of coefficients and e an error term and y is defined as

$y = 1\ [y^*>0]$

where 1[.] is an indicator function. Typically y* is not observed but y is. To interpret y* we may think of y* as representing an index of the likelihood of car ownership.

The normal probability function is used to represent binary choices so that

$z = \mathbf{X}\,\mathbf{a}$

$$F(z) = \int_{-\infty}^{z} f(v)dv$$

where f is the density function and F is the distribution function of the normal distribution.

In an ordered probit the binary probit model is generalized to cover multiple choices. In our case we expand it to the choice of owning either 0, 1, 2 or 3 or more cars.

We therefore observe the number of cars owned by the individual

$y = 0$	if	$y^* \leq \mu_1$
$= 1$	if	$\mu_1 < y^* \leq \mu_2$
$= 2$	if	$\mu_2 < y^* \leq \mu_3$
$= 3$	if	$\mu_3 < y^*$

Define $z = \mathbf{X}\,\mathbf{a} + e$ *without* intercept and $e \sim N(0,1)$

$Pr(y=0) = Pr(z < \mu_1)$

$Pr(y=1) = Pr(\mu_1 < z < \mu_2)$

$Pr(y=2) = Pr(\mu_2 < z < \mu_3)$

$Pr(y=3) = Pr(\mu_3 < z)$

The interpretation of this model is

$$Pr(y=0) = Pr(\mathbf{X}\,\mathbf{a} + e < \mu_1) = Pr(e < \mu_1 - \mathbf{X}\,\mathbf{a}) = F(\mu_1 - \mathbf{X}\,\mathbf{a})$$

Where F is the distribution function of the normal distribution.

$$Pr(y=1) = Pr(\mu_1 < \mathbf{X}\,\mathbf{a} + e < \mu_2)$$
$$= Pr(\mu_1 - \mathbf{X}\,\mathbf{a} < e < \mu_2 - \mathbf{X}\,\mathbf{a})$$
$$= F(\mu_2 - \mathbf{X}\,\mathbf{a}) - F(\mu_1 - \mathbf{X}\,\mathbf{a})$$

Now define y* as

$y^* = a\,I + bC + c\,Di + d\,U + f\,P + g\,D_1 + h\,D_2 + i\,D_3 + k\,P_{Ft} + m\,P_{Bt}$

Here I represents disposable income, C is the number of children of the individual, Di is the distance to the individual i's workplace, U is a dummy assuming the value 1 if the individual is between 18 and 24 years of age and 0 otherwise, P is a dummy assuming the value 1 if the individual is 67 years old or older and 0 otherwise. P_{Ft} is an index for car purchase costs in year t and P_{Bt} is the price of petrol in year t.

For most individuals the distance to work will also work as a dummy for the case that the individual is employed. An exception to this is individuals who work at home.

In this model we use a dummy specification for the number of cars held the previous year. This is done by defining the following dummies:

$D_1(i, t-1) = 1$ if $y(i, t-1) = 1$ and 0 otherwise

$D_2(i, t-1) = 1$ if $y(i, t-1) = 2$ and 0 otherwise

$D_3(i, t-1) = 1$ if $y(i, t-1) = 3$ or more and 0 otherwise

5.5 Estimation and results

The purpose of this project has primarily been to identify and estimate important determinants of car ownership in Sweden and not to develop estimation procedures. A general problem we have had has been that the maximum likelihood estimations have taken very long times to execute and in some cases they have not converged. Therefore we have not estimated panel models with dummies for years and individuals.

This model was estimated for two separate groups, inhabitants in urban and rural areas (including sparsely populated areas). We used the SAS Institute program PROC PROBIT. Each observation represents car ownership of the individual in December that year, the individuals' disposable income etc. Therefore the observations of an individual who has moved from, for example an urban to a rural area will appear first as base for the urban model and then for the rural model. This implies that we have used an unbalanced panel.

As we have such a large number of observations in the group of urban inhabitants (47 million) we were not able to compute the maximum likelihood maxima for the whole group. We therefore opted for calculating the maximum likelihood estimations for a random subset of the observations in the group of urban inhabitants, selecting random samples with the SAS-procedure PROC SURVEYSELECT. One percent of the observations have been sampled, implying that we used about 0,47 million observations of the urban inhabitants. For the group of rural inhabitants we used all of the approximately 14 million observations.

Parallell to the choice of private car ownership is a choice open only to some individuals, namely to chose a car provided by his or her employer. If these individuals otherwise would have been more likely to own cars than the rest of the population this potentially creates sample selection bias. In 2005 the number of company cars that could also be used privately was less than 6 percent of the number of privately owned cars. The total number of cars owned by legal persons was about 25 percent of the number of privately owned cars. In this paper we have not used any sample selection correction method.

There are some common observations that should be made for these estimations. Firstly there are several sources of bias that may disturb the estimates of car ownership likelihoods. It has already been indicated that if there is more than one member in a household that can use a car this influences the likelihood for the ownership of one as well as further cars. By using individual income and car ownership we take the risk of using an irrelevant measure of income, thus creating problems associated with measurement error in income.

Introducing the lagged car ownership variable inevitably comes with the risk of bias and inconsistency if there is correlation between the lagged car ownership and the error term. This could be avoided with the use a good instrumental variable for the lagged car ownership. This has neither been tested nor tried in this paper. Neither have we made any attempt to control for unobserved heterogeneity.

Finally we want to emphasize that the fact that we use only ten observations of yearly petrol price averages (and car purchase cost index) creates a bias in the estimated variances of the coefficient estimates leading to an underestimation of the variances (showed by Kloek, 1981 and Moulton, 1990). There are some suggested methods for

correcting such bias (Donald and Lang, 2007) that we have not tried. This bias implies that the estimate for these coefficients may not be significant.

The estimation results are presented separately for two area types, urban areas and rural areas. All the calculated estimates have very small variances.

5.5.1 Estimates for urban area inhabitants

Table 5.4 gives the estimation results for the model. Intercept1 to Intercept3 correspond to μ_1 to μ_3. Then follow estimates for the corresponding coefficients of variables and dummy variables.

Table 5.4 Estimation results for urban area inhabitants.

		Estimate	Standard Error	Pr > ChiSq
Intercept1		-2,56	0,142	<.0001
Intercept2		3,06	0,007	<.0001
Intercept3		4,66	0,012	<.0001
Income		-0,00007	0	<.0001
Dummy for Sex	Male	-0,32	0,005	<.0001
Children	6	-0		
Children	5	-0,045	0,083	<.58
Children	4	-0,049	0,072	<.50
Children	3	-0,044	0,069	<.53
Children	2	-0,030	0,069	<.66
Children	1	-0,012	0,069	<.85
Children	0	0,078	0,069	<.86
Distance to work		-0,00009	0	<.0001
Car purchase		-0,0018	0,0003	0,0001
Petrol price		-0,018	0,0016	<.0001
Dummy for young		0,21	0,0032	<.0001
Dummy for pensioned		-0,30	0,0024	<.0001
Cars t-1	3	-1,65	0,0188	<.0001
Cars t-1	2	0		
Cars t-1	1	1,90	0,0096	<.0001
Cars t-1	0	4,83	0,0111	<.0001

The coefficients and signs have a direct effect on y* thereby shifting the distribution but no direct interpretation in terms of the effects for the probabilities of the different numbers of car holdings. The car purchase cost index and the petrol price have expected signs, but they are both negligibly small. The income and the distance to work coefficients have unexpected signs. Otherwise it is not obvious what signs we should expect.

The estimates of μ_i and the parameters allow us also to calculate the probabilities of owning different numbers of cars for different variable values of individuals. These probabilities are interpreted as the short run responses to changes in the explanatory variables. As we will see below there is substantial amount of inertia in this model which implies that the long run responses to changes in explanatory variables will be larger. The long run responses have not been calculated here.

As there is no unique effect of independent variables on the different probabilities, one possibility suggested by Wooldridge (2006), is to calculate the effects of changes in independent variables on probabilities for some "model individuals". We have therefore chosen some "typical" individuals; a median man, a median woman etc. and calculated the effects of changes in central variables.

We start with a male with the median disposable income 154 000 SEK per year, without children, living in a urban area, with a distance to work of 30 kilometres, the level of the car purchase cost index in 2005 and a petrol price of 12 SEK/litre and who owned one car the previous year. We then look at how the estimated probabilities of car ownership levels are affected when these variables change. In the following table P_0, P_1 etc. denote the probability of car ownership at the levels zero, one to 3 or more.

Dispos income	Area type	Sex	C	Di	P_{Ft}	P_{Bt}	U	P	Cars (t-1)	P_0	P_1	P_2	P_3
154000	Urban	Male	0	30	100	12	0	0	1	0,05	0,87	0,07	0,001

When we recalculate the probabilities for the upper limit of the lowest disposable income quartile 110 000 SEK per year and for the lower limit of the uppermost quartile 208 000 SEK per year we find that the above calculated probabilities do not change. Hence the income elasticity of the probability of owning a car is extremely small. And, although there is no direct way of comparing the elasticities of the probability of owning a car to the estimates of Matstoms (2002) or of Dargay and Hanly (2007), we may still infer that their calculations indicate that some sensitivity to income is likely. This result clearly contrasts with the findings of the description in Table 3 where a marked correlation between income and car ownership was noted.

At this point we have no explanation to this finding. We do however know from previous studies (Dargay and Hanly, 2007) that a household's ownership of a car is strongly influenced by the number of car driving members of the household. We also know that the disposable income of an individual may be influenced by other individuals in the household. A possible strategy for improving data would be to create links between individuals who are members of the same households.

We now turn to a corresponding median income woman owning one car the previous year. Such women have a higher calculated probability than the corresponding men of ceasing their car ownership and a lower probability of increasing their ownership to two cars.

Dispos income	Area type	Sex	C	Di	P_{Ft}	P_{Bt}	U	P	Cars (t-1)	P_0	P_1	P_2	P_3
154000	Urban	Female	0	30	100	12	0	0	1	0,10	0,86	0,04	0,0004

The calculated probabilities do not change for a disposable incomes of 110 000 SEK per year and of 208 000 SEK per year. The comments on the effect of disposable income changes above apply for women also.

In the next step we recalculate the probabilities for at the median income male etc. but assume he owned no car the previous period. These individuals are very likely to continue not to own a car P_0=0,91 and have a likelihood of P_1=0,09 acquiring one car. The likelihood of acquiring more than one car is negligible.

The likelihood for a woman with the same characteristics to continue to own no car P_0=0,95 is higher, and she is less likely to acquire a car P_1=0,05. The likelihood of acquiring more than one car is likewise negligible.

Recalculating car ownership likelihoods for men assuming they have zero distance to work show that distance has no effect. This is true for women also.

The estimated effect of a price increase for petrol from 12 to 16 SEK have both expected and unexpected effects for male median income earners. The higher petrol price has no effect on the likelihood of owning one car to P_1=0,87 (from P_1=0,87) but it increases the likelihood of owning two cars slightly to P_2=0,08 (from P_2=0,07).

In contrast an increase in car purchase cost index by 10 percent has no discernable effect on the probabilities on the presented level of accuracy.

Young (18–24 years) male median income earners owning a car have a slightly larger likelihood of ceasing their car ownership P_0=0,08 (instead of P_0=0,05) and a smaller probability of increasing it to two P_2=0,05 (instead of P_2=0,07) compared to middle aged men. Men in this age group (18–24 years) are also less likely to acquire a car (P_1=0,06) than middle aged men (P_1=0,09) when they own no car.

Young female median income earners have a considerably larger probability of ceasing their car ownership (P_0=0,14) than young male car owners (P_0=0,08) and considerably lower probability of increasing it (P_2=0,03) compared to young men (P_2=0,06).

Pensioned male median income earners (67- years) have an even larger probability of ceasing their car ownership P_0=0,09 than young men and slightly smaller probabilities of increasing it P_2=0,04 than the young P_2=0,05.

Pensioned female median income earners have a considerably larger probability of ceasing their car ownership P_0=0,16 than pensioned male car owners P_0=0,09.

Now we look at the influence of a male median income earner having three children compared to no children. This decreases the likelihood of owning no car slightly and increases the likelihood of owning one or two cars slightly.

5.5.2 Estimates for rural area inhabitants

Table 5.5 Estimation results for rural area inhabitants.

		Estimate	Standard Error	Pr > ChiSq
Intercept1		-2,49	0,023	<.0001
Intercept2		3,00	0,001	<.0001
Intercept3		4,63	0,002	<.0001
Income		-0,0001	0	<.0001
Dummy for Sex	Male	-0,31	0,0009	<.0001
Children	6	0		
Children	5	0,025	0,012	0,035
Children	4	0,051	0,011	<.0001
Children	3	0,107	0,010	<.0001
Children	2	0,129	0, 010	<.0001
Children	1	0,134	0, 010	<.0001
Distance to work		-0,0002	0	<.0001
Car purchase		-0,0042	0,0001	<.0001
Petrol price		-0,0236	0,001	<.0001
Dummy for young		0,0567	0,002	<.0001
Dummy for pensioned		-0,337	0,001	<.0001
Cars t-1	3	-1,668	0,002	<.0001
Cars t-1	2	0		
Cars t-1	1	1,884	0,001	<.0001
Cars t-1	0	4,804	0,002	<.0001

In the model for rural inhabitants the car purchase cost index and the petrol price also have expected signs. The income and the distance to work coefficients have unexpected signs, but they are both negligibly small. Otherwise it is not obvious what signs we should expect.

As for inhabitants in urban areas we now look at how the estimated probabilities for car ownership levels change when explanatory variables change for inhabitants in rural areas. We start with a male with the median income 154 000 SEK per year, without children, with a distance to work of 30 kilometres, the level of the car purchase cost index in 2005 and petrol price 12 SEK, who owned 1 car the previous year.

Disposable income	Area type	G	C	Di	P_{Ft}	P_{Bt}	U	P	Cars (t-1)	P_0	P_1	P_2	P_3
154000	Rural	M	0	30	100	12	0	0	1	0,04	0,85	0,11	0,002

The likelihood of owning no or one car is slightly lower (P_0=0,04 and P_1=0,85 instead of P_0=0,05 and P_1=0,87) and the likelihood of owning two cars is slightly higher in rural areas than in urban areas (P_2=0,11 instead of P_2=0,07). The values do not change for a disposable income of 110 000 SEK per year and of 208 000 SEK per year. The comments on the small elasticities of income for urban inhabitants apply here also.

Women have a slightly lower probability of owning no $P_0 = 0,07$ (instead $P_0 = 0,10$) and a slightly higher probability of owning two cars $P_2 = 0,06$ (instead of $P_2 = 0,04$) than women in urban areas.

Disposable income	Area type	G	C	Di	P_{Ft}	P_{Bt}	U	P	Cars (t-1)	P_0	P_1	P_2	P_3
154000	Rural	F	0	30	100	12	0	0	1	0,07	0,87	0,06	0,0008

The probabilities do not change for a disposable income at 110 000 SEK per year and at 208 000 SEK per year.

Now look at median income men in the rural areas who owned no car the previous period. These individuals are less likely to continue not to own a car $P_0 = 0,87$ than their urban counterparts ($P_0 = 0,91$) and more likely to acquire a car $P_1 = 0,13$ (instead of $P_0 = 0,09$).

The corresponding numbers for women are that they are also less likely to continue not to own a car $P_0 = 0,93$ than their urban counterparts ($P_0 = 0,95$) and more likely to acquire a car $P_1 = 0,07$ (instead of $P_1 = 0,05$).

When an individual in a rural area owns no car in the previous period he or she is less likely not to own a car in the current period compared to an urban inhabitant. Women however have a significantly larger likelihood of owning no car and a lower likelihood of owning one car, if they had no car the previous year compared to men. These car holding likelihoods are only negligibly affected by income changes in the estimated model. Also note that the likelihood of owning no car is lower and the likelihood of owning a car is higher than in urban areas.

Like in the urban case the distance to work has no discernable effect on the calculated car ownership probabilities.

The estimated effect of a price increase for petrol from 12 to 16 SEK have both expected and unexpected effects for male median income earners. The higher price induces a slightly lower likelihood of owning no $P_0 = 0,03$ (instead of $P_0 = 0,04$) or one car and a slightly higher likelihood of owning two cars $P_2 = 0,13$ (instead of $P_0 = 0,11$).

An increase in car purchase cost index by 10 percent decreases the likelihood of owning no car slightly $P_0 = 0,03$ (instead $P_0 = 0,04$) and $P_1 = 0,85$ (instead of $P_1 = 0,85$) and increases the likelihood of owning two cars slightly $P_2 = 0,12$ (instead of $P_2 = 0,11$).

Young male median income earners in rural areas owning one car are considerably less likely to cease their car ownership and have lower probabilities as their urban area counterparts of continuing owning one car but higher likelihood of increasing it to two. When they have no car they are more likely to acquire a car $P_1 = 0,11$ than their urban area counterparts $P_1 = 0,06$.

Young female median income earners in rural areas are more likely to cease their car ownership $P_0 = 0,08$ than young men ($P_0 = 0,04$) and less likely to increase it. On the

other hand they are less likely to cease their car ownership and are more likely to increase their car ownership than their counterparts in urban areas.

Pensioned male median income earners in rural areas have higher likelihood of ceasing their car ownership $P_0 = 0,08$ and lower likelihood of increasing $P_2 = 0,06$ it than the young.

Pensioned female median income earners are less likely to cease their car ownership than their urban counterparts and more likely to increase it. On the other hand they have a higher likelihood of ceasing their car ownership and than their male counterparts and a lower likelihood of increasing it.

Now we calculate the influence of a male median income earner having three children compared to no children. This decreases the likelihood of owning no car slightly $P_0 = 0,03$ (instead of $P_0 = 0,04$) and increases the likelihood of owning one $P_1 = 0,84$ (instead of $P_1 = 0,85$) or two cars slightly.

5.6 Conclusion

This paper can be viewed as a first step in the analysis of socioeconomic and geographical differences in Swedish car ownership. As we have a uniquely rich data set this opens a potential for a detailed analysis of car ownership in different social groups as well as geographical areas.

Most of the findings in the present paper covering the period 1996 to 2005 are parallel to the results from an earlier Swedish car ownership model (Matstoms, 2002) for the period 1980 to 1995, but some results also go beyond the previous study by explicitly modelling the number of cars owned and by incorporating the following further explanatory variables: distance to work, number of children and car purchase cost index. We can also distinguish differences in determinants of car ownership in urban and rural areas according to a new area criterion.

We have modelled urban and rural areas separately with the intent of highlighting differences between these area types for car ownership. We find that rural inhabitants are more likely to continue owning a car and are less likely to cease owning a car, when they own one, than are urban inhabitants. Rural inhabitants are also more likely to acquire a car and less likely to continue not owning a car, when they own no car, than are urban inhabitants.

The most prominent finding is that car ownership is very persistent. The results suggest that the state dependence (in the form of lagged car ownership) has a completely dominant effect on current car ownership. It accounts for more than 80 percent of the probability that an individual continues to own or not owning a car. For a male person with median disposable income and no car ownership the predicted likelihood of continued non ownership will be more than 80 percent. If on the other hand he does own a car the likelihood of continued ownership will be more than 80 percent. This finding supports the findings from the earlier study. The present study indicates that this persistence is stronger in rural areas than in urban.

The results on exit from and entry to car ownership also support the earlier results. Men are less likely to cease their car ownership and more likely to acquire a car if they do not have one, than women are. Men are also more likely to increase their ownership than women.

For young men (18–24) Matstoms (2002) finds that they have had the largest propensity to acquire cars if they had none. This propensity dropped, however, during the 1990-ties, and in the present study we find a lower propensity to acquire a car than we do for the large group of ages between 25–67. The propensities to cease car ownership are largest for those elder than 67, followed by young and then the middle aged. It is significantly larger for women. In the present study we find that rural inhabitants are less likely to cease car ownership and more likely to acquire a car if they have none, than urban inhabitants.

An anomalous result is that the estimated effects from disposable income are so extremely small compared to what could be expected. This result clearly contrasts with the findings of the descriptive analysis where a marked correlation between income and car ownership was noted. The absence of income effect in this model may be a consequence of the strong effect from persistence. In Matstoms no quantitative elasticities for car ownership probabilities with respect to income are given. Matstoms says however that the car acquisition elasticities have the right sign. In the present study the estimated effects of disposable income changes are insignificant and close to zero.

A second anomaly is that increased petrol prices increases the likelihood of owning two cars and reduces the likelihood of owning no car. The estimated effect of price increases for petrol in urban areas are that it increases the probability of owning two cars and decreases the probability of owning one. In rural areas it decreases the probability of owning no cars significantly and increases the probability of owning two cars.

The effects of car purchase costs have the expected effects in urban areas but anomalous effects in rural areas where it decreases the probability of owning no car and increases the probability of owning two cars. The effects of distance to work have no effects on the probability of owning a car. The effect of having three children instead of none is that the propensity to have no or one car decreases and the propensity to have two increases in both urban and rural areas. The estimated effect of differences in distance to work is very small.

There are no directly comparable calculations from Dargay and Hanly's (2007) results. Dargay and Hanly note that car ownership is positively related to car ownership in the previous period. This comment in addition to the relatively low parameter value in Dargay and Hanly's paper indicate that the effect of previous car ownership is stronger in our data and model.

Furthermore Dargay and Hanly (2007) note that car ownership increases with income. They also find that car ownership is lower in households where the head is a woman. We examine individual car ownership in this paper and do not have data on which individuals form part of a household. We also find lower car ownership likelihoods for women ceteris paribus.

In Dargay and Hanly's estimations car purchase costs have a strong negative impact on car ownership. This impact is estimated to be small in our model. Dargay and Hanly also conclude that the number of children is the least important in determining car ownership. In our model the number of children has considerable effects. A possible explanation for this difference may be a difference in the definition of child. The Swedish definition is without restriction in the child's age. In the UK it appears as it may mean child under the age of 18 years.

The model used expands the detail with which we may describe the sensitivity of individual car ownership to changes in costs, disposable income as well as its

dependence on sex and type of residence area. The results require further development before reliable results for all the effects may be had. The model could be applied to various parts of the population or geographic regions which may be in need of further analysis.

Further research

The most interesting development that we foresee is to connect individuals in the same households. This could allow a more accurate mapping of the income and cars that individuals can utilize. This could also potentially reduce bias in the estimation of the influence of disposable income on car ownership.

Further reductions of the utilization of the data sets could hopefully also allow for application of panel data methods. This could include controlling for unobserved heterogeneity by using a random effects specification.

Finally a deeper more thorough analysis of individuals who cease their car ownership could possibly shed more light on further causes for terminations of car ownership like moving of house, job loss, disposable income loss etc.

5.7 References

Dargay, J., Hanly, M., 2000a. Car ownership in Great Britain: a panel data analysis, Transportation Research Record, 1718, Activity Pattern Analysis and Exploration, Travel Behavior Analysis and Modeling, 83–9.

Dargay, J., Hanly, M., 2000b. Car ownership in Great Britain: a panel data analysis, European Transport Conference, September 2000, Cambridge, TSU Ref 2000/17.

Dargay J. and Hanly M. 2007, Volatility of car ownership, commuting mode and time in the UK, Transportation Research A, 41, 934–948.

Dargay, J., Vythoulkas, P., 1999. Estimation of dynamic car ownership model: a pseudo-panel approach. Journal of Transport Economics and Policy 33 (3), 283–302.

de Jong, G.C., Fox, J., Daly, A., Pieters, M., Smit, R., 2004. Comparison of car ownership models. Transport Reviews 24 (4), 379–408.

Kitamura, R., Bunch, D.S., 1990. Heterogeneity and state dependence in household car ownership: a panel analysis using ordered response probit models with error components. In: Koshi, M. (Ed.), Transportation and Traffic Theory. Elsevier Science Publishing Co., Amsterdam.

Matstoms, P., 2002, Modeller och prognoser för arealt bilinnehav i Sverige. VTI rapport 476.

Wooldridge, J., 2006, Introductory Econometrics – A modern approach, Thomson-South Western.

6 Integrated references

von Bahr, J., 2009, Köra bil på landet och rädda klimatet, FORES Studie 2009:2.

Bjørner, Thomas Bue, 1999, Demand for Car Ownership and Car Use in Denmark: A Micro Econometric Model, International Journal of Transport Economics, Volume 26, No 3, sidorna 377–95.

Dargay, Joyce, 2007, The effect of prices and income on car travel in the UK, Transport Research Part A, Volume 41 pp. 949–960.

Dargay, Joyce and Hanly, Mark, 2004, Land use and mobility, Paper presented at World Conference on Transport Research.

Dargay, Joyce and Hanly, Mark, 2007, Volatility of car ownership, commuting mode and time in the UK, Transportation research Part A, Volume 41, pp. 934–948.

Dargay, J. and Vythoulkas, P., 1999, Estimation of dynamic car ownership model: a pseudo-panel approach. Journal of Transport Economics and Policy 33 (3), 283–302.

Dargay, J., Hanly, M., 2000a. Car ownership in Great Britain: a panel data analysis, Transportation Research Record, 1718, Activity Pattern Analysis and Exploration, Travel Behavior Analysis and Modeling, 83-9.

Dargay, J., Hanly, M., 2000b. Car ownership in Great Britain: a panel data analysis, European Transport Conference, September 2000, Cambridge, TSU Ref 2000/17.

Dargay J. and Hanly M. 2007, Volatility of car ownership, commuting mode and time in the UK, Transportation Research A, 41, 934–948.

Dargay, J., Vythoulkas, P., 1999. Estimation of dynamic car ownership model: a pseudo-panel approach. Journal of Transport Economics and Policy 33 (3), 283–302.

Donald, Stephen and Lang, Kevin, 2007, Inference with Differences and Other Panel Data, The Review of Economics and Statistics, Volume 89, Issue 2, pp. 221–233.

Farrington, Gray, Martin and Roberts, 1998, Car Dependence in Rural Scotland: Challenges and Policies, Scottish Office Central Research Unit. HMSO, Edinburgh.

Glesbygdsverket, 2007, Fakta.

Graham, D. and Glaister, S., 2002, Review of income and price elasticities of demand for road traffic, Center for Transport Studies, Imperial College of Science London.

Gray, D.; Farrington, J.; Shaw, J.; Martin, S.; Roberts, D., 2001, Car dependence in rural Scotland: Transport policy, devolution and the impact of the fuel duty escalator, Journal of Rural Studies 17, No 1, pp. 113–125.

Jansson J.-O. and Wall R., 1994, Bensinskatteförändringars effekter, Rapport till Expertgruppen för Studier i offentlig ekonomi.

Johansson-Stenman, Olof, 2002, Estimating individual driving distance by car and public transport use in Sweden, Applied Economics, Volume 34, Number 8, pp. 959–967

Jong, G.C. de (1990) An indirect utility model of car ownership and private car use, European Economic Review, 34, pp. 971–985.

Jong, G.C. de and Gunn H., 2001, Recent evidence on car cost and time elasticities of travel demand in Europe, Journal of Transport Economics and Policy 35. pp. 137–160.

de Jong, G.C., Fox, J., Daly, A., Pieters, M., Smit, R., 2004. Comparison of car ownership models. Transport Reviews 24 (4), 379–408.

Kennedy, Peter, 2005, Oh No! I Got the Wrong Sign! What should I Do? Journal of Economic Education, Volume 36, Number 1, pp. 77–92

Kitamura, R., Bunch, D.S., 1990. Heterogeneity and state dependence in household car ownership: a panel analysis using ordered response probit models with error components. In: Koshi, M. (Ed.), Transportation and Traffic Theory. Elsevier Science Publishing Co., Amsterdam.

Kloek, Teun, 1981, OLS Estimation in a Model Where a Microvariable is explained by Aggregates and Contemporaneous Disturbances are Equicorrelated" Econometrica, Vol. 49, pp. 205–207

Krantz, L.-G., 1999, Rörlighetens mångfald och förändring, Befolkningens dagliga resande I Sverige 1978 och 1996, Meddelanden från Göteborgs universitets geografiska institutioner, Serie B, Nr 95, Handelshögskolan vid Göteborgs universitet.

Matstoms, P., 2002, Modeller och prognoser för arealt bilinnehav i Sverige. VTI rapport 476.

Moulton, Brent, 1990, An Illustration of a Pitfall in Estimating the Effects of Aggreagte Variables on Micro Units, The Review of Economics and Statistics, Volume 72, No. 2, pp. 334–338.

Petersen, M., 2006, Estimating standard errors in finance panel data sets: Comparing approaches. Kellogg Finance Department Working Paper, 329.

Prop. 2008/09:93, Mål för framtidens resor och transporter.

Rouwendal, J. och de Vries, F., 1999, Short term reactions to changes in fuel prices - a panel data analysis, International Journal of Transport Economics, 3 Volume 26, sidorna 331–350.

Riks-RVU/RES 1994-2001.

SIKA, 2007, RES 2005–2006, Den nationella resvaneundersökningen, SIKA statistics 2007:19.

Statistics Sweden, 2002, Tätorter 2000, Statistiska meddelanden MI 38 SM 0101.

Vagland, Å. and Pyddoke, R., 2006, Hur hushållen anpassar sig till ändrade kostnader för bilinnehav och bilanvändning? VTI-rapport 545.

Wooldridge, J., 2006, Introductory Econometrics – A modern approach, Thomson-South Western.

Appendix: Tillgängliga data i studiens databas

Följande variabler har levererats från Statistiska Centralbyrån, utom bensinpris som kommer från Svenska Petroleum Institutet. Varje variabel levereras som ett årsvärde gällande i vid årsskiftet till nästföljande år.

Individer	**Finns i databasen för**
Födelseår	1980–2005
Kön	1980–2005
Antal barn i fastigheten	1998–2005
Bostadens rut-koordinat	1980–2005
Bostadens samskod	1980–2005
Bostadens kommunkod	1980–2005
Bostadens länskod	1980–2005
Sysselsättningsstatus	1985–2005
Studerandestatus	1985–2005
Näringsgrenskod	1985–2005
Arbetsställets rut-koordinat	1985–2005
Arbetsställets samskod	1985–2005
Arbetsställets kommunkod	1985–2005
Arbetsställets länskod	1985–2005
Disponibel inkomst[13]	1980–2005
Förmögenhet	1980–2005
Antal ägda personbilar	1980–2005
Årlig körsträcka för varje bil ägd av individen	1995–2005
Innehav av B-körkort	2003–2005
Fågelvägsavståndet från bostad till arbetsplats har beräknats[14]	1996–2005
Tidsseriedata	
Bensinpriser i fasta priser	1995–2005
Bilinköpsindex	1995–2005

[13] Definierad i appendix till kapitel 1
[14] Kan beräknas även för 1985-1995.

Appendix: Available data in the study´s database

The following variables have been delivered by Statistics Sweden, except for the petrol price which was received from the Swedish Petroleum Institute. Every variable represents yearly variables as recorded close to the end of each year.

Individuals	**Are available for**
Year of birth	1980–2005
Sex	1980–2005
The number of children	1998–2005
The coordinates of the home	1980–2005
The area code (samskod) of the home	1980–2005
The municipality code of the home	1980–2005
The county code the home	1980–2005
Employment status	1985–2005
Student status	1985–2005
Industry code	1985–2005
The coordinates of the workplace	1985–2005
The area code (samskod) of the workplace	1985–2005
The municipality code of the workplace	1985–2005
The county code of the workplace	1985–2005
Disposable income[15]	1980–2005
Capital	1980–2005
The number of cars owned	1980–2005
Odometer reading from each car owned by the individual	1995–2005
B drivers license	2003–2005
From the coordinates of the home and of the workplace the distance between the the home and the workplace is calculated as the crow flies[16]	1996–2005
Timeseriesdata	
Petrol prices in real terms	1995–2005
Car purchase cost index	1995–2005

[15] Defined in appendix to chapter 2
[16] Can be calculated for the years 1985-1995 also.

www.vti.se
vti@vti.se

VTI är ett oberoende och internationellt framstående forskningsinstitut som arbetar med forskning och utveckling inom transportsektorn. Vi arbetar med samtliga trafikslag och kärnkompetensen finns inom områdena säkerhet, ekonomi, miljö, trafik- och transportanalys, beteende och samspel mellan människa-fordon-transportsystem samt inom vägkonstruktion, drift och underhåll. VTI är världsledande inom ett flertal områden, till exempel simulatorteknik. VTI har tjänster som sträcker sig från förstudier, oberoende kvalificerade utredningar och expertutlåtanden till projektledning samt forskning och utveckling. Vår tekniska utrustning består bland annat av körsimulatorer för väg- och järnvägstrafik, väglaboratorium, däckprovnings-anläggning, krockbanor och mycket mer. Vi kan även erbjuda ett brett utbud av kurser och seminarier inom transportområdet.

VTI is an independent, internationally outstanding research institute which is engaged on research and development in the transport sector. Our work covers all modes, and our core competence is in the fields of safety, economy, environment, traffic and transport analysis, behaviour and the man-vehicle-transport system interaction, and in road design, operation and maintenance. VTI is a world leader in several areas, for instance in simulator technology. VTI provides services ranging from preliminary studies, highlevel independent investigations and expert statements to project management, research and development. Our technical equipment includes driving simulators for road and rail traffic, a road laboratory, a tyre testing facility, crash tracks and a lot more. We can also offer a broad selection of courses and seminars in the field of transport.

vti

HUVUDKONTOR/HEAD OFFICE
LINKÖPING
POST/MAIL SE-581 95 LINKÖPING
TEL +46(0)13 20 40 00
www.vti.se

BORLÄNGE
POST/MAIL BOX 920
SE-781 29 BORLÄNGE
TEL +46 (0)243 446 860

STOCKHOLM
POST/MAIL BOX 55685
SE-102 15 STOCKHOLM
TEL +46 (0)8 555 770 20

GÖTEBORG
POST/MAIL BOX 8077
SE-402 78 GÖTEBORG
TEL +46 (0)31 750 26 00