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National and Regional Aspects of Demographic Change

Edited by

Tobias Kronenberg and Wilhelm Kuckshinrichs

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National and Regional Aspects of Demographic Change

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In late 2009 our highly appreciated colleague Dr. Wolfram Krewitt faded away. With his competence, his friendly insistence, and his distinct sense of humour, he contributed significantly to the evaluation success, the team-building processes, as well as to the outcomes of the project.

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List of Abbreviations

BBR	Bundesamt für Bauwesen und Raumordnung (Federal Office for Building and Regional Planning)
CO_2	Carbon dioxide
COICOP	Classification of individual consumption by purpose
CPA	Classification of products by activity
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
EEA	Environmental economic accounts
EVS	Einkommens- und Verbrauchsstichprobe (expenditure and consumption survey)
GDP	Gross domestic product
HH	Hamburg
MV	Mecklenburg-Vorpommern
NO_X	Nitrogen oxide
NPISH	non-profit institutions serving households
SEA	Systematisches Verzeichnis der Einnahmen und Ausgaben (German version of COICOP)
StBA	Statistisches Bundesamt (Federal Statistical Office)
TFR	Total fertility rate

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Chapter 1
Introduction to Infrastructure and Demography (InfraDem)

Wilhelm Kuckshinrichs

Abstract Infrastructures link society, technology and the environment, and form the basis for the competitiveness and prosperity of a national economy. Classic examples are the transport networks (road, rail and waterways), as well as supply and disposal systems (energy, water, communications networks). Demographic development and the concept of sustainable development are gaining increasing importance. The following chapter sets the frame for a study on demography and infrastructures under the concept of sustainable development.

Keywords Infrastructure · Energy · Transport · Demography · Sustainable development

1.1 Background and Aim of the Project

Infrastructures link society, technology and the environment, and form the basis for the competitiveness and prosperity of a national economy. This study concentrates on the material infrastructure.[1] In this sense, the term infrastructure describes the basic provision of a national economy (of a country or region) with installations that can be considered as part of the capital stock of a national economy which advances the performance of the economic activity. Classic examples are the transport networks (road, rail and waterways), as well as supply and disposal systems (energy, water, communications networks). If these installations did not exist, the production of economic goods and the performance of services would be impossible, or at any rate they would be much less efficient (economy-related infrastructure).

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[1] In addition to material infrastructures, immaterial and institutional infrastructures exist. These comprise infrastructure in a broader sense, i.e. human infrastructure, and the institutional framework, i.e. legal, economic and social systems.

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Specific problems associated with material infrastructure, such as sensitivity and vulnerability, have long been known and they have been investigated adequately (Farrell, Zerriffi, & Dowlatabadi, 2004). The application of the guiding principle of sustainable development to material infrastructure is, on the contrary, rather new (Auer, 2004), especially in connection with demographic change (Just, 2004; Peterson, 2004). For example, in the Enquête Commissions on Demographic Change (Deutscher Bundestag, 2002a) and on Sustainable Energy Supply (Deutscher Bundestag, 2002b), the topics of demographic development and sustainable energy systems were treated extensively but separately. A synthesis of the two topics, particularly under the heading of sustainable development, has yet to be addressed.

For Germany and nearly all other European states, demographic development is expected to involve a decline in the domestic population, a change in the age pyramid and a disproportionate regional development of population densities (Jackson, 2003). The extent of immigration is open. Although other countries and regions in the world, such as China, await an increasing population, they will also be confronted with a similar development, albeit staggered in time for the age pyramid and regional developments (England, 2005).

This demographic change will be accompanied by a decline and a change in the demand for infrastructure services. An ageing population will need different services and it will use infrastructures in a different way, thus putting pressure on the system (Table 1.1). From the aspect of settlement structure, on the one hand, the spatial relocation of the population is gaining significance and will have an impact on the spatial distribution of the infrastructures. At the same time, the rising percentage of older people will have an effect on settlement structures and involve new functional demands on towns and communities, e.g. with respect to designing accommodation adapted to the needs of seniors. In the near future, ageing will dramatically increase, above all in suburban areas characterised by high mobility rates. The spatial distribution of the apparent demographic development will also be determined by technological factors (e.g. information and communication technologies), by political factors such as the European Union (regional policy), and by concentration processes (draining of areas vs. new conurbations). Concepts for

Table 1.1 Key features and pressure on systems

	Demographic key features		
	Decreasing population	Ageing	New regional distribution
Economic and social systems	++	++	+
End-use products	+	+	–
Pers./Inst. infrastructures	+	++	+
Grid-bound infrastructures	++ (Efficiency, capacity decrease)	+(+) (User behaviour)	++ (Demand, capacity use)

sustainable infrastructure provision must be analysed on the micro-level (regionally differentiated and adapted accordingly) and on the macro-level (nationwide).

Technical, economic and institutional policy solutions must be found, if the use of infrastructures in line with the economic, ecological and social sub-objectives of the sustainable development concept (including the conservation of resources and security) is also to be ensured in the long term. These solutions must meet the outlined requirements.

The aim of the project is to develop a methodology that will allow us to assess infrastructure projections according to the principles and rules of sustainable development and to develop corresponding strategies (Fig. 1.1).

The InfraDem approach will develop and use three core elements:

- Bottom-up models for a technology-oriented analysis of selected infrastructures, more precisely on energy and transports. These models can be used for representative regions.
- Top-down models for the analysis of the macro-effects of infrastructure-specific aspects integrating general infrastructure aspects.
- An indicator-based assessment frame for the evaluation of the sustainability of infrastructure policies. Indicators selected for assessment will be quantified on the basis of model runs to allow for prospective analysis. With respect to the model, the number of indicators must be kept fairly small, meaning that relevant indicators will have to be identified. The type of model will allow us to quantify, for example, income generation, energy use, emissions and labour demand, thus tackling each dimension of the three-pillar approach of sustainable development. With respect to strategy, the predominantly technology-focused and

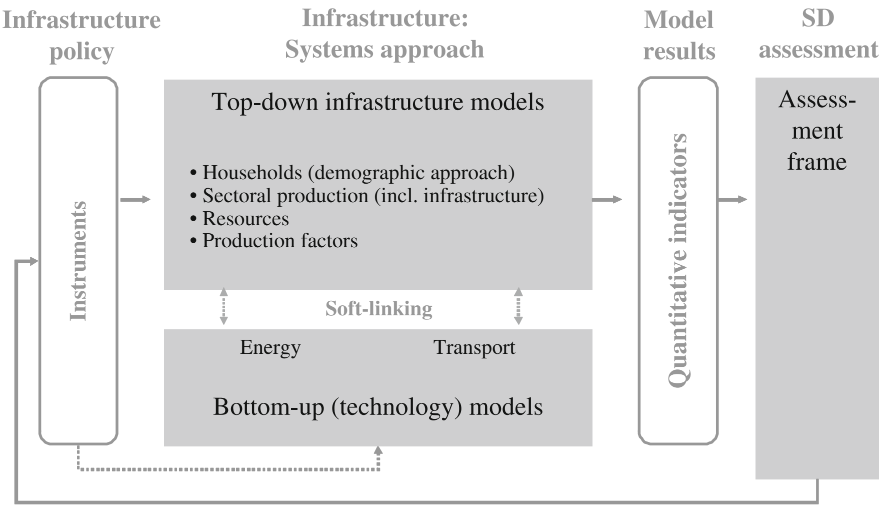

Fig. 1.1 InfraDem approach to analyse, develop and assess policies for grid-bound infrastructures

sector-specific approaches have to be completed by sector-general approaches which allow new forms of institutional and instrumental arrangements. The focus of the project is on grid-bound material infrastructures for Germany, i.e. on electricity and transport, but the approach provides a concept that can be readily adapted to other country studies or the study of other material infrastructures.

This study was conducted by a team of people from several systems analysis groups, including Forschungszentrum Jülich (FZJ), Institute for Energy Research – Systems Analysis and Technology Evaluation (IEF-STE) [Project coordination], the German Aerospace Center (DLR), and the Rostock Center for the Study of Demographic Change.

1.2 State of the Art

According to the broad approach, it is necessary to identify the state of the art for three research topics: infrastructure analysis, demographic development and sustainable development assessments.

1.2.1 Infrastructure – Intergenerational Basis for Economic Welfare

The extensive literature on current material infrastructure research can be assigned to four clusters: (1) engineering; (2) safety, reliability, vulnerability; (3) regional science and urban planning; and (4) economics. These clusters look at infrastructure aspects from different perspectives:

- The engineering approaches deal with technical solutions for specific infrastructure aspects, e.g. the hydrogen economy (Clark, Rifkin, O'Connor, Swisher, Lipman, & Rambach, 2005).
- After the 9/11 terrorist attack on New York and a number of electricity blackouts in the US and in Europe, several studies concentrated on the safety, reliability and vulnerability of infrastructures (Farrell, Zerriffi, Dowlatabadi, 2004; GAO, 2004).
- Regional science and urban planning deal with the impact of infrastructures on regional and urban development from both a housing and an economic perspective. Particular attention has been drawn to sustainability aspects of the current development, but also to the integration of national developments in the European context (Dosch, 2002).
- The economic perspective concentrates on the one hand on the public good's character and the economic efficiency of infrastructures and network industries (CPB, 2004; Vickerman, 2004) and, on the other hand, on the infrastructural impact on economic growth (Lau & Sin, 1997; Sanchez-Robles, 1998).

1.2.2 Demographic Development – An Intergenerational Trend

At the beginning of the twenty-first century, demographic developments constitute a historical challenge for the social and economic situation and for the political response of the majority of countries (Kinsella & Phillips, 2005). On the one hand, there are countries with high population growth rates and, on the other hand, there are countries like Germany, which expect a decreasing population (BBR, 2005). In particular, for Germany and other European countries, it is the coincidence and the dynamics of population reduction, ageing and regional redistribution that pose a new challenge for which there is no historical precedent.

While the extent of the demographic change is becoming clearer, the analysis of the impacts on nationwide infrastructure sectors is just beginning (O'Neill & Chen, 2002).

1.2.3 Sustainable Development Assessment

Few concepts have attracted as much attention as that of sustainable development. Since the publication of the Brundtland Report, the sustainability concept and its implementation have been discussed by the academic community and society in general (Beckerman, 1995; Daly, 1995; Solow, 1993). Today, sustainable development is a stated policy objective of many nations (GFG, 2002). Consequently, a broader range of problems is interpreted in terms of sustainable development. This is also true of demographic development.

Sustainable development indicators describe and define issues and circumstances which characterise sustainable development and work out the additional value of the sustainability paradigm. Sustainability indicators measure the difference between current conditions and a reference situation defined as sustainable and/or a reference technology. The availability of indicators is a condition for the conversion of the model of sustainable development into policies (SRU, 2002).

Over the last 15 years, three main concepts have been developed for the measurement of sustainability: (1) the three-/four-pillar concept; (2) the ecological concept based on the strong sustainability paradigm; and (3) the capital concept based on the weak sustainability paradigm.

The concepts differ in the significance they attach to humans in the sustainability system. The capital concept sets humans at the centre of its analysis, whereas the ecological concept sees humans as part of the overall ecological system. Within the three-/four-pillar concept, there is different emphasis concerning the significance of humans in a sustainability concept. Generally, the three-pillar concept refers to the fact that for sustainable development, economic, social and ecological questions and problems have to be solved simultaneously. Some concepts contain the institutions as a fourth pillar. Following this concept, concentrating on one pillar would be insufficient for sustainable development, since each pillar is of central importance for the implementation of sustainability and therefore cannot be neglected.

The three-/four pillars are located in close relation to each other and can only be arranged and described together as a holistic system for sustainable development.

1.3 Outline of the Content

This book is divided into four parts.

Part I of the book provides an analysis of demographic change and infrastructure use from a macro-economic perspective. In Chapter 2, *Stephan Kühntopf*, *Thusnelda Tivig* and *Robert Stelter* lay out the economic and demographic trends that form the background of the subsequent analysis. They develop a consistent scenario for the development of key economic figures such as GDP, unemployment, and imports of energy commodities. Based on these developments, they construct population and household projections for Germany as a whole and for two selected regions, the federal states of Hamburg (HH) and Mecklenburg-Western Pomerania (MV).

In Chapter 3, *Joachim Geske* presents an overlapping generations model (OLG model) for Germany. This macro-economic approach studies the economic impacts of demographic change which are of special interest for grid-bound infrastructures, i.e. the savings decision of households and the pace of capital accumulation.

In Chapter 4, *Tobias Kronenberg* analyses demographically induced changes in the structure of final demand and infrastructure use on a more disaggregated level. The analysis is based on micro-data from a household survey and on an extended input–output approach as well as sustainability indicators for energy, CO_2, and NO_x. The approach is used for Germany and the two regions HH and MV.

Part II consists of studies of specific types of infrastructures, following a bottom-up approach. In Chapter 5, *Markus Mehlin*, *Rita Cyganski* and *Anne Klein-Hitpaß* focus on the main determinants for the future travel demand and the results with respect to infrastructures. The analysis is based on a microscopic activity-based demand model for the federal states of Hamburg and Mecklenburg-Western Pomerania.

In Chapter 6, *Michael Hepting*, *Henry Pak* and *Dieter Wilken* study the demand for air transport and its consequences for the airports of Hamburg and Rostock (MVP). The analysis is based on a simulation approach for air transport development.

In Chapter 7, *Thomas Pregger*, *Joachim Nitsch* and *Wolfram Krewitt* discuss the impact of demographic developments on the German energy system, especially for the implementation of renewable energy targets and energy efficiency measures. The analysis is closely tied to the German Lead Scenario of the Ministry of Environment and Reactor Safety (BMU).

In Chapter 8, *Christoph Schillings* and *Sonja Simon* focus on the provision of district heat for the regions HH and MV. Their analysis is based on spatial modelling.

Part III turns to the social and cultural determinants of infrastructure demand. In Chapter 9, *Anne Klein-Hitpaß* and *Barbara Lenz* give a comprehensive overview of the empirical findings on the mobility behaviour of seniors followed by a simulation of future transport demand. The analysis is based on the activity-based demand model which is also used in Chapter 5.

In Chapter 10, *Kerstin Engel*, *Patrick Hansen* and *Tobias Kronenberg* provide results for the energy demand of households. The analysis is based on an econometric analysis of a set of micro-data and for Germany.

Part IV integrates the studies from both macro- and micro-perspectives, coming to an evaluation of the findings and revealing some policy options. In Chapter 11, *Hermann Keimel* and *Holger Schlör* develop the sustainability concept used in the InfraDem project together with a coherent set of sustainability indicators. The concept is based on the one hand on the national strategy for sustainable development of the German government, while on the other, it mainly deals with the issue of transferring the national strategy to the regional level of federal states.

Finally, in Chapter 12, *Wilhelm Kuckshinrichs, Tobias Kronenberg* and *Joachim Geske* provide a synthesis of the previous chapters from a policy point of view. They summarise the main findings on the relationship between demographic change and infrastructure use. Based on these findings, several policy options as well as their economic as social repercussions are discussed.

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Part I
The Macroeconomic Perspective

Chapter 2
The Setting: Demographic Trends and Economic Development in Germany and Two Selected Regions

Stephan Kühntopf, Thusnelda Tivig, and Robert Stelter

Abstract This chapter deals with the demographic and economic development in Germany and its federal states Hamburg and Mecklenburg-Western Pomerania between 2005 and 2030. It contains a common demographic-change framework and projection as input for all infrastructure models used or constructed within the InfraDem project. Germany is likely to experience ageing and shrinking of the population, but with large regional differences. For example, demographic change is expected to be exceptionally weak in Hamburg and particularly strong in Mecklenburg-Western Pomerania. The labour force is shrinking more strongly than the total population all over; it could even shrink in Hamburg, where the total population is still growing. The number of households is projected to increase and their size to decrease. Ageing is occurring within the smaller households; larger households (three and more members) stay young or are becoming even younger. The gross domestic product is expected to grow both in total and per capita, but at diminishing rates, and in regions with strong demographic change to a lesser extent.

Keywords Demographic trends · Population projection · Household projection · Labour force projection · Macroeconomic development

2.1 Introduction

Demographic and economic developments are major determinants of the demand for transport and energy infrastructure. The focus of the InfraDem project is on the demographic impact. The task of the Rostock Center in this project was to draw up a common demographic-change framework, and to provide demographic and economic projections as input for the infrastructure models used by the partners in the project.

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The chapter is structured as follows. Section 2.2 describes the framework of demographic change and presents population projections for Germany and two selected federal states: Hamburg and Mecklenburg-Western Pomerania. Section 2.3 briefly describes the method of household projections and sums up our results in terms of household members and main earners. Section 2.4 deals with the labour force projections. Section 2.5 is devoted to the development of gross domestic product and exports. Finally, Section 2.6 concludes.

2.2 Demographic Trends

In the twenty-first century, most countries and regions of the world are expected to undergo a process of demographic change. Demographic change here means the ageing of society with the perspective of the population shrinking. It is the result of increasing life expectancy and of low fertility. Migration is locally compensating or accelerating these developments. Demographic change is accompanied by societal change in many fields, leading most often to an increase in diversity.

With 43.9 years, Germany currently has the second highest median age in the world – only Japan's population is older. In 2050, it is projected that Germany will be among the oldest nations with an average age of 51.7 and Japan will be the oldest with 55.1 years (United Nations, 2009). In Tivig and Kühntopf (2009), we calculated that with a mean age of 41.8 years, Germany was second oldest among the 27 EU countries in 2004 (after Italy), and that with a mean age of 46.9 years, it will be third oldest in 2030, after Italy and Bulgaria.[1] The natural population development has been negative since 1972, but until 2002 it was compensated by net immigration in most years. Since 2003, net immigration is no longer filling the gap opened by natural population shrinking.

Demographic trends show high regional variance. Differences within countries are thereby often larger than differences between countries.[2] Germany displays a high demographic diversity for two reasons: reunification and federalism. Reunification brought together regions with a very different demographic history in more recent times (based, in part, on differences in population policies). It also disrupted the demographic development in the former socialist regions, leading to a sharp decline in fertility, high population outflows to Western regions, and a rapid increase in life expectancy. Reunification thus laid the foundation for long-lasting regional differences in Germany's demographic trends. The federal structure adds to this insofar as family-relevant infrastructure developments, e.g. in the child-care sector or in terms of schooling duration and organisation, are to a large extent the responsibility of the state and not that of the federal government. In order to account for the pronounced regional differences in demographic trends in Germany,

[1] For a comparison of different measures of ageing see Henseke, Hetze, and Tivig (2009) and the literature cited there.

[2] See Tivig and Kühntopf (2009) for regional and national differences in the European Union.

we will focus on two geographically nearby but in most other respects highly diverse regions: the city-state of Hamburg (HH) and the large-area state of Mecklenburg-Western Pomerania (MV). What they do have in common, besides being located in the North and sharing some Hanseatic traditions, is the current number of inhabitants: roughly 1.7 million each. Demographic prospects are, however, extremely different. MV stands as a model for regions with a rural settlement structure and bleak economic perspectives, where emigration of the young reinforces the rapid ageing and shrinking of the population. HH serves as an example of an urban region with a prosperous economy attracting immigrants, which successfully works against the trends of ageing and shrinking.

Population projections are naturally uncertain, the most uncertain component being migration. The reason is that migration reacts to a much higher extent than fertility and mortality to current socio-economic and political developments, and not only to major disruptions like wars, changes of the political regime, or – in the case of Germany – the reunification process. The usual way to account for uncertainty in deterministic models is to calculate several scenarios.[3] The projections are model calculations using the cohort component method; they show how the population would evolve if the underlying assumptions apply.[4] The assumptions concern vital rates and migration (age- and sex-specific fertility, mortality and migration rates), and correlations between these demographic components. For Germany, we selected two variants calculated by the Federal Statistical Office (Statistisches Bundesamt, StBA). For the two regions, we made two projections for each, varying the assumptions on migration, but not those regarding fertility and mortality; correlations between the demographic components were assumed to be perfect in all cases. The time frame for all projections was the period between 2006 and 2030, taking the population at the end of 2005 as the starting point.

2.2.1 Demographic Trends in Germany

The German Federal Statistical Office has provided coordinated population projections at the state level since 1965. The projections are coordinated with the statistical offices of the 16 federal states; assumptions are harmonised and the calculation method is the same. The most recent, 11th coordinated population projection (StBA, 2006) ranges up to 2050 and is based on three assumptions on fertility trends, two assumptions on mortality trends, and two assumptions on migration trends, yielding twelve possible variants, which are supplemented by three further and more hypothetical projections. For reasons explained below, we selected the variants 3-W1 and

[3]The alternative is stochastic forecasts. See a.o. Alho and Spencer (1985) and for a comparison of methods Lee (1998). Lutz and Scherbov (1998) as well as Härdle and Myšičková (2009) provide among others probabilistic forecasts for Germany. For a quick comparative view on a deterministic projection and a stochastic population forecast for Germany see Tivig and Hetze (2007, p. 13).

[4]Smith et al. (2001) provide a good explanation of the method.

3-W2 as our basis; the latter is also termed "relatively young population" because the implied age structure is the youngest among the 12 projection variants.

Both variants are based on the most optimistic of the three fertility trends considered in the projection. The conventional fertility measure is the total fertility rate (TFR). This is the average number of children that would be born to a woman if she experienced the current age-specific fertility rates over her lifetime. The West German TFR has oscillated around 1.4 since the mid 1970s, while the TFR in East Germany was much higher between 1975 and 1989 (up to 1.94 in 1980), but much lower after German reunification, reaching a minimum of 0.77 in 1994. By 2007, the East German TFR had almost reached the West German level of 1.37.[5] Due to the long-term trend in West Germany, the standard assumption for future TFR development is 1.4. However, the age-specific fertility rates underlying TFR have strongly changed in the past and still keep changing, with the major behavioural change being the postponement of births. In Germany, the mean age of women at childbirth increased from 26.2 years in the mid 1970s to 30.2 years in 2007 (Tivig & Hetze, 2007, p. 18; StBA, 2009). Ignoring these behavioural changes (demographers speak of "tempo effects") leads to an underestimation of the average number of children by the conventional TFR (Bongaarts & Feeney, 1998). Adjusting the TFR to these changes yields an average value of about 1.6 children per woman in Germany since the 1980s. This value corresponds to the completed fertility rates of women born in the 1950s and 1960s (Tivig & Hetze, 2007, p. 16). However, the postponement of births is subject to biological limits and late maternity – according to the current definition of the World Health Organization, taking place at age 35 and older – might continue to be exceptional, despite medical progress. The "tempo effects" will then diminish and the TFR will increasingly approach the adjusted TFR. Recent family policy measures in Germany, like the introduction of a parental benefit (Elterngeld) as well as the increasing availability of childcare services will most likely also lead to an increase in fertility rates. For these reasons, we depart from the standard assumption on the fertility trend and consider the two population projections of the Federal Statistical Office that assume that the TFR in Germany will increase to 1.6 until 2025 and remain constant thereafter.

The standard measure for mortality is life expectancy at birth. In Germany, it is rising steadily: initially due to decreasing mortality rates at young and middle ages, and in more recent decades primarily due to decreasing mortality at older ages. The StBA considers two trends in its coordinated population projection. Both assume that the increase in life expectancy in Germany will continue; but the basic assumption is that it will do so at a diminishing rate. The alternative assumption is that the rate of increase will follow the trend that has existed since 1970. In the basic variant, life expectancy at birth is expected to increase from 76.9 years in 2005/2007 to 80.6 in 2030 for men, while women are likely to experience a rise from 82.3 to 85.6 years over the same period. The gender gap in life expectancy will thus close

[5]Most recent numbers show that in 2008 the East German TFR of 1.40 exceeded the West German value of 1.37 for the first time since 1990 (StBA, 2009).

slightly, but it is nevertheless projected to encompass 5 years. We follow the basic assumption for two reasons. Firstly, in a study on the mortality of German nuns and monks, Luy (2003) presents very suggestive evidence for the hypothesis that non-biological risk factors play a major role in mortality differences between women and men in the general population. Nuns and monks, who live under nearly identical conditions, show only small differences in life expectancy at the age of 25, with monks living on average 5 years longer than men in the general population and nuns nearly as long as women in the general population. As the lifestyle and work-style of women increasingly approaches that of men, it seems plausible to assume that the rise in life expectancy of women will be somewhat smaller in future. Secondly, the increase in risk factors such as obesity and overweight (in adulthood as well as in childhood) may also contribute to a slowdown in the trend of increasing longevity for both sexes (Olshansky, Carnes, & Désesquelles, 2001), particularly under conditions of rising financial pressure exerted by demographic change on the German health care system.[6]

The third demographic component, migration, showed large fluctuations in the past in Germany. On average, about 577,000 persons emigrated annually between 1965 and 2007, and 675,000 since 1990. Immigration numbers show a much larger range, influenced by policy measures like bilateral agreements on labour recruitment between 1955 and 1973, the affiliation of repatriates of German origin since the late 1980s, agreements on family reunion and asylum granting. International migratory movements occur particularly at working age and are highest between age 20 and 25 with men migrating more often than women (StBA, 2006, p. 47). The immigration numbers were lowest in 1983 (354,000) and highest in 1992 (1.5 million), yielding an average of 784,000 in the long-run and 947,000 since 1990. Net external migration was generally positive, and since 1965, it has only been negative in 7 years, the last of which was 1984.[7] The long-term average for net migration is 207,000, while in the medium term, it is 272,000. However, net migration in recent years has been much lower: on average 98,000 in the period 2002–2007 and almost zero since 2006. Given these large differences, migration is difficult to forecast. The 11th coordinated population projection contains two assumptions regarding the annual balance of external migration: 100,000 (W1) and 200,000 (W2). We consider both scenarios, with a slight preference for the lower variant, given the development in recent years.

In what follows, in consistency with our regional population projections, we speak about the variants L for "low" instead of 3-W1 (low net migration, low population number) and H for "high" instead of 3-W2 (high migration balance, high number of inhabitants). Figure 2.1 shows the age structure of Germany in 2005 and 2030. The 82.4 million inhabitants in 2005 are distributed unevenly over the ages and the gap around age 60 is a consequence of World War II. The number of children

[6] However, Oeppen and Vaupel (2002) show that the record life expectancy followed a linear trend so far.

[7] Provisional data shows a negative migration balance for 2008 as well.

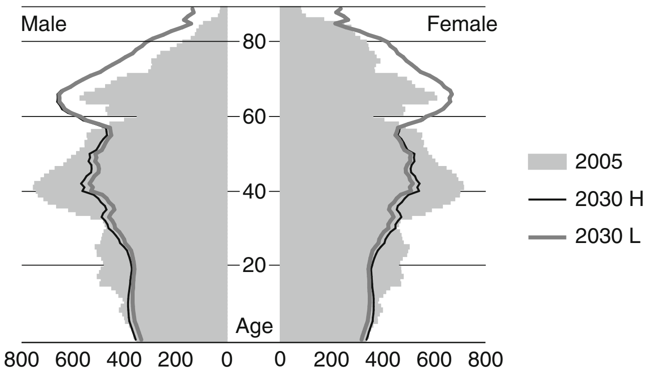

Fig. 2.1 Age pyramid for Germany in 2005 and 2030 (in thousands). (Data source: Federal Statistical Office.)

is less than half the number of persons around the age of 40 (the later baby boom cohorts).

The two age contours represent the projected age structure in 2030. The higher net migration in H than in L results in somewhat larger groups of children and particularly of persons aged 25–50 years. The population size is expected to shrink to 81.2 million (H) and 78.6 million (L) through 2030. However, the age structure is quite similar in both variants and is characterised by a strong shift to older ages. The number of children younger than 10 years of age decreases only slightly compared to 2005, whereas the age groups 15–29 and 34–54 experience strong shrinking. In contrast, more men and women are 58 years of age and older. While 60.8% of the population was aged 20–64 in 2005, this share falls to 52.3% (H) and 51.2% (L) in 2030. Simultaneously, the share of over 65 year-olds will increase from 19.3 to 30.3% (H) or 31.7% (L). The mean age of the total population, which was 42.3 years in 2005, increases to 46.6 (H) and 47.1 years (L).

In Section 2.3, we will also refer to work by the Federal Office for Building and Regional Planning (Bundesamt für Bauwesen und Raumordnung, BBR) because it also publishes regional labour force projections. Its aggregated regional population projection (BBR, 2006) lies between both variants in terms of population growth.[8] Based on a constant TFR of roughly 1.4 and on an increasing annual external migration balance (236,000 on average over the period 2006–2020), the number of Germany's inhabitants is projected to reach 81 million in 2030. The expected age structure also shows some differences, resulting in a mean of 45.1 years in 2020. With 45.4 (H) or 45.6 (L) years, the corresponding values of our projection are

[8]The general target year of this projection is 2020, but some less detailed data is available until 2050. A new projection with a planning horizon until 2025 was published in 2009 (BBR, 2009). The assumed external net migration is, based on recent trends, much lower than before, being 163,000 on average between 2006 and 2020. However, it is still expected to increase over time: net immigration is projected to be almost 300,000 in 2025 with an average of 260,000 until 2050.

somewhat higher. The assumption of a higher migration of rather young persons by the BBR obviously overcompensates for the lower fertility assumption.

2.2.2 Demographic Trends in Hamburg and Mecklenburg-Western Pomerania

The German Federal Statistical Office also provides population projections for the 16 federal states. However, the 11th coordinated population projections at state level were not yet available when the InfraDem partners needed them. Additionally, it was clear that they would only be calculated on the basis of an assumed constant TFR of 1.4 and a low net external migration. The alternative would have been to use regional projections by BBR (2006), but they diverge even more from what we consider to be the most plausible assumptions, and range only up to 2020. We therefore calculated our own population projections for Hamburg and Mecklenburg-Western Pomerania, which are consistent with the national projections in the variants 3-W1 (L) and 3-W2 (H). To do so, we used the usual cohort-component method.

The analysis of fertility trends in HH and MV yields that the total fertility rate in Hamburg has evolved at an almost constant rate of 0.16–0.2 below the West German TFR since 1980. Mecklenburg-Western Pomerania displays, however, a very different fertility pattern. The mostly rural region traditionally experienced a high fertility, which was supported since the mid 1970s by the pronatalist family policy of the former German Democratic Republic. The TFR almost reached 2.0 in the early 1980s, but started to decline towards the end of the decade, coming to rest at 0.74 in 1994. This sharp decline was accompanied and partly caused by a rapid postponement process of births after German reunification (Kreyenfeld, 2003). However, by 2007, the TFR of MV had almost reached the West German value of 1.37 (Fig. 2.2). Given the high fertility level in the past, the rapid recovery after 1994, the generally higher fertility rate of rural areas, and finally the exceptionally good child-care infrastructure in MV, we assume that MV's TFR follows the expected trend for Germany and will rise from 1.29 in 2005 to 1.6 in 2025, staying constant thereafter. For HH, we assume that the TFR remains below the German average, at a slightly lower distance from it than in the past, rising from 1.22 in 2005 to 1.45 in 2025, and keeping this level subsequently. For both regions, it is assumed that age-specific fertility rates increase mainly for age groups 30 and older in the course of a continuing but decelerating postponement of births.

The life expectancy at birth of Hamburg's male inhabitants has been slightly above the German average since the early 1990s, while women had a close-to-average life expectancy (Fig. 2.3). The corresponding values for 2005–2007 are 77.0 and 82.2 years, respectively. The life expectancy at birth of men in MV is, to the contrary, far below the German average. The causes for this include high alcohol consumption and an increased risk of cardiovascular diseases (Kibele, 2005). Groß (2007) shows that MV has the highest share of overweight persons in Germany, which is associated with a high mortality rate (Doblhammer, Hoffmann, Muth, Westphal, & Kruse, 2009). With 74.9 years in 2005/2007, life expectancy of men

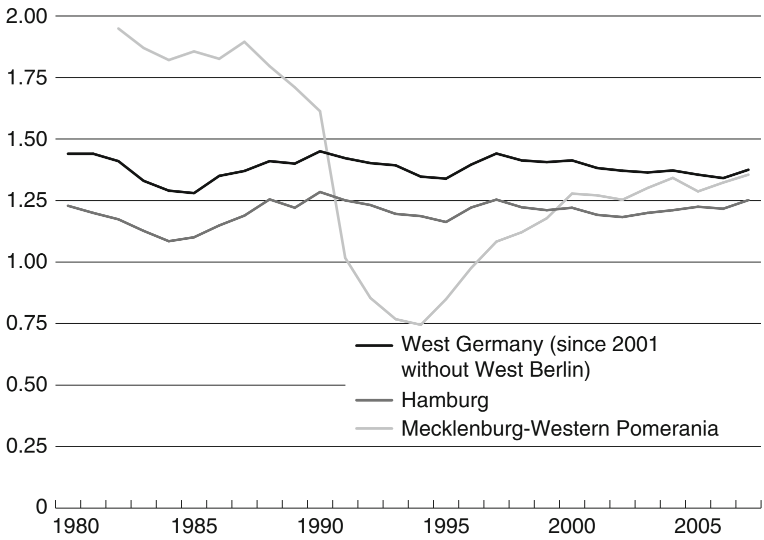

Fig. 2.2 Total fertility rate in West Germany, Hamburg, and Mecklenburg-Western Pomerania, 1980–2007. (Data source: Federal Statistical Office, Statistical Offices of HH and MV.)

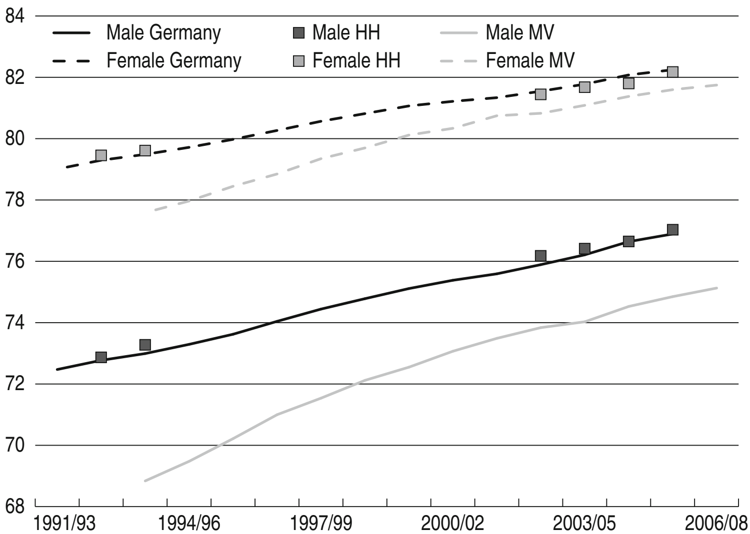

Fig. 2.3 Life expectancy at birth in Germany, Hamburg, and Mecklenburg-Western Pomerania, 1991/1993–2006/2008. (Data source: Federal Statistical Office, Statistical Offices of HH and MV.)

in MV is the lowest in Germany. The life expectancy at birth of women in MV is closer to the German average, lying at 81.6 years. However, the decline in mortality of men and women in MV has been higher than average since the mid 1990s. The persistence of the gap between this figure and the German average, particularly for men, is to some extent due to the fact that the "good risks" emigrate (Luy & Caselli, 2007). The national trend of a closing gender gap in life expectancy is observed in both regions. Given these developments, we assume that life expectancy in Hamburg will remain close to the German average, amounting to 80.8 years for men and 85.5 years for women in 2030. For the population in Mecklenburg-Western Pomerania, we assume that life expectancy will further increase without fully catching up. The projected values are 79.0 years for men and 84.9 years for women. According to the existing findings, we assume that age-specific mortality rates decrease mainly at higher ages (Gjonça, Brockmann, & Maier, 2000).

Hamburg belongs to the most prosperous regions in Europe. It has benefited from net immigration since the mid 1980s (Fig. 2.4). The growing population in recent years results mainly from inflows from other (East and West) German regions, and from MV in particular, as well as from immigration from abroad. However, net migration is highly age-specific: strongly positive for the roughly 15–30 year-olds (apprentices, students, young workers), and slightly negative for the other age groups. The latter fact is often caused by young families migrating to nearby districts.[9] In contrast to HH, Mecklenburg-Western Pomerania has always suffered from emigration, particularly in the second half of the nineteenth century (Lubinski, 2004). After reunification, it was particularly the age group 15–30 and women that

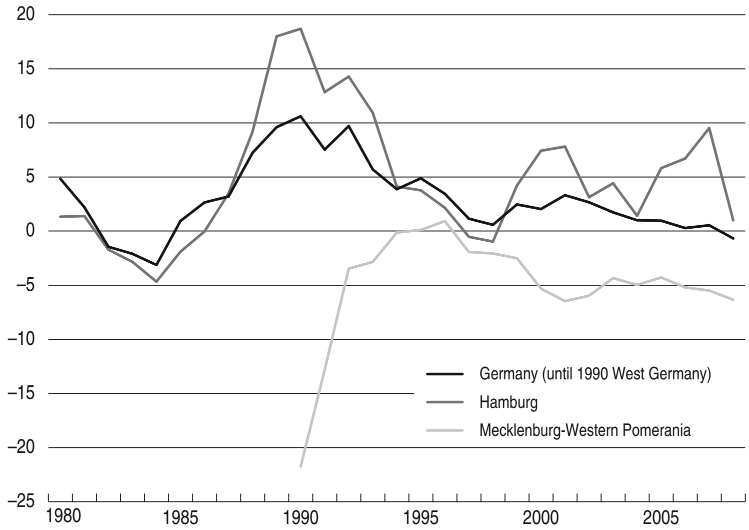

Fig. 2.4 Migration balance of Germany, Hamburg, and Mecklenburg-Western Pomerania, 1980–2008 (per thousand inhabitants). (Data source: Federal Statistical Office, Statistical Offices of HH and MV; authors' calculations.)

[9] We also made a population projection for the 14 districts of the Hamburg Metropolitan Region. However, as it was not further used in the infrastructure planning models of our InfraDem partners, we refrain from presenting it here. See Kühntopf and Tivig (2007) for more information.

emigrated, while the migration balance of the over 50-year-olds was and remains positive (Dinkel, 2004).

When projecting the migration component, we followed the usual procedure of considering age- and sex-specific emigration *rates* and immigration *numbers*. The reason is that emigration arises from the known domestic population, while immigration, in contrast, comes from the "unknown" (in the sense of not simultaneously projected) population of the rest of the world (Dinkel, Salzmann, & Kohls, 2006). We assume that in the high variant (H), Hamburg benefits from constant immigration numbers at the average level for the period of 2001–2005 when the migration balance was quite high compared to the long-term trend. We thereby conjecture that declining internal immigration will be compensated by rising external immigration from abroad, and assume that the former is due to an improvement in living conditions in East Germany and the general shrinking of the German population at migration ages. Regarding emigration rates, we assume that they diminish for persons younger than 40, particularly because suburbanisation is slowing. In the low variant (L), we assume declining immigration numbers and increasing emigration rates. In this scenario, immigration from abroad does not make up for the declining number of German immigrants. The decrease applies to all age groups below 45 years of age, particularly to the 15–35 year-olds. The emigration of relatively young persons in the course of suburbanisation remains constant, but pensioners increasingly emigrate to other German or foreign regions.[10]

For Mecklenburg-Western Pomerania, the high variant (H) assumes an increase in immigration numbers and a decrease in emigration rates, hence an increasing net migration balance. The former comes presumably in the form of an increased inflow of older "repatriated" persons as well as of older persons that decide to spend their retirement in the scenic German northeast. Additionally, an increased inflow of younger people from abroad, particularly from the new EU member states may be observed. As far as emigration is concerned, the assumption of decreasing emigration rates amongst the younger age group is fed by an improvement in economic perspectives and the increased attractiveness of its universities. The low variant (L) assumes constant immigration numbers and emigration rates, based on the average migration flows between 2001 and 2005. Since the population size of MV displays strong shrinking, particularly among the younger mobile age groups, the absolute number of emigrants is assumed to decrease in this variant. The migration balance would even be positive in this case from 2016 onwards.[11]

The shape of Hamburg's age structure in 2005 is at a first glance similar to that of Germany (Fig. 2.5). However, the shares of both the young and the elderly in the total population are smaller. Only 17.7% were younger than 20 and 18.3% were aged 65 or older, while the corresponding values for Germany were 20 and 19.3%, respectively. The mean age of the total population amounted to 42 years and was

[10]Both regional migration assumptions (H and L) thus differ in more than the net migration with other countries; the variants also imply different scenarios for internal migration.

[11]Table 2.2 in the appendix displays a summary of all assumptions.

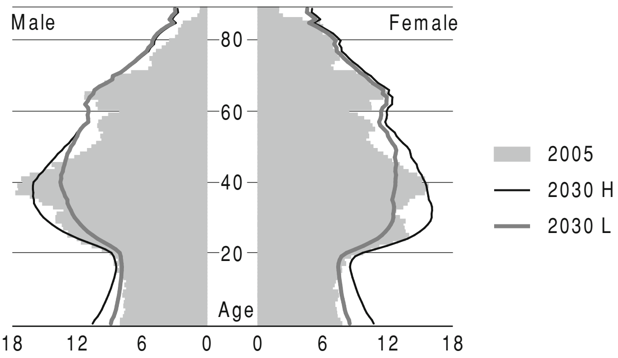

Fig. 2.5 Age pyramid for Hamburg in 2005 and 2030 (in thousands). (Data source: Statistical Office of HH, authors' calculations.)

hence slightly below the German average of 42.3 years. Given the optimistic migration assumption, the number of inhabitants is projected to grow from 1.74 million in 2005 to almost two million in 2030. In contrast, the low variant yields growth until 2023 and shrinkage thereafter, such that the population size remains almost constant up to 2030 in relation to 2005 (1.79 million).[12] The projected age structures for both variants differ little for those over 55; the size of most older age groups increases between 2005 and 2030. However, differences for younger ages are large. The number of persons younger than 14 grows in this variant too, but it is 12–22% larger in the high migration variant. The number of 14–46 year-olds shrinks by up to 22%, while the older age groups grow. In contrast, variant H implies a mostly constant or growing size of these age groups, which is more pronounced for women. The mean age of Hamburg's population rises to 43 years (H) or 44.5 years (L) in 2030. The projected ageing is thus much slower than on the national level.

The age structure of Mecklenburg-Western Pomerania in 2005 and 2030 is displayed in Fig. 2.6. Its shape differs strongly from that of Germany and HH. All three breaks at roughly ages 60, 30 and 15 are primarily results of strong fluctuations in the fertility rate, associated with World War II, a pronatalist family policy after the end of the common baby-boom years, and German reunification. The number of inhabitants is projected to shrink from 1.71 million to 1.54 (H) and 1.49 (L) million, respectively. It will thus shrink by an additional 200,000 compared to the loss already incurred between 1990 and 2005.[13] It is particularly the former large cohorts of 14–57 year-olds which are affected by shrinking – even in the high migration variant up to 54%. In contrast, the number of elderly people is expected to strongly increase. The age structure in 2030 is characterised by a large number of

[12]The 11th coordinated regional population projection for Hamburg shows a size of 1.8 million in 2030, while it is only 1.76 million in the projection of the BBR.

[13]In the 11th coordinated population projection, the population size shrinks to 1.43 million by 2030, while the BBR expects a size of 1.55 million for MV.

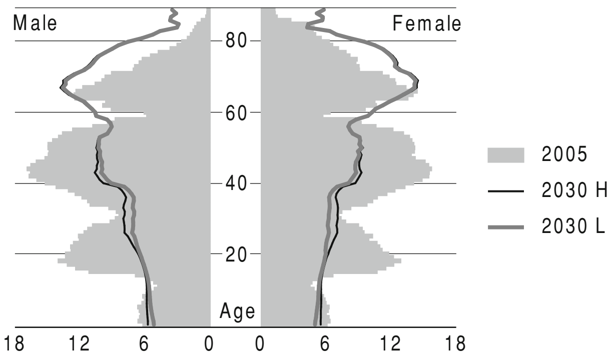

Fig. 2.6 Age pyramid for Mecklenburg-Western Pomerania in 2005 and 2030 (in thousands). (Data source: Statistical Office of MV, authors' calculations.)

persons aged 60 and older, while the size of younger cohorts decreases with age. The different migration assumptions primarily affect the age groups below 50 years, but the variation range is small. With a mean age of 35.4 years in 1989, the population of MV was the youngest in Germany. This was no longer the case in 2005, when the mean age amounted to 43.3 years. Our projection yields a mean age of 50.2 (H) or 50.9 years (L) by 2030.[14]

2.2.3 *Population Projections at District Level for Mecklenburg-Western Pomerania*

Some infrastructure models within the InfraDem project are based on a smaller regional scale. We therefore calculated projections for the 18 districts of MV (see Fig. 2.7), which are in sum consistent with the projection at state level. For small-area population projections, an aggregation to 5-year age groups is reasonable to allow differentiation of the demographic components by age and sex. This step goes along with a 5-year projection interval to "preserve the integrity of age cohorts" (Smith, Tayman, & Swanson, 2001, p. 137).

The average fertility in the period 2001–2005 varied strongly between the districts. With a TFR from 1.15 in Greifswald to 1.20 in Wismar, the fertility was lowest in the four Hanseatic cities. Causes are the consequences of suburbanisation as well as a rather high share of young (and still) childless women. Fertility was highest in the western district Ludwigslust (1.44), which belongs to the enlarged environs of Hamburg, benefitting from the immigration of persons at typical family-starting age (over 30 years). We assume that regional fertility trends will persist, meaning

[14] In Tivig and Kühntopf (2009) we calculated that ageing between 1990 and 2030 in Mecklenburg-Western Pomerania will be strongest among the 264 NUTS 2 regions of the European Union. The mean age of MV is among the highest in the EU by 2030.

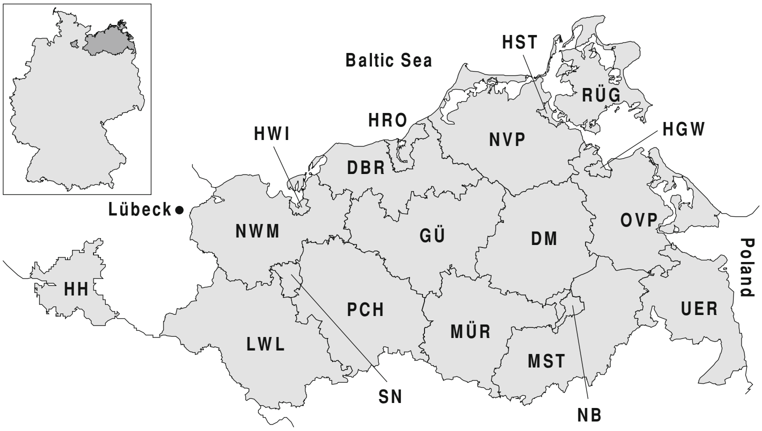

Fig. 2.7 Hamburg and the districts of Mecklenburg-Western Pomerania

that the age-specific fertility rates will develop according to their ratio to the MV average between 2001 and 2005. Regions with a high fertility in the past will keep it in future, and low fertility regions will continue to have a low TFR in future. The expected strong increase in late maternity yields will lead to the lowest TFR of 1.44 in Stralsund in 2026–2030, while Greifswald will have a somewhat higher value of 1.46. The TFR of both cities is thus similar to the currently highest value in Ludwigslust, which however displays a TFR of 1.76 in the last of the projection intervals.

A regional differentiation of age- and sex-specific mortality is not possible due to the limited number of deaths, particularly at young ages. For example, only one woman in MV died at age 10–14 years in 2005 and 24 women of this age group died between 2001 and 2005. The distribution over the 18 districts would yield extremely vague mortality rates. The mortality rates and their evolution until 2030 are thus assumed to be equal to that of the state level for all regions.

Migration flows differ strongly between the districts, in terms of their size as well as their age structure. For example, Ludwigslust experienced high inflows of 15–40 year-olds from outside MV in the past, which are far above the outflows. The population suffers, however, from high net outflows to other districts of MV. The university city Greifswald saw many immigrants aged 20–25, but also net emigration of 25–30 year-olds who had finished their studies. Rostock, as the largest city of MV, displays strong migration flows of persons aged 20–40 who move within MV as well as beyond its borders. The economically weak district Demmin suffers from large population outflows. Generally, the strong suburbanisation during the 1990s significantly diminished in the last few years and is projected to follow this trend in future. We hence assume that the six city districts will experience less emigration of persons younger than 15 years of age and those aged 30–55 in future. The cities are also more attractive for immigration at the expense of nearby districts. We assume that the internal migration is the same in both projection variants but that the external migration trends differ according to assumptions on the federal-state level for MV, in other words, rising immigration numbers and declining emigration rates in variant H and constant immigration numbers as well as emigration rates in variant L.

As a result of these assumptions, three districts are projected to experience an increasing population in the projection variant H: Greifswald, Rostock and Nordwestmecklenburg, despite the strong shrinking of MV's total population (Table 2.1). While Rostock and Greifswald are university cities, Nordwestmecklenburg benefits from its proximity to Lübeck (in the nearby federal state Schleswig-Holstein), Wismar and Schwerin. Ludwigslust and Wismar are projected to experience population growth from 2020 onwards which is, however, not strong enough to compensate for shrinkage before 2020. At the other extreme are the rural districts Uecker-Randow and Demmin, which are likely to lose a quarter of their inhabitants between 2005 and 2030. The projection variant L implies, to the contrary, shrinking of the population in all districts and over the whole projection period, ranging from –1% in Nordwestmecklenburg to –29% in Uecker-Randow. Of the six city districts, Neubrandenburg is by far expected to experience the strongest population decline (–22%). The current and future age structures of the districts differ considerably. With a mean age of 41.6 years, Greifswald had the youngest population of MV in 2005, closely followed by Nordwestmecklenburg. Three cities,

Table 2.1 Population size and mean age of MV's districts in 2005 and 2030

	Population size			Mean age		
District	2005	2030(H)	2030(L)	2005	2030(H)	2030(L)
Greifswald (HGW)	53,281	55,843	51,386	41.6	44.6	45.3
Neubrandenburg (NB)	68,188	55,750	53,287	42.8	48.7	49.3
Rostock (HRO)	199,288	204,457	193,424	43.5	46.3	46.9
Schwerin (SN)	96,656	89,045	85,653	44.1	49.0	49.5
Stralsund (HST)	58,708	55,180	52,682	44.5	48.9	49.4
Wismar (HWI)	45,391	44,049	42,094	44.7	48.8	49.3
Bad Doberan (DBR)	119,912	116,697	113,970	42.3	52.1	52.4
Demmin (DM)	86,756	64,788	62,946	43.7	52.7	53.3
Güstrow (GÜ)	105,704	86,487	83,881	43.2	51.3	51.8
Ludwigslust (LWL)	128,487	125,762	122,659	42.4	49.5	49.8
Mecklenburg-Strelitz (MST)	83,500	71,284	69,005	43.5	52.2	52.7
Müritz (MÜR)	67,495	60,893	58,974	43.3	51.7	52.1
Nordvorpommern (NVP)	112,177	91,944	89,474	43.8	53.2	53.6
Nordwestmecklenburg (NWM)	120,313	121,586	118,542	41.7	48.7	49.0
Ostvorpommern (OVP)	110,289	97,278	93,931	43.8	52.1	52.6
Parchim (PCH)	102,675	84,772	82,174	43.4	52.7	53.3
Rügen (RÜG)	71,294	61,530	59,209	44.0	51.8	52.3
Uecker-Randow (UER)	77,152	56,983	54,563	44.3	53.7	54.5

Data source: Statistical Office of MV, authors' calculations.

as well as the rural districts Rügen and Uecker-Randow, showed a mean age of over 44 years in 2005, with Wismar on top with 44.7 years. The mean age increases by 2.7–9.8 years (H) or 3.4–10.2 years (L) over the period of 2005–2030. Ageing is slowest in Rostock and Greifswald, and fastest in Bad Doberan and Uecker-Randow. While Bad Doberan, situated nearby Rostock, was relatively young in 2005, Uecker-Randow already belonged to the oldest districts. The regional spread of the mean age rises from 3.1 years in 2005 to more than nine years in 2030, with Greifswald still being the youngest district and Uecker-Randow the oldest.

2.3 Household Projections

Some of the infrastructure models in the InfraDem project are not only based on demographic trends, but also on the development of the size and structure of private households. A private household is defined either as a group of persons living together and forming an economic unit or as a person living and keeping house alone (Statistische Ämter des Bundes und der Länder (StABL), 2007, p. 27). Group quarters like nursing facilities, military barracks or prisons and their residents do not belong to households. If a person has a principal and a second residence, he or she could be a member of both and will be counted twice. The number of household members may thus differ to some extent from the population number.

Household projections are subject to great uncertainty. Not only do they rely on uncertain population projections, they are also subject to all of the uncertainties associated with household formation and dissolution. The latter is additionally strongly influenced by socio-economic and legal developments, ranging from social norms regarding the cohabitation of generations to housing policy and divorce legislation. Finally, the information on household members is gained from the German microcensus which is inevitably subject to estimation errors. There are two basic approaches used in Germany to project private households: the headship-rate method projects the number and size of households by age and sex of the household heads, whereas the so-called household members' quota method shows the distribution of the age- and sex-specific population by different household sizes.[15] For the infrastructure models used in the InfraDem project, we need information on both members and heads. We therefore first calculated the number and structure of household members until 2030. Subsequently, we assessed for each household size the heads by their age and gender.

2.3.1 Household Members

German households tend to become smaller in size, which leads to an increase in the number of households. According to the Federal Statistical Office, from 1991

[15] Other approaches for household projections are micro- and macrosimulation models. The ProFamy method is an example of the latter (Zeng, Vaupel, & Wang, 1998). However, these approaches rely on higher data requirements like, for example, family status.

to 2005 the number of households rose four times faster than the number of people living in them. This trend was also observed for Hamburg and Mecklenburg-Western Pomerania. Major contributing factors are low and later fertility, high or even rising divorce and cohabitation rates, increasing and gender-specific life expectancy, and high job mobility (StABL, 2007, p. 26).

For a household projection, the projected population at the principal residence must first be converted to household members at the principal and second residence using age- and sex-specific ratios. Then, the household members' quotas are extrapolated according to past long-term and medium-term trends. These quotas show the share of persons living in a household of a certain size among all persons of the same age and gender. Finally, the projected population in private households is multiplied by the members' quotas. The number of households arises from the ratio of the number of household members and the household size.

In 2007, the German statistical offices published the results of a household projection at national and state level until 2025 (StABL, 2007), based on their preferred variant of the 11th coordinated population projection (constant TFR at 1.4, low migration). In addition to the demographic development, it considers changes in household structures made apparent by the long-term data of the microcensus. The microcensus contains about 390,000 households with 830,000 members. However, a simultaneous differentiation by nine age groups, gender, household size and federal state leads to problems with the sample size. For HH and MV, for example, the statistical offices do not publish information on the number of household members aged 55 and older in households with four or five and more members. Therefore, the statistical offices pooled the federal states into three groups with similar household patterns: city states (including HH), East German territorial states (including MV) and West German territorial states.

In our household projections for the InfraDem models, we sought consistency with the statistical offices' assumptions concerning changes in the household formation. The Federal Statistical Office does not release their projected household member quotas but they did calculate household projections for Germany, HH and MV on the basis of our population projections. We thereby assume that the quotas remain constant between 2025 and 2030. Due to the fact that the projection by the statistical office only starts in 2006, we used the microcensus from 2005 to make our own calculations of the quotas for 2005.

The distribution of household members by household sizes is shown in Fig. 2.8. As the average household size in Germany is projected to decrease from 2.10 in 2005 to 1.96 (H) or 1.95 (L) in 2030, the number of private households increases despite the shrinking population. While Germany had about 39.4 million private households in 2005, this number rises to 41.5 (H) or 40.3 (L) million by 2030. However, the distribution of their members by household size, gender and age differs only little between both the projection variants. The already large share of single- and two-person households rises by 10–16%, while the number of households with three and more members declines by 17–29%. The development is strongly driven by the demographic trends already mentioned, particularly the rising number of elderly and the decrease in the number of families with children.

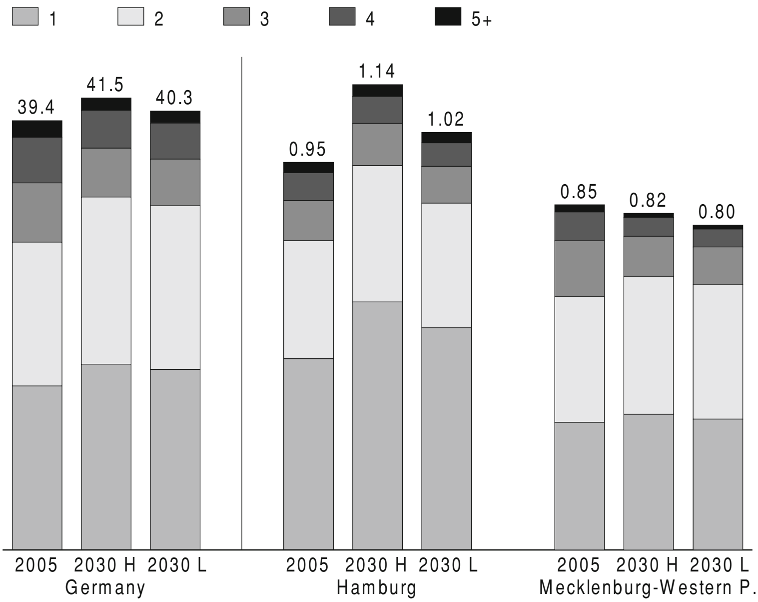

Fig. 2.8 Number of private households (in millions) by household size in Germany, Hamburg and Mecklenburg-Western Pomerania, 2005 and 2030. (Data source: Federal Statistical Office.)

The number of 60–69 year-old members in single- or two-person households, for example, decreases by 10 and 9% in 2011. Thereafter, the baby-boomers enter this age group, which leads to a strong overall increase by 30–33% of both household sizes between 2005 and 2030. In contrast, the number of singles below the age of 50 decreases, with a maximum of 32% for age group 15–19 in the low projection variant. Three-person households show a rising number of members younger than 5 and older than 70 years, and a declining number of members of all other ages. The number of persons living in households with four or five and more members decreases in most age groups; the exception are 50–59 year-olds in four-person households, which show a strong increasing number until 2019 and over the period 2005–2030 still show slight growth. The proportion of female members is 48.7–49.9% in households with three and more members and 50.8–54.6% in smaller households. This asymmetry is mainly the result of the higher life expectancy of women.

In Hamburg, the number of households is projected to increase from roughly 950,000 in 2005 to 1.14 million (H) and 1.02 million (L), respectively, in 2030. The average household size thereby decreases from 1.84 to 1.76 (H) or 1.75 (L). These values are way below the German average due to a larger share of single-person households and smaller shares of typical family households with three and more members. The number of single-person households is expected to increase even in the low population scenario: it rises overall by 30% (H) or 16% (L) and for all age groups but the youngest (aged 15–19 years), for which it decreases. The latter decrease is projected for men; the number of female single-households increases in variant H. In the low projection variant, the declining number of male single-households is compensated by the rising number of female one-person households. In general, women leave their parents' home earlier than men, and the young depart from home in cities earlier than in rural areas (Schimpl-Neimanns, 2006). The number of households with two members increases by 16% (H) or 6% (L), but not for all age groups. Less household members will be aged 40–59 (H) or 20–59 (L). Households with three and more members are projected to shrink by 17–29% between 2005 and 2030. In the lower variant, the number of members aged <15, 50–59 and 70+ in households with three or five and more members grows, yet not in four-person households. All in all, the results of the Federal Statistical Office on the basis of our population projection for the city state Hamburg point towards a trend of families with one child or three and more children but less families with two children.

The average size of private households in Mecklenburg-Western Pomerania is projected to decrease from 2.03 in 2005 to 1.87 (H) or 1.86 (L) in 2030. Despite the strong population decline, the number of single- and two-person households grows by 2–10%, while the number of households with three and more members shrinks by 29–45%. Mainly because of fewer households with four and more members, MV displays a smaller household size than Germany on average, yet a larger one than in Hamburg. Since the general trend to smaller households does not make up the decline in the population size, the number of households decreases from nearly 845,000 to 825,000 (H) and 796,000 (L), respectively. While the number of one-person households younger than 60 years of age is projected to decline, the number of over 70 year-old solitarily men more than doubles even in the low projection variant between 2005 and 2030. The number of young (<15 years) and old (60+ years) members in two-person households increases at the expense of middle-aged groups. Private households with three and more members display a strongly shrinking number of members for most age groups. The size often more than halves until 2030. Exceptions are members at age 5–14 and 70+ in three-person households, whose number still grows in both variants.[16]

2.3.2 Household Heads

One InfraDem model uses data from the German sample survey of income and expenditure that is related to the age and gender of the household heads in terms of the member with the highest net income. For this model, the projection of household members had to be converted to demographic characteristics of the head. Changes in the number and structure of private households like, for example, the trend towards smaller sizes are already considered. We only had to distribute the heads for each

[16]More detailed data on the household members and heads by age, sex and size is presented in the appendix of Kühntopf and Tivig (2008a) as well as in Kronenberg, Kühntopf, and Tivig (2010).

household size by their age group and gender. The youngest age group which could be the head of a household is 15–19 years old. For single-person households, which accounted for 38% of all households in Germany in 2005, 49% in HH and 37% in MV, the head corresponds to the member. Hence, the conversion applies only to households with two and more members.

It is difficult to project what age and gender the main earner of a household will be in future. As household members get older due to demographic change, it is assumed that heads also age. However, most households with three and more members are families. Their heads should thus mostly remain at the typical age of parents. Furthermore, the increasing work participation of women could lead to a greater share of female main earners. To complicate matters further, an analysis of the past trend is not possible because the microcensus has only defined the head as main earner since 2005.[17] Detailed 2006 official statistics for HH and MV are incomplete due to the limited sample size of the microcensus.[18] A scientific use file of the 2006 microcensus for our own analysis did not exist at the time of our calculation. We therefore based our assumptions about the development of main earners until 2030 purely on the 2005 data and plausibility reasoning.

We differentiated the main earners into seven age groups (15–19, 20–29, . . . , 60–69, 70+), by gender, and by household size, as done in the household projection of the Federal Statistical Office. To achieve a greater sample size, we followed the Federal Statistical Office's procedure and pooled the federal states into three categories: city states, East German territorial states, and West German territorial states. Nonetheless, for some combinations of age, gender and household size, the sample of the 2005 scientific use file remained empty on the regional level or contained only very few cases. This applies particularly to households with four or five and more members and young (15–19) or old (60–69, 70+) main earners. In these cases, we additionally considered the household distribution on the national level.

Firstly, we calculated the share of the household members of a certain age and gender, who were the main earner. For example, 28.6% of Hamburg's 20–29 year-old male members in three-person households were the heads of households in 2005, while this figure was 24.9% in East German territorial states like MV and 29.0% in Germany. As expected, men are much more often the main earner than women (older men more often than young men), even though the share of female heads in HH and MV is clearly above the German average. For example, in Hamburg's three-person households, 76.3% of male members aged 40–49 features as heads.

Secondly, we calculated the distribution of the main earners by age, gender and household size. As a result we found, for example, that 20.8% of the main earners

[17] Before 2005, the head was the first person on the questionnaire. This still applies today if two household members have the same income group or no information is available.

[18] The household projection of BBR provides only demographic information on the household heads but not on its members. When simultaneously considering gender and household size at state level, they distinguish between only three age groups, not seven.

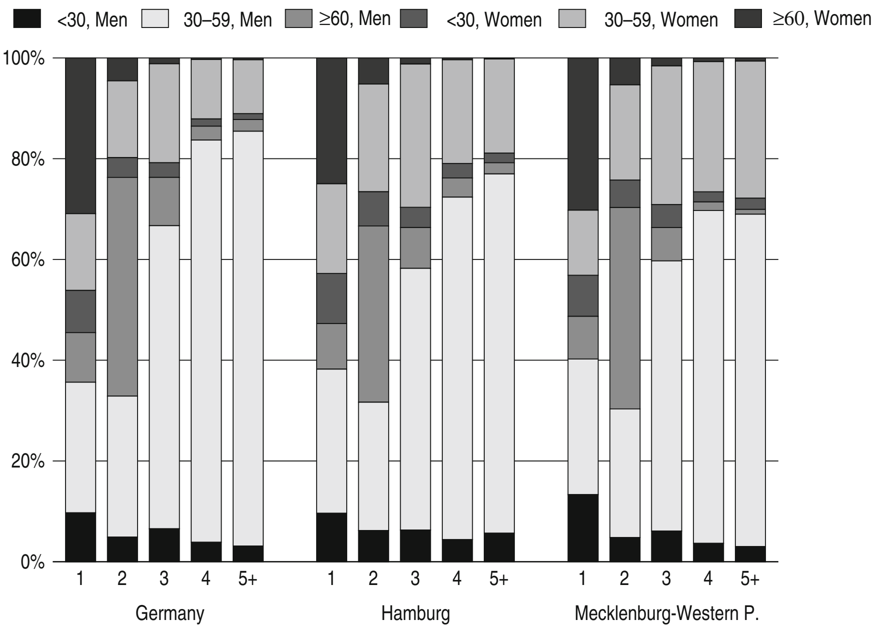

Fig. 2.9 Distribution of household main earners by age, gender and household size in Germany, Hamburg and Mecklenburg-Western Pomerania, 2005. (Data source: SUF Microcensus, 2005; authors' calculations.)

in Hamburg's three-person households are 40–49 year-old men and that two-thirds of the heads of households are male. The sum over all age groups and both sexes is 100% for each household size. Figure 2.9 shows the distribution in 2005 for three accumulated age groups. As can easily be seen, between 76 and 88% of the main earners in German households with two and more members are men. However, the share of female main earners in Hamburg and Mecklenburg-Western Pomerania lies, as already mentioned, way above the German average. For households with at least three members, the head tended to be aged 30–59 and most likely supporting a family. In two-person households, a relatively large share of the heads were men over the age of 60, probably often living together with a woman after the children had moved out. Single households are half male and half female and are quite frequently made up of old women.

For the projection of these shares, we assumed that the heads age with the household members. For example, if the share of 40–49 year-old male members amongst the members of three-person households decreases by 1%, the fraction of corresponding heads decreases by 1% as well. It is assumed that the growing work participation and rise in the education level of women will lead to an increase in the share of women as main earners, particularly amongst middle-aged women and older. To represent the increasing weight of female main earners, the age-specific shares of all heads are lowered to a certain extent for men and raised to the same extent for women. However, because of a presumed lower labour participation of women (in terms of numbers and working hours) and a persistent gender wage gap, the share of male main earners is likely to remain much higher. This applies particularly to households with children.

The extrapolation of the distribution of main earners by age and gender is carried out by:

$$H_t^{i,x,s} = H_{t-1}^{i,x,s}\left(\frac{M_t^{i,x,s}}{M_{t-1}^{i,x,s}}\right) + z^{i,x,s} \tag{2.1}$$

with $H_t^{i,x,s}$ as the fraction of main earners of age x and sex s living in households of size i at time t in all households of that size. The variable $M_t^{i,x,s}$ corresponds to the same fraction of household members. The factor $z^{i,x,s}$ considers the expected growing share of female main earners and is defined as negative for men and positive for women. In the course of extrapolating the fractions for the future, the sum of $H_t^{i,x,s}$ over all age groups and both sexes often no longer equals 100% for each household size. The shares $H_t^{i,x,s}$ are therefore increased or decreased slightly by the same percentage until the sum is 100%. Finally, the projected age- and sex-specific shares of main earners by household size are multiplied by the number of households of each size, obtained from the household members' quota approach. The result is the evolution of the number of households by size, age and gender of its main earner in Germany, Hamburg and Mecklenburg-Western Pomerania between 2005 and 2030 for both population scenarios (high and low).

Despite demographic change, the distribution shown in Fig. 2.9 changes little by 2030. There are only some apparent movements towards the elderly for single- and two-person households, explained to a large extent by the ageing of the baby boomers. Nonetheless, the main earners of family households (three and more persons) are assumed to age as well, but within the age group 30–59. The combination of the trend towards smaller households due to demographic and socio-economic developments (Fig. 2.8), and shifts in the age- and sex-specific distribution of main earners, leads to considerable changes in the number of household heads.

2.4 Labour Force Projections

One part of the InfraDem project deals with the transport infrastructure. For the assessment of future demands in this field, not only demographic trends but also the development of the labour force is of importance; the latter is also an input for the macroeconomic projections in Section 2.5. We performed the labour force projection in three steps. First, we calculated the working-age population from our population projections. Second, we applied expected labour force participation rates to this. The result is the future workforce in Germany, Hamburg, and Mecklenburg-Western Pomerania. Finally, we made assumptions on the unemployment rate in order to obtain a projection of employment in Germany, HH and MV.

2.4.1 The Working-Age Population in Germany, Hamburg and Mecklenburg-Western Pomerania

In accordance with the labour force projection of BBR (2006), we define the working age as lying between 15 and 69 years.[19] In 2005, some 60.3 million persons in Germany were of working age. This is 73% of the total population. The size of the working-age population is projected to shrink by 10% to 54.4 million (H) or 13% to 52.4 million (L) by 2030. The decline is thus much stronger than for the total population, which decreases by 2% (H) and 5% (L), mainly because the large baby-boom cohorts age out the working-age interval. The share of potentially active persons in the total population declines to 67% in both projection variants.

In the high migration scenario (H) the working-age population of Hamburg grows by 9% from 1.30 million in 2005 to 1.42 million in 2030. This is still weaker than the 14.5% growth in the total population. In the low migration projection variant (L), the latter increases by 2.4%, while the number of persons aged 15–69 shrinks by 4% to 1.25 million. With 75% in 2005 and 71% (H) or 70% (L) in 2030, the active share of Hamburg's population remains above the German average of 73% in 2005 and expected 67% in both variants in 2030.

In Mecklenburg-Western Pomerania, nearly 1.32 of the 1.71 million inhabitants were at working-age in 2005; the active share was 77% and thus higher than in HH and Germany. The number of working-age persons is projected to decline to 0.99 (H) or 0.95 (L) million by 2030, which corresponds to shrinkage of 25 and 28%, respectively. At the district level, the development is likely to show strong variation, ranging from a 5% growth in Greifswald to a 26% shrinkage in Uecker-Randow in the projection variant H and a decline of 3% in Rostock to a 29% shrinkage in Uecker-Randow in the projection variant L. The active share of the total population in MV falls to 64% in both variants, hence below the German average.

2.4.2 Projection of the Labour Force

Only part of the working-age population is actually working or seeking work. The corresponding shares are calculated as age- and sex-specific labour force participation rates. Like household projections, projections of the labour force are much more complex and uncertain than population projections, particularly at the regional level. Short- and medium-term business cycles, changes in education duration or requirements, policies aiming to increase compatibility between work and child rearing, as well as labour participation of the elderly influence the supply of labour. The Federal Employment Agency only publishes data on employees subject to social insurance contributions. Projections of the labour force are therefore based

[19] There is no standard definition for the working-age. While the German Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung, IAB) limits it to 15–64 years, the International Labour Organization defines it as 15–74 years.

upon the microcensus, which however often implies a limited sample size when differentiating regional labour force participation by age and sex. The Federal Office for Building and Regional Planning provides the most comprehensive regional analysis of labour force participation based on microcensus data.[20] It has cooperated for the last two decades with the Federal Statistical Office to determine labour force participation rates at (a) a detailed spatial level (97 regions) but with little differentiation by age and sex, and (b) an only rough spatial level (clusters) but with detailed information on age- and sex-specific labour force participation. The two data sets are then connected to yield labour force data which is detailed in both respects (BBR, 2006, p. 58). Their latest projections at the time the InfraDem project started were trend extrapolations until 2020 of the rates between 1991 and 2003. In what follows, we base our labour force projection on these rates, assuming that after 2020 and until 2030 they remain constant at the level of 2020.[21]

Figure 2.10 shows the age- and sex-specific labour force participation rates in 2005.[22] As the projection provides no data for the whole of Germany, we calculated

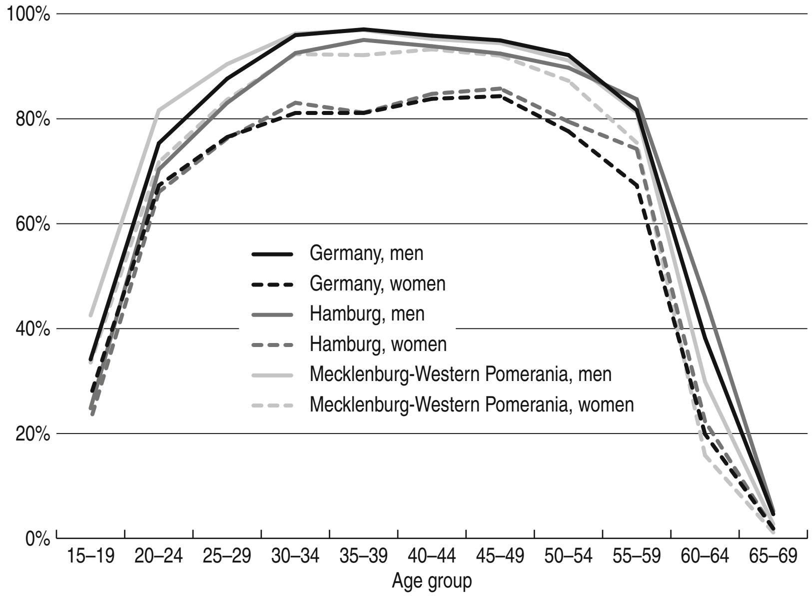

Fig. 2.10 Labour force participation rates by age and sex in Germany, Hamburg and Mecklenburg-Western Pomerania, 2005. (Data source: BBR (2006); authors' calculations.)

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[20]IAB provides sophisticated labour force projections until 2050. However, regional differentiations consider at best West and East Germany (Fuchs & Söhnlein, 2009).

[21]Meanwhile, the government enacted a gradual increase of the regular pension age from 65 to 67 years between 2012 and 2029, which is not considered here.

[22]These rates are already a projection of past trends.

national labour force participation rates by extending the ratio of the aggregated federal state level data on the labour force to the aggregated federal state level population data. Some common patterns of labour force participation were observed for the regions considered. Men show higher participation rates than women in all age groups.[23] As a result, primarily of longer education, labour participation is rather low at young ages and increases by the age 30. It then remains high up to age 54, declining substantially for older age groups. However, the figure displays considerable differences between the regions. While the age-specific participation rates in Germany and HH are similar for women, they are below the German average for Hamburg's men younger than 54 years and above the average for older men. Women in Mecklenburg-Western Pomerania show a higher work orientation than in HH or the German average, particularly when younger than 54 years. This is not only a consequence of the greater work orientation of East-German women in general, but also due to a better child care infrastructure in East Germany. If their labour force participation is lower at older ages, then this is due to higher unemployment than in HH and Germany on average and the traditional early female retirement. Men in MV show higher participation rates than in Germany on average at younger ages (<30) but significantly lower rates at older ages (60+).

Participation rates are projected to increase on average in Germany, and in Hamburg, but to decrease in MV. The labour force participation of men is projected to change little in Germany and Hamburg up to 2030.[24] It is projected to be 4.3 or 3.3% points lower than in 2005 for the age group 20–24 because of the expected education expansion (higher share of students). Participation rates decrease slightly for the 40–49 year-olds, but are likely to increase by 2.9 or 2.7% points for the age group 60–64. Labour force participation of MV's men is expected to decline for all age groups younger than 60 years, although this decrease will be modest at less than 1% point. Exceptions are the decrease of 7.5% points for age group 20–24 and that of 1.8% points for the 30–34 year-olds. However, the projected participation rates still lie substantially above the German average for men younger than 25 years and relatively close to the average for all age groups except 60–64 year-olds. The participation of the latter remains well below that of Germany and HH, despite an expected increase of 5.2% points. The expected evolution of female workforce participation rates is similar in Germany and HH. They decrease in age group 20–24 years as well, but are projected to rise strongly for age groups 25–64. The increase lies between 3.4 (age 25–29) and 8.7 (30–34) percentage points in Germany and 4.0 (25–29) to 9.5 (30–34 and 55–59) percentage points in HH. In contrast, labour force participation of women in MV is likely to decline in all age groups except the over 60 year-olds, with a maximum of 4% points for age group 20–24. However, this rate remains above the German average. The age group 60–64 shows a labour force participation of women that is 8.2% points higher in 2030 than

[23]If calculated in working hours, the gender gap would considerably widen, as women display a much higher share of part-time work.

[24]Up to 2020 in the projection of BBR (2006).

in 2005. Overall, the gender gap diminishes for Germany as a whole and HH, while the trend is ambiguous in MV. However, the level of female labour force participation will remain far below that of men – in Germany and MV to a greater extent than in HH. In Hamburg, women are likely to catch up with men in three age groups (30–34, 45–49 and 55–59) while remaining far behind at ages 35–39 and 60–64.[25]

For projections on the district level for Mecklenburg-Western Pomerania, we first calculated the ratio of labour force participation rates of the districts to that of MV on average, calling this a "district factor". We then multiplied the district factor by the age- and sex-specific participation rates of MV at the federal-state level in order to obtain approximations for the labour force participation rates on the district level. The resulting rates display only small regional differences for 2005, partly because the procedure ignores age- and sex-specific differences between the districts.[26] At 80%, the rate was highest in Nordwestmecklenburg, which benefits from proximity to cities like Lübeck, Wismar, Schwerin and even Hamburg. The participation rate was lowest in Stralsund at 77%, even economically weak rural districts had higher rates. The average participation rate of MV is projected to decrease from 78.3% in 2005 to 75.6% in 2030. Economically less attractive cities such as Neubrandenburg and Schwerin and most rural districts are expected to keep the 2005 rate of 77.4%. Labour force participation in 2030 is expected to be highest at 77.5% in Wismar and Nordwestmecklenburg, while it will be lowest at 73.7% in Uecker-Randow.

The application of the participation rates thus calculated to the working-age population obtained from our population projection yields the labour force. Although the participation rates of German women are increasing, they do not compensate the demographic development. The size of the German labour force is projected to shrink from 41.4 million in 2005 to 36.4 (H) or 34.7 (L) million by 2030. While half of the population was working in 2005, this share will decrease to 44.8% (H) or 44.2% (L) by 2030. There are large age- and sex-specific differences in the expected development which are due to both demographic change and changes in the labour orientation of men and women. The number of male workers decreases more strongly than that of female workers. The corresponding shrinking rates in the high migration variant are 14.7 and 9.1%. The decline is particularly strong for age groups 15–24 and 35–44. In contrast, the number of over 55 year-old workers increases.

The labour force of HH is expected to grow by 13.2% between 2005 and 2030 in the projection variant H – from 0.91 to 1.03 million. All age groups except the 20–24 year-olds show an increase with the highest growth at 32.7% for age group 50–54. The number of female workers is likely to rise by 19.4% and hence much more than that of men (7.9%). In the projection variant L, the labour force shrinks by 1.6%, despite the still growing total population. However, age groups 45–64 will

[25] Kühntopf and Tivig (2008b) provide a summary of some age- and sex-specific labour force participation rates used here. For detailed data see BBR (2006).

[26] A direct analysis of microcensus data on the district level was not possible because of the already mentioned small sample size problem.

experience growth of up to 26.3%. The share of workers in the total population is higher than the German average, amounting to 52.2% in 2005. However, it is projected to fall to 51.6% (H) or to 50% (L) by 2030.

The evolution of the labour force in Mecklenburg-Western Pomerania is marked by emigration, particularly of young persons. The labour force is projected to shrink from 0.94 million in 2005 to 0.65 (H) or 0.61 (L) million in 2030. The corresponding shrinkage is –30.9 and –34.4%, respectively. Due to the decreasing labour force participation of women of many ages, the decline is expected to be somewhat stronger for women than for men. Driven by demographic change, younger age groups are particularly affected by shrinking. Even in variant H, the labour force aged 15–54 shrinks by a range of one third (age 50–54) to more than half (15–19). Only the number of over 60 year-old workers increases by roughly half. While 54.8% of the population were economically active in MV in 2005, this share falls to 41.9% (H) or 41.2% (L) by 2030. The projection shows large differences at district level, which we discuss briefly for variant H. Although the number of inhabitants grows in Greifswald, Rostock and Nordwestmecklenburg, the labour force shrinks by 9.5, 8.7 and 21.5%, respectively. However, the rural and economically very weak districts Demmin and Uecker-Randow undergo a decline of almost 50% in their labour force. Only 36.6% of the population is expected to participate in the labour force in Uecker-Randow in 2030.

The final and equally uncertain step is the projection of the unemployment rate, which leads from the size of the labour force to the number of employees. We first determined unemployment rates between 1991 and 2007 which were calculated from the microcensus. Based on the past trend and plausibility considerations for the future, we then set a target unemployment rate for 2030 and calculated a geometric series for the intervening period. The results show a similar trend of unemployment in Hamburg and in Germany on average. The corresponding rates reached their maximum within the observed period at 10.7% in 2004 and 11.1% in 2005. We expect unemployment to decrease to 6.3% by 2030 in HH as well as in Germany overall, which is still above the levels in the early 1990s. The unemployment rate of MV is roughly twice the German average since 1992. It reached its maximum of more than 22% in 2004. We assume a decline to 10.5% by 2030, partly caused by labour shortage in the course of demographic development and against the background of improving economic conditions.

The application of a general unemployment rate on the labour force leads to the expected number of employees. The age- and sex-specific development of the employees is almost the same as for the labour force, only their number differs. While Germany had roughly 36.8 million employees in 2005, their number is projected to shrink to 34.1 (H) or 32.6 million (L) by 2030. In contrast, Hamburg will experience an increase from 0.81 million to 0.97 (H) or 0.84 million (L) over the period. With a decline of 21% in variant H, the number of employees in Mecklenburg-Western Pomerania shrinks three times more than in Germany on average – from 0.74 million to 0.58 million. In variant L, the expected decline by a quarter to 0.55 million in 2030 is more than twice the corresponding German average.

2.5 Macroeconomic Development

Macroeconomic developments regarding the gross domestic product (GDP) and exports are major determinants of infrastructure demand as modelled in the InfraDem project. We tried to give a rough estimate of the GDP trend development until 2030, which is consistent with our population projections. This estimation should not be taken as a forecast but rather as a possible scenario calculated on the basis of a theoretical growth model that ignores business cycles and encompasses only some of the links between the demographic and economic development.[27]

Long-term projections of the GDP for Germany are scarce. Examples include Werding and Hofmann (2008) and Institut für Wirtschaftsforschung Halle (IWH, 2006) but they are both based on other population and labour force projections and not those performed for the InfraDem project. We therefore chose to feed the model of the Institute for Economic Research (ifo) described in Werding and Hofmann with our demographic data.[28]

The theoretical framework is that of a neoclassical Solow-Swan growth model. Gross value added in year t, $\tilde{Y}_t$, results from the Cobb-Douglas production function:

$$\tilde{Y}_t = A_t K_t^{\alpha} \left(h_t L_t\right)^{1-\alpha} \;;\; 0 \leq \alpha \leq 1 \tag{2.2}$$

with L_t as labour input, K_t as capital input, A_t as total factor productivity, and the average human capital endowment h_t as a measure of the skill level and the efficiency of the labour input. The partial production elasticities are α for the capital input and $1 - \alpha$ for the labour input in efficiency terms. The capital accumulation evolves according to:

$$K_t = (1 - \delta)\, K_{t-1} + s\tilde{Y}_{t-1} \tag{2.3}$$

with s as exogenous savings rate and δ as exogenous depreciation rate. For the extrapolation of the total factor productivity and the efficiency of the labour input, logarithmical growth rates $\dot{a}$ and $\dot{h}$ are assumed:

$$A_{t+1} = A_t e^{(\dot{a}/100)} \tag{2.4}$$

$$h_{t+1} = h_t e^{(\dot{h}/100(1-\alpha))} \tag{2.5}$$

Adjustment by an exogenous net tax rate ε yields the GDP Y_t:

$$Y_t = (1 + \varepsilon)\, \tilde{Y}_t \tag{2.6}$$

[27] The model captures neither business cycle phenomena, nor the recent financial crisis and its short- and medium-term consequences. Furthermore, it ignores the influence of economic developments on demographic trends.

[28] We are deeply indebted to Martin Werding for providing the model and extensive advice.

The determination of the productivity parameters until 2004 is based on the ifo productivity database (see Roehn, Eicher, & Strobel, 2007), which displays a capital stock of about €7.85 trillion in 2004. The depreciation rate is assumed to be 3% and thus equal to the average over the period of 1991–2003. Following the same approach, the constant savings rate is set to roughly 23%. The labour force data comes from our two projections variants, H and L. Like in Werding and Hofmann, we assume that the joint growth effect of the increase in the efficiency of the labour input and in the total factor productivity amounts to 0.99%; $\dot{h}$ is thereby set to 0.66 (0.46 thereof is assumed to come from structural change and 0.2 from increased education), and $\dot{a}$ to 0.33. The initial value of h_t in 2004 is normalised to 1, while A_t amounts to 1331 in 2004. The output elasticity of labour, $1 - \alpha$, is assumed to be roughly 0.70, which corresponds to the average value between 1992 and 2004. Finally, ε is set at 9.8% for similar reasons. Substituting (1.3)–(1.6) in equation (1.2) and using the annual values of the exogenous labour force yields the GDP growth rate.

The results show that although the total population and the labour force are projected to shrink, the GDP still grows in both demographic variants, albeit at a decreasing rate. The average annual growth rate is 2.05% (H) or 2.03% (L) in the period 2004–2010; 1.52% (H) and 1.38% (L) between 2011 and 2020; and 0.82% (H) or 0.62% (L) from 2021 to 2030. These rates are higher than in Werding and Hofmann (2008) and IWH (2006) for the beginning of the period and lower towards its end. For the whole period of 2004–2030, the average annual growth rate is 1.4% in the high immigration variant H, and 1.3% in the low immigration variant L. The real GDP of Germany thereby increases from €2.12 trillion in 2005 to €3.03 (H) or €2.93 (L) trillion in 2030 (all values in prices of 2000). The differences in the demographic development have hence a rather weak impact on the GDP development at the national level.

The GDP per capita increases in Germany from €25,709 in 2005 to €37,350 (H) or €37,245 (L) by 2030. The GDP per worker grows from €57,605 to €89,014 (H) or €89,912 (L) over this period. The welfare measure GDP per capita is thus somewhat higher in variant H than in L, while the productivity measure GDP per worker is lower. The differences are due to the higher population in variant H and the higher capital intensity in variant L.[29]

Starting from the results for Germany, we estimated consistent regional GDP developments for the two model regions chosen, HH and MV, by applying a simplified procedure. First, we calculated the ratio of the GDP per worker in both federal states to the German average for the period 1991–2004. Then, we made an assumption on the level of this ratio in 2030 and interpolated the values within the period. By applying this ratio to the regional and national labour force projections and the national GDP projections, we calculated the GDP trend for Hamburg and Mecklenburg-Western Pomerania.

[29]The capital intensity is the ratio of capital to labour.

The GDP per worker in HH was roughly 1.8 times the German average in the early 1990s. The ratio decreased to almost 1.6 by 2000 and has increased slightly since. We assumed a value of 1.6 in 2030. The GDP per worker thus grows from €96,202 in 2005 to €142,462 (H) or €143,900 (L) in 2030. The GDP increases from €78.4 billion to €137.5 (H) or €120.7 billion (L) by 2030. The differences in demographic developments thus have a considerable impact on the expected GDP value. However, the gap is much lower in terms of GDP per capita: GDP per capita was at €44,961 in 2005 and it grows to €68,855 (H) or €67,616 (L) by 2030.

In contrast, the GDP per worker in MV was less than half the German average in 1991. However, the ratio subsequently increased to nearly 0.75 but slightly declined since the turn of the millennium. With an expected value of 0.8 in 2030, we assume convergence to the German average. The GDP per worker thus increases from €43,653 in 2005 to €71,208 (H) or €71,926 (L) by 2030. The GDP of €32.2 billion in 2005 was only 41% of the value of HH, which showed a similar population size but a 10% larger labour force. With projected values of €41.4 (H) and €39.7 billion (L) in 2030, the future GDP of MV is expected to amount to only 30 or 33% of that of HH. The GDP per capita grows from €18,857 in 2005 to €26,836 (H) or €26,697 (L) in 2030 and is thus much weaker than in HH.

These GDP projections are based on the model of a closed economy. We therefore estimated the future development of exports (which was needed as an input parameter for the model of air transport infrastructure) by simply extrapolating the past trend of the export quota[30] and applying it to the GDP projection. The national accounts display a German export quota of 0.258 in 1991, which declined to 0.223 by 1993 and subsequently increased to 0.469 in 2007. Based on the past trend, we expect a further rise in the export quota by 2030 but with a decreasing slope. The expected export quota of 0.72 in 2030 is similar to that of Prognos (2006) and lower than in IWH (2006); the latter project a value of 0.86. Exports and foreign trade are thus assumed to substantially gain in importance.[31] Globalisation in general, the increased labour division in particular, and the demographic development in Germany are expected to lead to this rise in the export quota within the next 2 decades. When applied to the GDP projection, this development of the export quota yields a growth in German exports from €0.87 trillion in 2005 to €2.2 (H) or €2.12 trillion (L) by 2030.

To emphasise the effect of demographic change on the macroeconomic development, we additionally calculated the GDP for a stationary population. The latter means that the demographic components of fertility, mortality and migration are such that they result in a constant age structure and size of the population. Here, we take the German population in 2005. All economic assumptions are the same as for both normal projection variants, including the expected change in the age- and

[30]The expert quota is defined as the ratio of exports to the GDP.

[31]The temporary slump in German exports due to the recent financial crisis is not considered in this estimation. However, as the GDP declined as well, it is not clear what the final effect of the crisis on the export quota will be.

sex-specific labour force participation rates and unemployment rate. Their application to the population in 2005 leads to an increase in the number of employees from 36.8 to 39.9 million through 2030, whereas it shrinks to 34.1 million in variant H and 32.6 million for L. The larger labour force in the stationary population scenario leads, as expected, to stronger GDP growth. However, the evolution of the capital intensity has somewhat of a decelerating effect. The GDP is projected to be €3.4 trillion in 2030. The demographic change thus lowers the GDP development until 2030 by €300 (H) or €400 (L) billion, which is a considerable effect given the growth of roughly €900 billion in variant H and €800 billion (L) between 2005 and 2030. The GDP per capita increases by 62% from €25,709 to €41,577.

2.6 Conclusions

Germany is likely to experience a process of demographic change that affects the macroeconomic development and the demand for transport and energy infrastructure. Population projections show shrinking of the population size from 82.4 million in 2005 to 81.2 or 78.6 million in 2030, depending on the migration assumption. The mean age of the population is expected to increase from 42.3 years to 46.6 years if annual net migration amounts to 200,000, and 47.1 years if the migration balance is half as high. However, demographic trends display substantial regional variance as demonstrated for two geographically nearby but in most other respects highly diverse regions: the city state Hamburg and the territorial state Mecklenburg-Western Pomerania. Our population projections yield an exceptionally weak demographic change in the former region, while it is particularly strong in the latter. Hamburg can expect a constant or even growing number of inhabitants, which moreover stays relatively young. In contrast, MV is affected by a very strong decline and ageing of its population. Demographic change in MV is thereby likely to be weakest in the university cities Rostock and Greifswald, as well as in the districts next to Hamburg, and strongest in Uecker-Randow and Demmin. Hence, even on the level of a single federal state, ageing is global while shrinking remains a local phenomenon.

Despite population shrinking, the number of private households in Germany is projected to increase from 39.4 million in 2005 to 41.5 or 40.3 million in 2030. The reason is a trend towards smaller households, implying a rise in the already large share of single- and two-person households and a decline in the number of households with three and more members. The trend is partly a consequence of population ageing. While Hamburg will see a growing number of households, this is projected to decrease in Mecklenburg-Western Pomerania. Households with three and more members are most often families, as seen from their age structure, and are thus projected to stay young. Ageing occurs mainly within the smaller households. The main earner of the family households is expected to remain most often a man aged 30–59 years. Single- and two-person households show a large share of over 60 year-old heads, which is projected to increase further with population ageing.

The labour force shrinks more strongly than the total population all over because large cohorts will leave working age or at least the age with high labour participation by 2030. Rising participation rates of women in the workforce in Germany and in Hamburg are not compensating the demographic effect, while the decreasing rates of female labour-force participation in Mecklenburg-Western Pomerania adds to the strong population decline. The active share of Hamburg's population remains above the German average, while it is likely to fall below it in MV.

Applying our population and labour force projections to a neoclassical Solow-Swan growth model yields that the GDP will grow substantially even under demographic change, both in total and per capita. However, the growth rate is diminishing, and it is lower in regions with strong demographic change. A decomposition of the growth rate using a stationary population indicates a strong demographic impact on GDP growth. Finally, based on the GDP development and on assumptions concerning the export quota, we expect German exports to be roughly 2.5 times higher in 2030 than in 2005.

Appendix

Table 2.2 Summary of assumptions of the population projections

		Germany	Hamburg	MV
Total fertility rate		Increasing from 1.34 in 2005 to 1.60 in 2025, then constant	Increasing from 1.22 in 2005 to 1.45 in 2025, then constant	Increasing from 1.29 in 2005 to 1.60 in 2025, then constant
Life expectancy at birth		Rising from 76.2 male/81.8 female in 2005 to 80.6/85.6 in 2030	Rising from 76.4 male/81.7 female in 2005 to 80.8/85.5 in 2030	Rising from 74.0 male/81.1 female in 2005 to 79.0/84.9 in 2030
Migration balance	High	200,000 p.a.	Constant immigration numbers, decreasing emigration rates	Rising immigration numbers, decreasing emigration rates
	Low	100,000 p.a.	Decreasing immigration numbers, rising emigration rates	Constant immigration numbers, constant emigration rates

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Chapter 3
Macroeconomic Conditions for Infrastructure Adaptation to Demographic Change

Joachim Geske

Abstract Demographic transition impacts on economies in different interdependent ways. We have developed a macroeconomic overlapping-generations (OLG) model that respects a large set of these interactions and mechanisms of endogenous growth. The model is quantified for data on Germany. Simulations using the expected demographic transition in Germany reveal that alternative growth channels reduce the economic impact of the transition. These results are of special interest for private infrastructural investment.

Keywords Infrastructure capital · Endogenous growth · Human capital · Overlapping generations model · Numerical solution

3.1 Introduction

The demographic structure in Europe will change unprecedentedly over the coming decades. Some of these developments have already started and are thus inevitable. In contrast, much less is known about the economic impact of demographic change. The economic effects can be classified as behavioural and caused by aggregation. An aggregation-induced change is a market demand or a supply shift caused by population composition and size, while age-specific behaviour does not alter. In addition to these aggregation-induced behavioural changes, behavioural changes could also exist that are exclusively time dependent. Aggregation and behavioural effects are highly interdependent because shifts caused by aggregation in market demand and supply induce price adjustments, which in turn generate behavioural changes.

Our research aims to develop an endogenous growth overlapping-generations (OLG) model for Germany, which accounts for a large set of aggregation and behavioural changes transmitted through different markets. We expose this model

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to an exogenous demographic development and solve it numerically. The insights from these simulations will contribute to the analysis of economic effects caused by demographic change.

The economic impact of demographic change is of special interest for infrastructure planning. Grid-bound infrastructure is defined as capital stock used for the production of selected services. Profitability aspects have gained importance for the provision of infrastructures for two reasons: 1. For the largest part of the twentieth century, infrastructure capital stock has been owned mainly by public institutions. Since 1980, privatisation efforts have promoted profit-orientated private ownership. Therefore a substantial part of the infrastructure capital stock is owned by private investors. 2. Public infrastructure investment projects have also come under transparency and accountability pressures (Deutsche Bundesbank, 2009, p. 34). Hence, public infrastructure is at least partially managed by private investors or is increasingly being managed as if it was owned by private investors. For these two reasons, issues that influence the profitability of infrastructure investment, such as financing (including costs caused by interest rates and the timing of the cash flow) and demand will have to be considered. This analysis discusses the extent and the impact of these profitability changes on investment conditions for infrastructure capital with respect to demographic change.

As the previous ownership reasoning suggests, infrastructure and related investment decisions are not explicitly modelled. Instead, infrastructure is interpreted as part of real private capital stock. Therefore, infrastructure-related economic aspects are derived from conditions for investment in real capital stock. This is unsatisfactory as the longevity of infrastructures and its economic function is not respected, as was the case, for example, with vintage capital. Nevertheless to keep the model traceable, the focus of this analysis will lie on demography-consistent demand structures and the interest rate development.

What is meant by demography-consistent demand structures and the interest rate development? Population cannot be interpreted as a parameter that scales the economy linearly. Stylised facts of the contemporary demographic state are and have been for decades: life expectancy alters monotonically, fertility stays below preservation level and migration substantially increases the population (at the national level). This development has a substantial impact on the economy via different channels:

1. Market interaction: If all prices remain constant even though demographic parameters alter, it can be expected that individual behaviour will remain unchanged. Nevertheless, as previously mentioned, aggregation effects cause price effects, which induce behaviour adaptations. Thus, changes in population structure generate economic adjustments.
2. In a similar way, aggregation is important with respect to non-market interaction. The most prominent example is the pension system. In the case of a demographic change that alters the relation of retirees to working-age people, the financial balance of the pension system changes. Necessary adjustments of contribution, benefits and retirement age will result from a political and economic process that has a strong age-dependent distribution aspect.

3. Demographic changes also influence individual decision making. Increases in life expectancy, for example, cause individuals to plan for a longer retirement period. This makes it necessary to increase savings to hold consumption constant during the life cycle. These age-dependent decisions to save and dissave will strongly influence the formation of prices on capital markets.
4. A population decrease raises the per capita bequest of successors. The positive income effect eases consumption and savings in early years. On the other hand, the increased life expectancy also shifts the date of bequest and shortens the period of potential usage.
5. Particularly in Germany, migration has had and will continue to have an effect on the population structure. The permanent inflow of migrants counteracts population decrease and poses serious threats on integration policy.

These considerations show the complexity of possible economically relevant conditions. To study their interaction, a model was set up including the previously described features. The modelling process has two focuses:

1. A key parameter of long-term economic development is the growth rate of the economy. Standard OLG analysis is based upon the assumption of exogenous productivity growth. To overcome this restrictive assumption, endogenous growth theory established several reasons for long-term (balanced growth path, BGP) economic growth (Section 3.2) in the 1990s. A task in contemporary growth theory is the unification of these different approaches. The model developed will contribute to this by additionally accounting for short-term transition dynamics (Section 3.3).
2. Modelling rational life-cycle behaviour in a deterministic environment of demographic changes requires that individual decision makers are perfectly informed about all relevant demographic parameters. It is thus necessary to break demographic development down into parameters that influence life-cycle decision making. The method and results of this decomposition will be presented in Section 3.5.

After setting up the model, the structure parameters will be quantified (Sections 3.4 and 3.5) and the model numerically solved. The results will then be presented in Section 3.6.

It is assumed that the exchange of goods with foreign countries is of negligible volume. The model economy will thus be closed[1]. This has an impact on capital markets where the savings of the young and the old equilibrate. The relation of aggregate savings is shifted, causing interest rate effects in a closed economy. This assumption is obviously inappropriate. However, if the same demographic development takes place in all relevant economies, the closed economy assumption is no longer inappropriate. At least for a large part of Europe, this is expected to be the case. We will thus assume a closed economy.

[1] Nevertheless there is significant migration.

A crucial parameter for the analysis is demographic development. For simulation, we used the demographic model of Leslie (1945). The model describes the time-discrete evolution of an age-structured single-sex population. The parameters of this model are time series of the fertility and age-dependent survival rate. The simulation of population development thus requires the handling of a huge data set. To reduce the data burden, a logistic regression is used for the parameters infant mortality, life expectancy and variance of life expectancy. This reduces the complete demographic development to four single-value time series. In addition to the data reduction aspects, this method has the advantage of interpolating the existing data sets, easing interpretation and enabling the consideration of the survival rate in rational decision-making processes.

3.2 Endogenous Growth

In this section, the requirements for modelling demographic change will be derived. Three facts of demographic transition within the next 50 years are the rise of the fraction of old people, a higher life expectancy and a population decrease. While the population decrease will show up significantly after 2050, the ratio of retirees to working people has already begun to increase significantly. An economic effect caused by a population decrease is the reduction of aggregate labour supply. The labour market will transmit a substantial effect of the demographic changes. The approach of modelling labour supply as purely time based in a society that heavily depends on knowledge is too simple.

Instead, we follow the approach of Heckman, Lochner and Taber (1998). In their model, the labour market is exclusively interpreted as the place where companies demand and consumers supply human capital of different skill levels. Therefore, wages are interpreted as the price of lending human capital. From the consumer point of view, by introducing human capital accumulation, we add an additional method of generating individual savings: while capital savings enable retirees to finance consumption, human capital enables working people to finance consumption and to save real capital. The decision on the level of human capital savings was modelled explicitly for the complete life cycle of an age-class representing consumer. To derive empirically plausible age profiles, investment cost functions were proposed and calibrated.

The introduction of consumer-owned human capital (Barro & Sala-i-Martin, 2003) is not only desirable because it is more realistic; it further allows for the existence of an equilibrium, where all aggregates grow at a constant rate. In this model, growth is interpreted as the possible result of a rational decision-making process. There are several (other) prominent explanations for endogenous growth: 1. human capital accumulation (Uzawa, 1965; Lucas, 1988), 2. increasing product variety, i.e. specialisation (Romer, 1987) 3. improvements in product quality (Grossman and Helpman, 1991b), 4. imitation, and 5. diffusion.

In our research, a simplified but integrated model is presented, which entails human capital and increasing specialisation as growth motors. Similar approaches have been used by Lau (2009) and Heijdraa and Romp (2009). A theoretical analysis can be found in Arnold and Kornprobst (2008). Our model is a neoclassical non-scale one-sector version that has been proposed by Barro and Sala-i-Martin (2003). The focus of our analysis is the numerical deviation of the transitional dynamics. Non-scale assumptions make it possible to abstract consequences from the strategic interaction that have resulted from the original monopolistic innovation problem and the appropriate modelling of patents.

Innovations induce company profits that have to be distributed to age-class representing consumers. A plausible distribution scheme is the distribution according to the savings share of age classes as hypothetical interest rate subventions. To keep the model simple, the rough approximation of a lump sum distribution according to the population share of age classes was chosen. These transfers do not completely crowd out private savings. Nevertheless, the ratio of profits generated by innovations and the GDP is 30% in our simulations. Thus a significant share of the GDP is distributed via a non-market channel.

To understand the growth mechanism in our model, it is useful to refer to the classical Solow growth model. It describes the way in which an exogenous productivity improvement propagates through an economy. It does not explain growth endogenously because the accumulation of a single factor (real capital) with decreasing returns to scale lowers its own marginal productivity thereby its price and the incentive to accumulate it. Uzawa (and Lucas) showed that as soon as both factors in a technology with constant returns are reproducible, the growth damping nature of the model is removed. As second reproducible factor next to real capital, Lucas proposes human capital. With this formulation, factor prices that generate the incentive to accumulate depend solely on the relation of capital stocks. Therefore, a constant growth of both stocks does not alter factor price or capital stock relation. Thus the key to understanding growth in this model is the balance of capital stocks. Balance disturbances dampen the growth rate until the long term capital stock ratio is reached.

A consequence of this modelling is that absolute values of the capital stocks in long-term equilibrium are not *ex ante* defined. The long-term stock values are only determined by transitional dynamics. Thus, convergence between different economies is not guaranteed. Further capital stocks can be introduced without changing these basic properties. This allows technical knowledge to be introduced, modelled as increased product variety (specialisation) according to Romer. Romer models aggregate output Y as produced by a Cobb Douglas production function from the factors labour L and the sum of I_k intermediate products $\sum_{i=1}^{I_k} X_i$.

$$Y(I_k) = L^{1-\alpha} \left(\sum_{i=1}^{I_k} X_i \right)^{\alpha} \tag{3.1}$$

In the standard version of the model, the intermediates are produced as synchronously produced services under monopolistic competition. Barro alternatively proposes producing the intermediates X_i solely using capital k_i.

$$X_i = \left(k_i\right)^{\alpha_i{}'} \tag{3.2}$$

The model can be reinterpreted as one sector version of Uzawa Lucas if the simplifications $\alpha_i{}' = \alpha'$ and $k_i = K/I_k$ are imposed and the additional factor is the index I_k instead of human capital. A comparative static analysis reveals the reaction of the production Y on an increase in the number of intermediates I_k $(= n\ )$ by one:

$$Y\,(n) < Y\,(n+1) \tag{3.3}$$

Elimination of X from (3.1) results in

$$L^{1-\alpha}\left(\sum_{i=1}^{n} k_i^{\alpha'}\right)^{\alpha} < L^{1-\alpha}\left(\sum_{i=1}^{n+1} \bar{k}_i^{\alpha'}\right)^{\alpha}. \tag{3.4}$$

The key to understanding the effect of an increase in I_k $(\ = n)$ is the diminishing marginal product of capital in intermediate production. A newly introduced intermediate has three effects on aggregate output: 1. Capital productivity in all old intermediate sectors increases because of reduced per-sector capital input (productivity increase). 2. Production in all old intermediate sectors decreases (contraction). 3. Additional production in the newly invented sector (expansion).

The overall effect is

$$n^{1-\alpha'} < (n+1)^{1-\alpha'}. \tag{3.5}$$

Therefore, productivity and expansion effects dominate the contraction effect because the new intermediate sector has very high capital productivity. This can be exploited by redistributing capital from other sectors to the new sector, which increases overall capital productivity and production even though the output in older sectors shrinks. Therefore specialisation has an inherent creative-destruction quality.

It is worth noticing that the new intermediate product does not directly improve productivity in the old sectors. Productivity is only indirectly affected by the redistribution of capital to all intermediate sectors. Hence capital is used more specifically, motivating the interpretation of I_k as an index of economic specialisation in factor usage – in other words technical knowledge. This also reflects production technological knowhow that is owned by the aggregate company. A further feature of the model is its transitional dynamics. If intermediates are produced synchronously to final goods production, allocating resources across time is unproblematic and no transition dynamics occur. This is different with the introduction of capital-based intermediate production and investment costs. Both features enable the analysis of transition processes.

Eliminating the intermediates results in

$$y_{it} = L_{it}^{1-\alpha} \sum_{i=1}^{I_k} k_{it}^{\alpha} \tag{3.6}$$

$$y = I_k \left(\frac{K}{I_k} \right)^{\alpha} = I_k^{1-\alpha} K^{\alpha}. \tag{3.7}$$

The previously described addition of human capital and technical knowledge to the model guarantees endogenous growth. We can now think of I_k as a steady variable whose production is costly but positive and which takes place at an aggregate level. I_k thus becomes a state variable that can be derived together with innovation activity – the investment in I_k – from a dynamic decision problem facing the company, which we will address in the next section.

It is assumed that technical knowledge is owned by companies. An equivalent interpretation is that companies rent the knowledge at a price according to its marginal product. We do not want to address legal questions of patent ownership and its duration. Profit-maximising companies can decide to invest in technical knowledge and receive revenues on it. Inventiveness is therefore treated as an additional component in company profits. We thus add the possibility of adapting a knowledge stock to the analysis of the economic impact of demographic change.

By symmetry, not only can capital be objective of technical knowledge, so can human capital. As a result, introducing labour organisation to our analysis was straightforward. A company can decide whether to improve its technical knowledge about real capital as well as about human capital. This additional option could further buffer the effects of demographic change. For example, as labour gets scarce, the investment in labour organisation could reduce a company's labour dependence. This substitution is limited by the substitution elasticity of labour and capital. This allows us to discuss aspects of the direction of technical change.

In summary, the proposed model can be interpreted as a synthesis of a simplified homogenous version of Heckman et al. (1998) and an endogenous growth model in line with Uzawa (1965) and Lucas (1988) enriched by a capital service interpretation (Barro & Sala-i-Martin, 2003, p. 215ff) of the endogenous growth approach of Romer (1987). The model will be presented in the following section.

3.3 Model

Consumers maximise the expected lifetime utility

$$\max_{c_{ij}} \sum_{i=1}^{I} \beta^{i-1} s_{ij} U\left(c_{ij}\right) \tag{3.8}$$

that is generated from a lifetime consumption plan c_{ij}. I is the length of the planning horizon. β represents the discount rate. s_{ij} is the probability of reaching an age i at time j. U is a standard CRRA utility function. Utility is maximised with respect to budget restrictions guaranteeing the equivalence of earnings and expenditure at each point in time:

$$s.t.: \left.\begin{matrix} w_j h_{i-1,j-1} - \tau_{rt} & i < T_r \\ \theta_{tr} & i \geq T_r \end{matrix}\right\} + r_j a_{i-1,j-1} + \pi_{i,j} + b_{i,j} = c_{i,j} + a_{i,j} + h_{i,j}$$
$$+\varphi_a \left(a_{i,j} - a_{i-1,j-1}, a_{i,j}\right) + \varphi_h \left(h_{i,j} - h_{i-1,j-1}, h_{i,j}\right) \tag{3.9}$$

Earnings consist of labour income $w_j\ h_{i-1,j-1}$. Each agent can accumulate human capital $h_{i,j}$. This human capital is paid at a price of w_t – the wage. The investment cost in human capital $h_{i,j}$ is directly modelled as resource (instead of time) consumptive usage. The consumer is only paid for his human capital until retirement age T_r. After retirement, he receives a pension θ_{tr} or the interest rate payment $r_j\ a_{i-1,j-1}$ on private savings $a_{i-1,j-1}$. To smooth consumption over a consumer's lifetime, it is necessary to generate savings in advance of the retirement age and to finance consumption in retirement age. Positive savings require labour income which can only be derived from accumulating human capital.

A further smoothing of the paths for both forms of capital accumulation is reached by introducing investment costs $\varphi^{a,h}$. To prevent an implausible late investment in human capital h, investment cost $\varphi^h(h_{i,j}–h_{i-1,j-1},h_{i,j},i)$ is additionally assumed to be influenced by i.

Further income components are individual shares in company profits $\pi_{i,j}$ and bequests $b_{i,j}$. Bequests result from the savings a of old-age consumers who die before age I. Collection-scheme savings of dead people are collected and redistributed in a lump sum manner across consumers of all age classes according to their population share. Further restrictions to the maximisation problem are

$$\begin{aligned} &s.t.: a_{I,j} = 0 \\ &s.t.: h_{i,j} - h_{i-1,j-1} = 0 \quad i \geq T_r \\ &s.t.: a_{0,j} = h_{0,j} = 0 \\ &s.t.: a_{i,0} = a_i^{BGP} \quad h_{i,0} = h_i^{BGP} \\ &j = t - 1 + i,\ i = 1 \ldots I \end{aligned} \tag{3.10}$$

The representative enterprise produces the consumption good using a constant return production function f. It determines the factor inputs of real (K_t) and human capital (H_t) and innovation investment i_{ht} and i_{kt}.

$$\begin{aligned} \max_{K_t,H_t,i_{kt},i_{ht}} \Pi = \sum_{t=1}^{\infty} \beta_{ut}^{t-1} \big[& f\left(K_t, H_t, I_{kt}, I_{ht}\right) - \left(w_t + \delta_h\right) H_t - \left(r_t + \delta_k\right) K_t \\ & - i_{kt} - i_{ht} - \varphi_{Ik}\left(i_{kt}, I_{kt}\right) - \varphi_{Ih}\left(i_{ht}, I_{ht}\right)\big] \\ & s.t.: I_{kt+1} = \left(1 - \delta_{Ik}\right) I_{kt} + i_{kt} \\ & s.t.: I_{ht+1} = \left(1 - \delta_{Ih}\right) I_{ht} + i_{ht} \\ & s.t.: I_{0k} = I_{kBGP} \quad I_{0h} = I_{hBGP} \end{aligned} \tag{3.11}$$

For calibration purposes, investment costs φ_{Ik}, φ_{Ih} are additionally introduced. In a one-consumer or representative-agent economy, the owner determines the company discount rate $\beta_{Ut} = \beta$. In an OLG model with age-specific survival rates βs_{ij}, further assumptions on the decision process of a company are required. The optimal consumption plan of consumers can be expressed by an Euler equation. Solving this for the individual discount rate β and inserting it into an age-class-weighted aggregation scheme ($U(c) = c^{1-g}/(1-g)$ and $c_{i+1,t+1} = \gamma\, c_{i,t}$, γ: steady-state growth rate) follows the anonymous relation

$$\beta_{ut} = \frac{1}{N_t}\sum_{i=1}^{I} N_{it}\beta_{it} = \frac{1}{N_t}\sum_{i=1}^{I} \frac{N_{it}U'(c_{it})}{U'_{t+1}(c_{i+1t+1})(1+r_{t+1}-\delta)} = \frac{\gamma^g}{1+r_t-\delta}. \tag{3.12}$$

This is a microfounded deviation of the standard assumption $1/\beta_{Ut}$ equals the interest rate of real capital r_t respective to its steady state value r_{ss}. Therefore, a decrease in interest rate increases discounting which means near-future profits become more important.

Innovation activity leads to a surplus Π_t that is redistributed according to age class i of consumers according to the share of their age class ($N_{i,t}$) in the population living at t

$$\pi_{i,t} = \frac{N_{i,t}}{\sum_{j=1}^{I} N_{j,t}}\Pi_t \tag{3.13}$$

In the pension system, earnings equal expenditure. The pension payment θ_{rt} is endogenously variable and τ_{rt} is the contribution.

$$\sum_{i=1}^{T_r-1} N_{i,t}\tau_{rt} = \sum_{i=T_r}^{I} N_{i,t}\theta_{rt} \tag{3.14}$$

Labour, capital and consumption good (Y_t is the quantity of the consumption good that is produced) markets are cleared[2].

$$\begin{aligned} H_t &= \sum_{i=1}^{I} N_{i,t}h_{i,t} \quad | \, i < T_r \\ K_t &= \sum_{i=1}^{I} N_{i,t}a_{i,t} \\ Y_t &= \sum_{i=1}^{I} N_{i,t}c_{i,t} \end{aligned} \tag{3.15}$$

[2] Questions of incompletely cleared labour markets are not part of the analysis.

3.4 Calibration and Simulation

Numerical solution of the model requires further definitions of the time horizon, functional forms and parameters, as well as the incorporation of the exponential growth of the variables. These issues will be discussed in the following section.

A technical but ultimately methodical question is the definition of the time interval to be simulated. The infinite-horizon, dynamic, general equilibrium model is described in the form of first-order conditions and restrictions – hence a system of nonlinear difference equations. A standard approach for solving this system is to inflate it up to a finite point in time and solve the resulting finite equation system simultaneously e.g. by a Newton-style algorithm (path). The finite inflation of the difference equation system requires a cut-off time point. At this time point, some equations refer to future variables whose values are generally unknown. However, the values are at least known to be constant if a steady state is reached at the cut-off point. This knowledge is generally sufficient to solve the equation system. It is thus an important requirement for the selection of the simulation length to choose a cut-off point that is closed to the steady state. This condition is fulfilled if the solution reaches steady-state values at the cut-off point. In our case, a simulation length of 100 periods is chosen.

Furthermore, the equation system refers to state variables before $t = 1$. We have no detailed information on the age profiles of human capital and savings at intermediate points in time. The standard method of generating these profiles is to use steady-state values as initial values. This assumption is of course only justified if the economy initially had a steady state. In the OLG scenario, in addition to the economic model variables, separate demographic parameters could also have a steady state. A population steady state can be a stationary or a stable population. Both concepts are based on age shares remaining constant. They differ with respect to population growth. A stable population might grow or shrink, while the size of a stationary population is constant. When we think of demographic development and economic development, different constellations are possible:

1. Economy grows/shrinks, population grows/shrinks
2. Economy static, population grows/shrinks
3. Economy static, population static

We chose the last scenario as our starting point. To find a steady state, we must find a point in time when the economy and population are static, such as a period before demographic transition and industrial revolution. The methodical approach thus requires long-term economic perspective. At first glance, this comes at the cost of reliable data and modelling but it allows us to embed the actual situation in a wider demographic and economic context.

With this long-term perspective, the theoretical foundation of growth becomes a central aspect for the quality of the simulation. The sound theoretical foundation of growth requires the release of productivity development from the black box of exogeneity to interpret it as result of decisions of consumers and companies.

As previously mentioned, the model elements of real and human capital, as well as technological development, guarantee endogenous growth in this model. Therefore, we can analyse which decisions are affected by demographic change and whether growth contributors substitute or complement each other at each point in time of the demographic transition.

Our analysis was conducted in 5-year intervals. Demographic parameters shifted from the beginning to the end of the simulation, and thus changed the BGP. Therefore, the initial and the end BGP and its growth rate must be computed separately. To ease convergence, the endogenous variables are normalised by the (end) BGP growth rate. Thus, besides prices, the economic variables become constant in the long term.

It was assumed that people have a maximum life expectancy (planning horizon) of 25 periods which equals a period of 125 years. Death before this age generates positive savings that are redistributed as a lump sum to surviving people of all age classes. The same redistribution scheme was used for positive profits that stem from as company's innovation activities. It would be more appropriate to add these payments to real and human capital payments, but for simplicity we decided not to do so. The pension budget was equilibrated. Benefits were endogenously determined and distributed as a lump sum to all retirees from revenues of an exogenous constant wage tax of 20%.

As a top-level production technology, a CES specification was used with the parameters of substitution elasticity σ and share parameter μ. Output Y is generated by I_{hit} human-capital-rich intermediate goods Vp_{hit} and I_{kit} real-capital-rich intermediates VP_{kit}

$$Y = \left(\mu \left(\sum_{j=1}^{I_{hit}} Vp_{hijt} \right)^{\frac{\sigma-1}{\sigma}} + (1-\mu) \left(\sum_{j=1}^{I_{kit}} Vp_{kijt} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3.16}$$

Intermediates VP_{hit} and VP_{kit} are produced in specialised human- and real-capita sectors using a CD technology with parameter α'

$$Vp_{hijt} = h_{ijt}^{\alpha^h} \quad Vp_{kijt} = k_{ijt}^{\alpha^k} \tag{3.17}$$

Sufficiently symmetric sectors imply

$$Y = \left(\mu \left(I_{kit}^{1-\alpha^k} K_{it}^{\alpha^k} \right)^{\frac{\sigma-1}{\sigma}} + (1-\mu) \left(I_{hit}^{1-\alpha^h} H_{it}^{\alpha^h} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3.18}$$

Calibrated parameters and functional forms are shown in Tables 3.1 and 3.2. Substitution elasticity σ was taken from Deutsche Bundesbank (2002) as 0.46 (approximated as 0.4). Even though this estimation did not entail aspects of human and real capital efficiency, we assumed that they were constant during the estimation period. In this case, the estimation parameter represents short-term substitution

Table 3.1 Functional forms of utility, technology and investment cost

Functions	
Utility function	$U(c) = \frac{c^{1-\gamma}}{1-\gamma}$
Production function	$f(K, H, I_k, I_h) = z\left(\mu\, g\left(K, I_k, \alpha^k\right)^{\frac{\sigma-1}{\sigma}} + (1-\mu)\, g\left(H, I_h, \alpha^h\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$
	$g\left(K, I_k, \alpha^k\right) = I_k\left(\frac{K}{I_k}\right)^{\alpha^k}, g\left(H, I_h, \alpha^h\right) = I_h\left(\frac{H}{I_h}\right)^{\alpha^h}$
Investment cost	$\varphi(i, k, I_k) = I_k \frac{i^2}{k}$
Discounting	$\beta^p_{t,i} = \beta^{i-1}\frac{s(t,i)}{s(t,1)}$
	$\beta^u_t = \frac{1}{\lambda^{-g}\left(r_{t+1} + 1 - \delta^k\right)}$

Table 3.2 Parameters

Function	Parameter	Symbol	Value
Utility function	Discount rate	β	0.7
	Relative risk aversion	γ	1
Production	Productivity	z	4.5
	Substitution elasticity	σ	0.4
	Income share capital	μ	0.6
	Income share capital innovation	α^k	0.55
	Income share human capital innovation	α^h	0.55
Investment cost	Savings	I_{k^s}	0.525
	human capital accumulation at age i	I_{k^h}	0.03 i^2
	Innovations in real capital	$I_{k^{I_k}}$	0.3
	Human capital innovations	$I_{k^{I_h}}$	0.5
Depreciation	Real capital	δ^k	$1–(1–0.07)^5$
	Human capital	δ^h	$1–(1–0.025)^5$
	Know-how real capital	δ^{I_k}	$1–(1–0.01)^5$
	Know-how human capital	δ^{I_h}	$1–(1–0.01)^5$
Retirement	Age of retirement	T_r	10
	Pension		0.225

relations that can be used in the top-level production function with efficiency changes.

As a utility parameter, $\gamma = 1$ (log utility specification) was chosen. Discount rate β was selected according to King and Rebelo (1999). They calibrated the steady state of an advanced real business cycle (RBC) model for quarterly US data to $\beta = 0.984$. This value was adapted to our 5-year periods $(0.984^4)^5 = 0.73$ and approximated by 0.7. The depreciation rate for real capital δ^k was determined as the average (7%) of the values found in the RBC literature $1–(1–0.025)^4 = 9.6\%$ (e.g. King & Rebelo, 1999) and more recent estimates of 4% e.g. Ludwig, Schelkle, and Vogel (2007) and Abadir and Talmain (2001). The depreciation rate of human capital δ^h was based on Jones, Manuelli, and Siu (2005) who reviewed the discussion on this parameter and concluded $\delta^h = 0.025$. We chose $\delta^h = 0.02$ because recent discussions such as in Arrazola and de Hevia (2004) point to a smaller value of $\delta^h = 0.01$. Few sources were available for the depreciation rate of ideas δ^{Ih} and δ^{Ik}. Exceptions are Johnson, Weshah, Razzak, and Stillman (2005) and Hall and Scobie (2006). Johnson et al. assume an annual depreciation rate of 0.05 while Hall and Scobie use 0.3. In our opinion, these values are too high for an information society with an almost unlimited storage capacity. We therefore chose $\delta^{Ih} = \delta^{Ik} = 0.01$. After setting the utility parameter $\gamma = 1$ BGP, convergence could only be reached for values of the productivity parameter z out of the interval [4, 4.75]. As a consequence z was set to 4.5.

The factor share parameter μ of the CES technology was determined to fit the real data. Thus, factor shares of capital and labour were computed from the German GDP (€2,062,500 million) and German wage payments (€ 1,101,660 million) (Statistische Ämter des Bundes und der Länder, 2009) in 2000. The result of this calculation is a factor share of labour of 0.53. In order to replicate this figure, μ was fixed at 0.6. The factor shares in the model were defined as the sum of the original factor payment and the income of associated innovation stock.

To generate age profiles of wealth as measured e.g. in Graham and Webb (2005), the investment cost of savings and human capital was introduced. Had we not done so, the accumulation of savings would have started shortly before retirement age and with too high a speed. Furthermore, wealth generation was preceded by an implausibly late start and too high a speed of human capital acquisition. The latter effect was ruled out by introducing an age-dependent, increasing, marginal cost of human capital acquisition. Moreover, the investment cost for savings was necessary to slow down savings accumulation. As a functional form, we chose the standard RBC specification i^2/k, which renders steady-state marginal investment cost independent of stock size.

The remaining indirectly observable parameters Ik^{Ik}, Ik^{Ih}, α^k and α^h were calibrated to replicate the long-term growth rate in both BGPs. The growth rate was determined as the real per capita income growth of Germany from 1870 to 1992 (Maddison, 2001). The final BGP growth rate should coincide with the average growth rate of the late years of the data set. Therefore, the average growth rate of Germany from 1950 to 1992 was determined as 3.5%. To reduce the impact of German post-war recovery, this value was lowered to 3% as the calibration target. The initial average growth rate of Germany was calculated as 1.75% (1870–1900). The calibrated BGPs showed growth rates of 1.05% (initial BGP) and 3.01% (final BGP). Therefore, the calibrated parameters Ik^{Ik}, Ik^{Ih}, α^k and α^h caused a satisfactory match of simulated and actual growth rates in both BGPs. This is remarkable because the parameters did not differ apart from the demographic parameters. In other words, the difference between the actual growth rates in 1870 and 1992 is sufficiently explained by the model and its static parameterisation.

3.5 Demography

We used the model by Leslie (1945) to simulate demographic development. His model describes the time-discrete evolution of an age-structured single-sex population. The population was divided into I age classes, all with an equal length of 5 years. Individuals in an age class either progress to the next age class or die within a time interval of 5 years. All members of the I-th age class die during this interval. The probability of surviving from age class i to age class i+1 is denoted $s(i,t)$. $L_{i,t}$ is the people aged i at time t. $L_t = (L_{1,t},\ldots,L_{I,t})$. Each individual in age class i has an expected offspring of size $F_{i,t}$. The matrix M_t: $m_{1,i} = F_{it}$ $i = 1\ldots I$, $m_{j+1,j} = s(j,t)$ $j = 1\ldots I$–1 and all other elements of M_t equal to zero allows us to describe the dynamics of the population by equation

$$L_{t+1} = M_t L_t \tag{3.19}$$

To give functional insights into demographic development, we used a data-reductive decomposition analysis of historic data on mortality and fertility.

Survival probability $s(i,t)$ was derived from mortality tables retrieved from the Max Planck Institute for Demographic Research. To reduce the data burden, an interpolation of the death rate 1– $s(i,t)$ was approximated by a logistic regression of the function

$$f(x) = \frac{G}{1 - e^{\frac{x-m}{\sigma}}} \tag{3.20}$$

The information in mortality tables could thus be decomposed and reduced to time series of three parameters (G_t, m_t, σ_t). The interpretation of the parameters was straightforward: G is the saturation value of the logistic function ($lim_{x\to-\infty}$ $f(x) = G$), m is the value of the inflection point ($f''(m) = 0$) and $1/\sigma$ the slope of the tangent at the inflection point ($f'(m) = -(G/4)^2/\sigma$). G can be interpreted as infant mortality, m as life expectancy, and σ as its variance. The time series of these parameters is a logistic graph for G_t, a linear trend for m_t and a constant for s_t. The logistic graph, the linear trend and the constant were estimated and extended at the beginning of the simulation and at the end as constants. The corresponding time series are presented in Fig. 3.1[3] for G (InfSurv) and m (LifeE).

Fertility $F_{i,t}$ was broken down further into $F_{i,t} = A_i$ TFR_t where A_i is time-independent age distribution and TFR_t the total fertility rate. The time series used for TFR_t is shown in Fig. 3.1.

Infant mortality was at its lowest in 2000 and it cannot be expected to decline further. Life expectancy grew linearly for almost 150 years from 1850. The survival rate decreased at a constant rate. To simulate a stationary population at the beginning and at the end of the simulation, the corresponding TFR values were computed. The

[3]The parameters explain the population development of Germany. They are based on assumptions of the Federal Statistical Office.

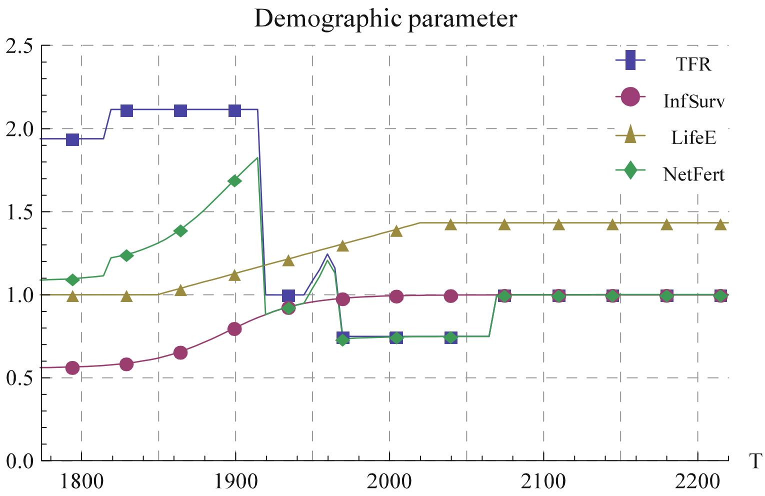

Fig. 3.1 Time serieses of demographic parameters used for simulation (TFR: total fertility rate, InfSurv: infant survival rate, LifE: index of life expectancy, NetFert: netto fertility)

time series of TFR was extended by these values in Fig. 3.1. The values at the beginning and end differ because of the extended life expectancy and reduced infant mortality.

The decomposition of fertility makes it possible to derive demography dependent household consumption data through a rough heuristic. This is particularly important because consumers in the model are interpreted as households. A household is assumed to be an economically active entity above an age of 20. This assumption is useful as these age groups have full legal capacity for the contracts necessary to unfold economic activity. Therefore, the consumption of a consumer at the age of 25 in the model includes the consumption of its offspring. The additional consumption expenditure will be modelled by a dynamic correction factor in the budget constraint: consumption expenditure at age i equals the utility generating consumption of a consumer at age i multiplied by (1 + 0.5 (number of offspring sired at age $i - 1 + \cdots +$ number of offspring sired at age $i - 4$)). For any age class, the number of per capita offspring is calculated from fertility and infant mortality data. As fertility in the initial BGP and the final BGP differs by a factor of 2, the household size also differs substantially. The economic impact of the decrease in household size is a need to finance less consumption at earlier stages in the lifetime. This will have implications for the need to accumulate human capital.

The analytical potential of Leslie's model can best be presented by parameter changes that unveil the impact of changes in fertility, life expectancy and migration on long-term population development. For example, the unisex population development model permits the generation of hypothetical scenarios. Figure 3.2 shows time series for a population development excluding 1. deaths during both world wars, 2. migration and 3. the offspring of the baby boomers whose fertility exceeded 0.75.

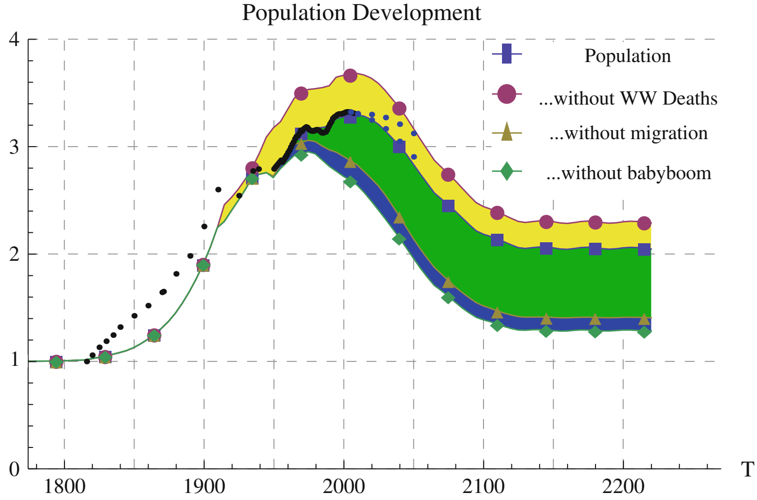

Fig. 3.2 Hypothetical population development (*black dots*: historical data, *blue dots*: official projections: "high variant" and "low variant")

The shaded areas mark population differences. Nevertheless, besides its attractive simplicity, the unisex model lacks realism and is therefore difficult to interpret:

The shaded areas in Fig. 3.2 do not disappear as time goes by even though the baby boomers themselves are no longer alive at the end of the simulation. Nevertheless, in Leslie's model, the single-sex hypothesis facilitates the identification of the offspring of the baby-boom generation, their offspring and so on. No group vanishes completely. This concept makes no sense from a sexual reproduction point of view because the mixture of groups forms a more homogenous society. It is thus useless to say that migrants will represent one third of the population in 2100 according to the assumptions implied in Fig. 3.2. However, it is meaningful to state that migrants contributed significantly to the population in 2100. With these limitations in mind, Fig. 3.2 shows that without migration, the population would have started to decrease in 1975. Migration has thus been the dominant demographic factor for the last 30 years.

3.6 Results

Figures 3.3 and 3.4 outline the development of the simulated population, real population data and population prognoses. In the first step of the analysis, we evaluated the accurateness of the simulated population and its age structure in comparison to historical population data.

The simulated population shrinks from 2010. This is one 5-year period after real data exhibited a population decrease from 2002 – annual data are plotted as points up to 2006. From 2006, the simulated population lies in the interval of the population data prognoses "low variant" (3-W1) and "high variant" (3-W2) of the

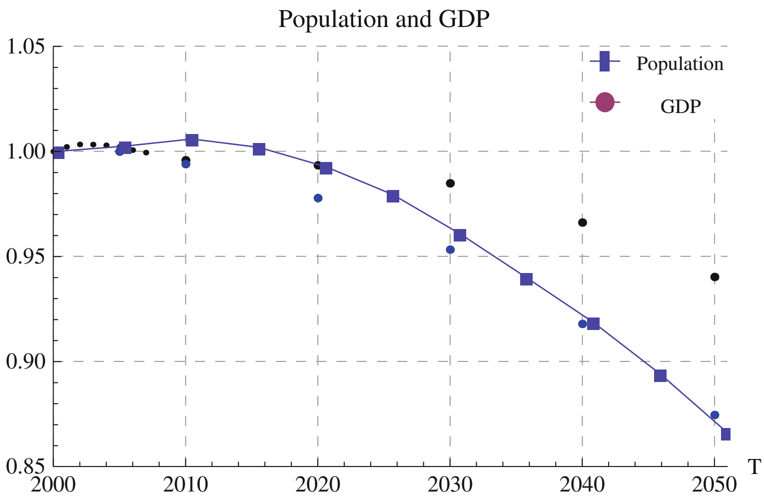

Fig. 3.3 Index of simulated population, actual population and prognosis of population development (as changes compared to 2000)

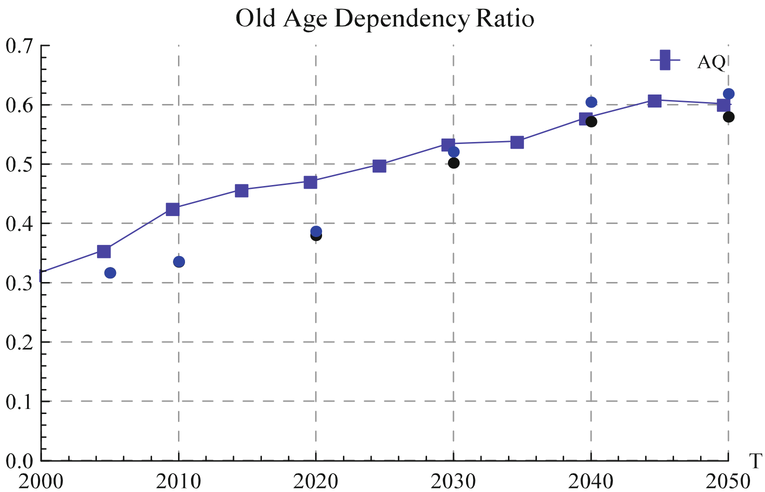

Fig. 3.4 Old-age dependency ratio

Federal Statistical Bureau. The projections are presented as isolated points from 2010 in 10-year steps. Up to 2020, the simulated population is more accurately approximated by the prognosis “high variant” and after this, by the “low variant”.

To assess the accurateness of the simulated age structure, the old-age dependency ratio is a decisive indicator. It is defined as the ratio of the population including age classes above 65 to the population consisting of age classes from 20 to 65. It is thus a measure of the economically meaningful retiree/employee relation. The old-age dependency ratio of the prognosis increases from 0.32 in 2005 (Fig. 3.4) to 0.58 and 0.62 (for prognoses in the “high variant” and “low variant”, respectively) in 2050.

Time series of these data are plotted as points from 2010 to 2050 in Fig. 3.4. These data were overestimated by the simulated population until 2030. From 2030 to 2050, it fits well.

The initially simulated population exceeded the official prognoses on population size and the old-age dependency ratio. In the second half of the simulation, the simulated population size and old-age dependency ratio lay in between the official prognoses (3-W1) and (3-W2). The simplifying assumptions of demographic development generated a population with characteristics that sufficiently fitted the actual population data and the official prognoses.

The successful evaluation of the demographic simulation enables us to analyse the economic impact of demographic changes. The most important indicator of economic development is the GDP. Its growth rate drops from 3.3% (2000–2020) to 2.7% (2020–2050) in 2020 (Fig. 3.5). Decomposing the GDP into the contribution of the population decrease and a per capita GDP fraction indicates that the per capita growth rate remains almost constant. Therefore, the GDP drop can be attributed to the decline in population.

In addition to the negligible changes in the productivity growth rate, stock structure adapts in reaction to the rise in the old-age dependency ratio. Figure 3.6 gives an overview of the evolution stocks measured by their relation to their contemporary sum normalised by their values in 2000.

Stock shares shift from real and human capital towards innovations. The share of human capital decreases by more than 5%. This drop neither indicates a decrease in aggregate human capital stock nor a reduction in individual human capital aggregation. Human capital would only fall if the rate of decrease per period exceeded the economy-wide growth rate (8% per 5 years). However, human capital falls with a rate < 2.5%. Therefore, human capital stock continues to rise.

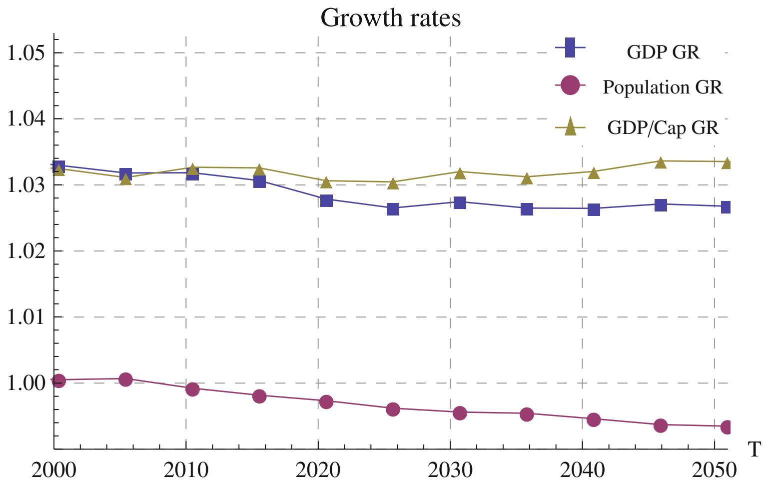

Fig. 3.5 Annual growth rates (GR) of simulated population, GDP and GDP per capita

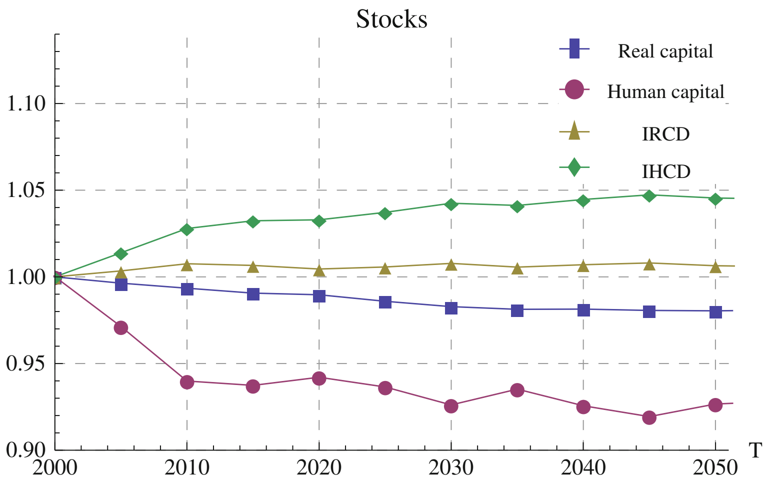

Fig. 3.6 Indexes of stock shares of total stocks [as changes of shares compared to 2000]

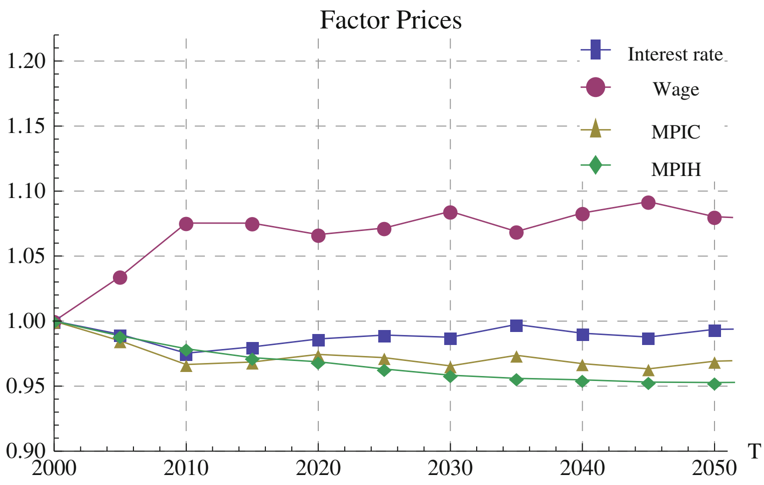

Fig. 3.7 Indexes of factor prices [as changes of shares compared to 2000]

Real capital stock shares also decrease but only slightly (less than 2% in 2050 of its initial share). The index of real capital specialisation increases marginally (by less than 1% in 2050 compared to its initial share). The share of human capital specialisation index compensates for the decrease in human capital (by less than 5% in 2050 compared to its initial share). The research activities of companies aim to improve human capital specialisation.

These stock adjustments can be interpreted in the following way: The old-age dependency ratio increases. Hence, aggregate human capital decreases while

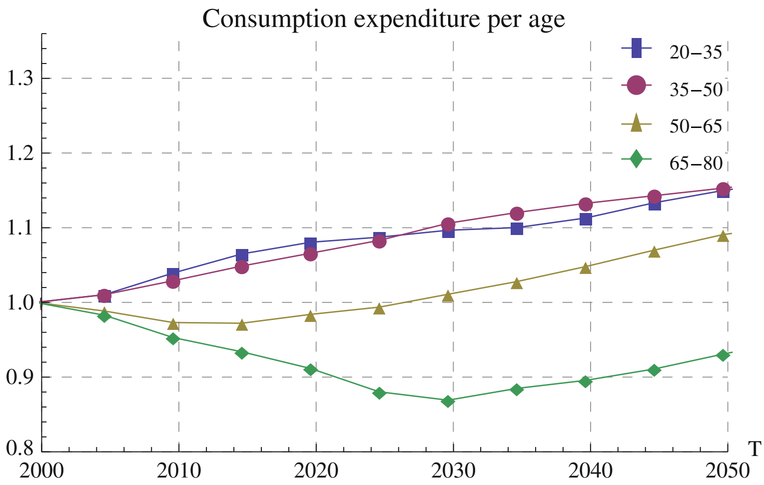

Fig. 3.8 Consumption expenditure by age class [as changes compared to 2000]

savings of retirees increase. While population and consumption demands remain constant, this causes: 1. an excess supply of savings on real capital markets which causes real interest rates to fall (Fig. 3.7), and 2. an excess demand of human capital that causes wages to rise (Fig. 3.7). Thus, investment in human capital saving specialisation becomes profitable and the stock of innovations is above average. On the other hand, real capital innovations become less profitable.

The age class structure of the model makes it possible to analyse the intergenerational distribution effects of demographic change. In Fig. 3.8, the age-specific consumable income normalised by its initial values in 2000 are presented. The development of consumable income of people below the age of 50 differs substantially to that of those aged above 50. While people below the age of 50 profit from increasing wages, older people – especially retirees – do not. From 2030, consumable income grows at a constant rate and age relations stay constant. Thus, a permanent shift occurs towards the income of people below the age of 50.

3.7 Conclusion

The economic impact of demographic transition was analysed in an equilibrium model integrating detailed aspects of this demographic transition and endogenous growth. The goal of this research was to analyse infrastructural investment. Hence, findings were presented as changes in the economic environment of an infrastructure investor who is able to choose between two identical sets of investment options today and in the future. If for example (c.p.) interest rates rise, not all options that are profitable today will remain profitable in the future. Therefore, the investor will select different strategies in both cases due to changes in the economic environment. The outcome of our analysis is robust against this change in investment strategies because a general equilibrium approach is used. General equilibrium analyses go beyond partial analysis of optimal investment decisions insofar as reactions of market participants to investment decisions are considered. However, optimal strategies and the economic environment of the investors can be derived.

Changes in the economic environment can be evaluated from a social welfare and an investor's perspective. Both points of view should not be confused: an interest rate rise might reduce the profits of an investor but the allocation can nevertheless be Pareto efficient and therefore desirable. The following is a description of a change in environment that requires adjustment of an optimal investment strategy.

For the simulation period 2000–2050, the investment environment does not shift substantially. Interest rates and productivity growth rates stay relatively constant. This is due to the various adaption mechanisms that were introduced in the model. The possibilities of direct specialisation and of accumulating real and human capital ease adjustments. Generation-specific analysis indicates significant changes of consumable income among the age classes. Thus, the planning of age-specific infrastructures requires additional adjustments. To summarise, the environment for long-term private infrastructure investment will not worsen substantially.

Nevertheless, the complexity of the model did not allow modelling of vintage capital nor load-specific aspects of grid-bound infrastructures. Both problems could be addressed in more advanced settings. Furthermore, a deeper analysis of the inter-age-class distributional effects could provide fruitful insights for political debate on intergenerational burden sharing.

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Chapter 4
Demographically Induced Changes in the Structure of Final Demand and Infrastructure Use

Tobias Kronenberg

Abstract As consumption patterns differ between households depending on the age and number of household members, demographic change alters the structure of overall consumption expenditure. This chapter presents an extended input–output model, which was used to study the impact of demographically induced changes in the structure of consumption expenditure on infrastructure use. The analysis is performed for the cases of Germany, Hamburg, and Mecklenburg-Western Pomerania. Selected sustainability indicators (energy use and emissions of CO_2 and NO_X) are quantified to study the implications for sustainable development. The results show that although the shift in consumption patterns tends to reduce energy use and emissions, it does not achieve the required decoupling of GDP growth and emissions.

Keywords Demographic change · Infrastructure · Energy use · Emissions · Input–output model

4.1 Introduction

A core task of InfraDem consists of estimating the impact of demographic change on consumption patterns and evaluating it from a sustainability perspective. This entails a quantitative discussion of sustainability indicators such as energy use and CO_2 emissions. To this end, an input–output modelling approach was applied in order to estimate the impact of demographic change on energy use and emissions of CO_2 and NO_X in Germany between 2006 and 2030. As in Chapter 2, the same analysis was performed for Mecklenburg-Western Pomerania and Hamburg. This

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chapter presents the methodological background of the input–output approach and discusses the results.

In addition to demographic change, a variety of other factors influence consumption patterns over time, for instance income effects and altered preferences. In order to unambiguously identify the effects of demographic change, a decomposition analysis was performed. The following section shows the effects that can arise by means of a simple example with only two goods. Following this discussion, the input–output approach is used to quantify *demographic effects* and *income effects*. The results show that although demographic and income effects provide a contribution toward reducing energy use and emissions of CO_2 and NO_X, further changes of a technological or behavioural nature are required if a decoupling of GDP growth and emissions is to be achieved.

4.2 Motivation

As Chapter 2 has shown, demographic change affects the size of a population as well as its age structure. Ceteris paribus, a smaller population will consume less energy and emit a smaller amount of pollutants. From a sustainability perspective, this is clearly beneficial. However, since consumption patterns differ between age groups, the changing age structure may increase or decrease overall energy use and emissions. In the former case, the effect of population ageing works against the effect of population shrinking. Theoretically, the former effect might be stronger, and the overall effect on energy use and emissions might be positive. A priori, it is not clear whether demographic change will tend to increase or decrease energy use and emissions. Therefore, the purpose of this chapter is to provide a numerical estimate of the effect of demographic change on energy use and selected emissions. Since energy use and emissions are affected by various other factors, a decomposition analysis is applied in order to isolate the effect of demographic change. This approach is described in the following paragraphs.

In reality, the consumption of all goods is directly or indirectly linked to emissions. Even in services, which appear to be "clean" on first sight, a certain amount of emissions is always embodied, as the production of services requires the use of various intermediate inputs whose production did cause emissions. However, for ease of exposition it is convenient to assume that a distinction can be made between "clean" goods, whose consumption generates no emissions, and "dirty" goods, whose consumption generates direct or indirect emissions.

The key equation of the decomposition analysis applied in this chapter is the following equation:

$$E = \left(\frac{E}{A}\right)\left(\frac{A}{C}\right)\left(\frac{C}{Y}\right)Y. \tag{4.1}$$

Y stands for GDP, *C* for the level of consumption expenditure, *A* for the amount of "dirty" goods consumed, and *E* for the level of emissions. Equation (4.1) shows that from a very simple point of view the level of emissions is proportional to the level of GDP. However, the factor of proportion depends on the development of three other factors: the share of consumption expenditure in GDP (*C*/*Y*), the share of "dirty" goods in total consumption expenditure (*A*/*C*), and the emission intensity of those goods (*E*/*A*). If these three factors remain constant, any growth in GDP leads to a proportional increase in emissions. Hence, a decoupling of emissions from GDP requires that at least one of the three factors is reduced over time.[1]

The share of consumption expenditure in GDP is usually relatively constant over time – in Germany it has fluctuated around 60% in recent decades. There is no theoretical or empirical reason to expect a major reduction. Therefore, the construction of scenarios in the subsequent analysis is based on the assumption that this share remains constant.

The emission intensity of the "dirty" goods depends to a large extent on the state of technology. Improved production processes can lead to a reduction in emission intensity. In some instances, further improvements in energy intensity may be impossible due to the laws of nature. However, the fact that in many areas considerable improvements are still possible is not controversial. Reducing the emission intensity of "dirty" goods can therefore contribute significantly to the desired decoupling of GDP and emissions.

The share of dirty goods in total consumption as shown in Eq. (4.1) is a stylised representation of a consumption structure which in reality is much more complicated.[2] This structure can change for a variety of reasons, as illustrated in Eq. (4.2), where $g_{A/C}$ stands for the growth rate of (*A*/*C*):

$$g_{A/C} = \varepsilon_d + \varepsilon_y + \varepsilon_S + \varepsilon_P. \tag{4.2}$$

An *income effect* (ε_y) occurs if households react to an increase in income by changing the structure of their consumption patterns. In economic theory, the relationship between income and consumption expenditure on a certain type of good is represented by means of an *Engel curve* (Fig. 4.1). The income elasticity tells us by how many percent the expenditure on good *A* rises if the total budget rises by 1%. If this value is equal to one, the relationship between *C* and *A* is proportional. In this case, the Engel curve is represented by a straight ray starting in the origin.

[1] Strictly speaking, Eq. (4.1) reflects only those emissions that are linked to consumption. If *C*/*Y* falls, the share of other GDP components would increase by definition. Therefore, reducing *C*/*Y* is not a sensible emission reduction strategy.

[2] In the general case, there are *n* variants of consumption goods. The consumption structure can then be described by a vector of length *n*, in which each element represents the share of a certain consumption good in total consumption. For the simplified representation in Eq. (4.1), it was assumed that only two different goods exist. In this case, the vector describing the consumption structure contains only the elements (*A*/*C*) and (1–(*A*/*C*)). Thus, the entire consumption structure can be described by the value of (*A*/*C*), which allows for a simplified notation. Without this assumption, the mathematical presentation would have to be written in matrix form, causing problems for readers who are not familiar with matrices.

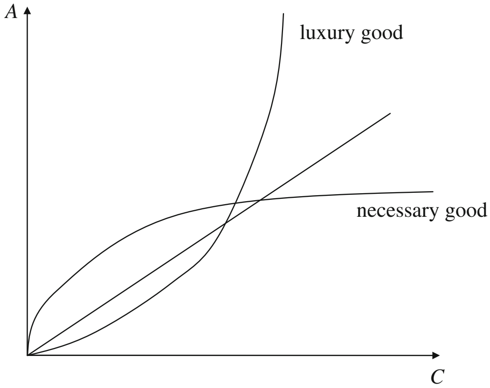

Fig. 4.1 Engel curves for luxury goods and necessary goods

Households with low income usually spend a large share of their total budget on goods such as food and shelter. These are necessary goods. If the income of poor households rises by x percent, their expenditure on these goods rises by less than x percent, the income elasticity being smaller than one. This leads to a concave Engel curve. For luxury goods, the opposite is true; their Engel curves are therefore convex.[3] An increase in income will always be accompanied by a shift in consumption structures, expect for the very unlikely case where the income elasticities of all households for all goods are equal to one.

A *demographic effect* (ε_d) occurs when the relative weights of age groups, which display different consumption patterns, shift. This is where demographic change comes into play. Even if all other parameters remain constant, demographic change leads to an alteration of the macroeconomic consumption structure, which after all represents a weighted average of the age-group-specific consumption structures. As demographic change raises the share of older age groups, their consumption patterns receive a larger relative weight. This effect is at the core of InfraDem.

A *substitution effect* (ε_s) can arise when the relative price of a good changes. The substitution elasticity tells us by how many percent the demand for some good falls if its price rises by 1%. Usually, a consumer will attempt to substitute another good with similar characteristics for the good that has become relatively more expensive. The success of this attempt depends on the availability of appropriate substitutes.

The estimation of substitution effects is complicated by the fact that different goods can be complementary or substitutable, which is expressed by the cross-price elasticity between two goods. If, for example, an increase in gasoline prices leads to a reduction in the demand for automobiles, as consumers switch to other transportation means, the cross-price elasticity between gasoline and automobiles is negative. In the same example, however, it is possible that the demand for new cars rises, as

[3] A necessary good is defined as a good whose income elasticity is between zero and one, and a luxury good is defined as a good whose income elasticity is larger than one (Lewis, 2008, p. 230)

consumers replace their old cars with newer models with better mileage. In this case, the cross-price elasticity is positive. Therefore, the effect of altered relative prices on the structure of consumption expenditures can only be estimated if the cross-price elasticities between all available goods (which may not even be symmetrical) are known.

A *preference effect* (ε_P) can occur, for example, when a change in social norms motivates consumers to change their consumption patterns. This mechanism is the idea underlying certain information campaigns and persuasion strategies, which are intended to change the preferences of consumers in such a way that they value "green" goods more highly. In the context of demographic change, cohort effects may be of some importance.[4] From an economic point of view, they can also be interpreted as preference changes, because they lead a group of households to make different decisions under otherwise identical circumstances.

For more clarity, Table 4.1 presents a list of these effects including a short explanation.

One of the major goals of InfraDem was to estimate the direction and size of the demographic effect in order to assess the issue of demographic change from a sustainability perspective. The remainder of this chapter explains how an input–output modelling approach was applied to this task. Some of the other effects were not taken up in the same model as doing so would have required working at a much more aggregated level, which would have invalidated the desired focus on the demographic effect. It was possible, however, to take up the level effect and the income effect without making concessions in terms of aggregation. Thus, the following sections will discuss level, demographic, and income effects. Preference effects (cohort effects) are discussed in Chapter 9, whereas technology features more prominently in Chapter 7.

Table 4.1 List of effects which are identified in the decomposition analysis

Effect	Explanation
Level effect	Ceteris paribus, an increase in the level of GDP leads to an increase in the level of emissions
Structural effects	
Income effect	An increase in income changes the composition of consumption expenditure between luxury goods and necessary goods
Demographic effect	An increase in the share of old age groups raises their relative "weight" in total consumption expenditure
Substitution effect	A change in (relative) prices alters the (relative) demand for goods
Preference effect	After a change in preferences, households alter the allocation of their consumption budget over different goods. This includes cohort effects
Technology effect	After a change in technology, the consumption of a given good causes a different amount of emissions

[4] Cohort effects therefore receive more attention in Chapter 9.

4.3 Methodology

This section lays out the methodology which was applied to identify the effects of an increase in GDP and income per household as well as a change in the demographic structure on energy use and emissions of CO_2 and NO_X.

4.3.1 Econometric Estimation of Consumption Patterns

In order to model the effect of an altered demographic structure and growing income per household, an econometric estimation method was employed. The dataset was taken from a *scientific use file* of the EVS 2003, which was obtained from the Federal Statistical Office. The variables that were entered into the estimation equation are defined in Table 4.2.

The parameter values were estimated for 133 consumption purposes using the following equation:

$$\gamma^m = \alpha + \beta_1 D\_AGE_1 + \cdots + \beta_5 D\_AGE_5 + \beta_6 D\_SIZE_1 + \cdots + \beta_9 D\_SIZE_4 + \beta_{10} LN\_C + \varepsilon \quad (4.3)$$

Households were distinguished by six age groups and five sizes. Since in every instance one group serves as a reference category, it was necessary to use five age dummies and four size dummies. The variable LN_C was included in order to estimate the impact of total consumption expenditure on the share of purpose *m*. In the following, that effect is interpreted as an income effect.

The estimation results make it possible to compute for each household group the expected consumption structure for a given level of monthly consumption expenditure. Therefore, some assumptions had to be made concerning the macroeconomic context and the distribution of income between households.

4.3.2 Macroeconomic Context

Operation of the open input–output model, which represents in a stylised way all the transactions that are made in a market economy over the course of a year, requires

Table 4.2 Variables entered into the econometric estimation

Label	Description
γ^m	Share of consumption purpose *m* in the total consumption expenditure of a household
D_AGE_1,. . ., D_AGE_5	Age group dummy (reference category: U30)
D_SIZE_1,. . ., D_SIZE_4	Household size dummy (reference category: 1 person)
LN_C	Monthly consumption expenditure (in log form)

Table 4.3 Allocation of German GDP in 2006

Allocation purpose	Value (billion EUR)	Share (%)
Consumption private households	1,304	56.1
Consumption NPISH	38	1.6
Consumption government	436	18.8
Gross investment	397	17.1
Net exports	148	6.4
Sum (= GDP)	2,322	100.0

Source: Statistical Yearbook (Federal Statistical Office)

the full specification of final demand expenditure. The most important component of final demand is consumption expenditure. In the national accounts, a distinction is made between the consumption expenditure of private households, non-profit institutions serving households (NPISH), and government. Further components of final demand are gross investment and exports.

The concept of final demand is closely related to that of GDP, which is by definition equal to the sum of consumption, investment, and net exports. Table 4.3 shows the allocation of Germany's GDP over these purposes in 2006. By far the greatest share of GDP (56.1%) was allocated to consumption of private households. Other important components were government consumption (18.8%) and gross investment (17.1%). Net exports accounted for a share of 6.4%. The smallest entry in the table shows that consumption by NPISH amounted to a share of only 1.6% of GDP.

The allocation of GDP has remained relatively stable in recent decades. Therefore, the allocation shares shown in Table 4.3 were assumed to remain constant over the period from 2006 to 2030. Based on the projections of GDP and exports from Chapter 2, this assumption yields a projection of the components of final demand. This projection, however, concerns only the *level* of consumption by private households. The demographic effect discussed above, however, will affect the structure of consumption by private households. Therefore, the next step was to break down the projection of total consumption expenditure into different consumption purposes.

4.3.3 The Structure of Households' Consumption Expenditure

Once the time path of total consumption expenditure of households is assumed to be given by the macroeconomic projection outlined above, the question arises as to how it will be distributed among individual households. This issue was solved by an assumption that was considered plausible and practical. Usually, policymakers attempt to distribute macroeconomic income gains (or losses) rather evenly among all social groups. Taking an optimistic view, it was assumed that this goal is achieved. As a consequence, consumption expenditure per household grows at the same rate in all household groups.[5]

In the next step, the results of the econometric estimation of (4.3) were used to compute the allocation of each household group's total consumption expenditure over 133 consumption purposes. The outcome was a projection of consumption expenditure by 133 consumption purposes valued at consumer prices. This had to be converted into commodity groups and producer prices.[6] Finally, a projection of consumption expenditure by 71 commodity groups valued at producer prices was available to be used in the next step.

4.3.4 Sectoral Production and Emissions

In order to estimate the effect of demographic change on sectoral production, energy use and emissions of CO_2 and NO_X, an environmentally extended input–output (EIO) model was used. The required data was obtained from the Federal Statistical Office's most recent input–output table (for 2005) and various tables from the Environmental Economic Accounts (EEA). For reasons of tractability, it was assumed that the input–output coefficients (which relate the output of an industry to the different inputs) computed from the 2005 table remain constant. Energy and emission intensities were equally assumed to be constant. This is not to say that there will be no technical change in these fields; the input–output approach deliberately puts technical change aside to focus on the demographic aspect and leaves technical change, especially in the energy sector, to be discussed in Chapter 7. For the federal states of Hamburg and Mecklenburg-Western Pomerania, input–output tables were not available. Therefore, the CHARM approach (Kronenberg, 2009a) was used to construct input–output tables for these regions. A brief overview of this approach is provided in the appendix to this chapter.

4.4 Results

Using the EIO approach outlined above, two scenarios ("high" and "low" population variants) were computed for Germany, Hamburg, and Mecklenburg-Western Pomerania. In the following, we concentrate on the results for Germany in the "low" population variant. The "high" population variant is discussed in Section 4.4.4 as a

[5]This assumption can be interpreted as a successful attempt by the government to adjust all measures affecting the intergenerational distribution of income (e.g. tuition fees, pensions etc.) in such a way that, in sum, they do not alter that distribution.

[6]Consumption statistics record expenditure according to the COICOP classification (the EVS uses SEA, the German implementation of COICOP) and are valued at consumer prices. The German input–output tables, by contrast, follow the CPA classification and are valued at purchaser prices. Hence, the consumption expenditure had to be converted accordingly. For more details, see Kronenberg (2009b).

means of sensitivity analysis. The main findings for Hamburg and Mecklenburg-Western Pomerania are summarised in Section 4.4.5.

4.4.1 Effects on Consumption Expenditure

Figure 4.2 shows the results of the model calculations concerning total consumption expenditure and its allocation over 13 broad consumption categories.[7] The level effect leads to an expenditure increase by 34.7% in all categories. The reason for this is simply that according to the projections of Chapter 2, GDP grows by the same percentage between 2006 and 2030. Thus, in the absence of structural effects, consumption expenditure in all categories would grow by 34.7%. However, Fig. 4.2 shows that there are significant structural effects triggered by rising income per capita and demographic change.

A strong negative income effect can be observed in the field of food and non-alcoholic beverages. These are classical necessary goods. A negative income effect is therefore not surprising. In addition, there is a (small) negative demographic effect. In sum, the expenditure on food and non-alcoholic beverages grows by only 7.1%. Further negative income effects are displayed for alcoholic beverages and tobacco, communication, housing and water, and electricity, gas and other

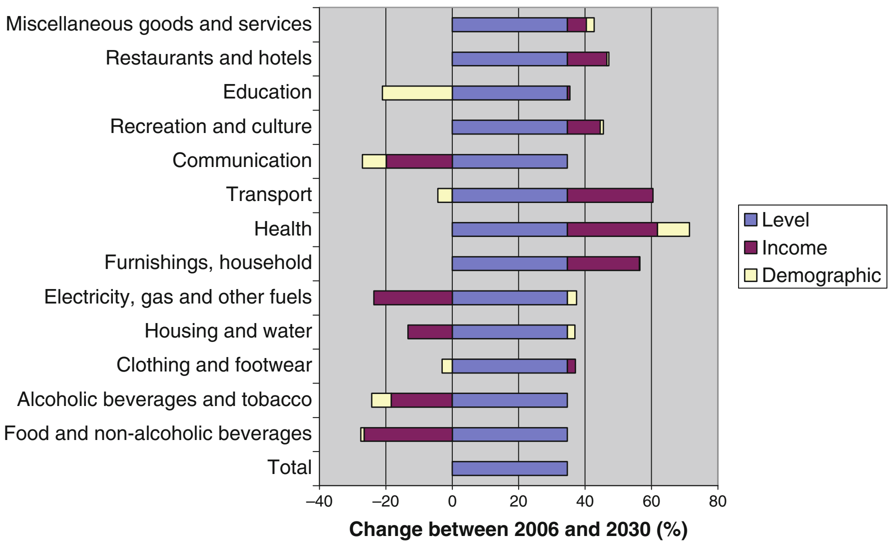

Fig. 4.2 Effects on overall consumption structure

[7] At the two-digit level, COICOP reaches a disaggregation of 12 categories. Figure 7.2 uses that disaggregation with one exception by mentioning electricity, gas and other fuels as an individual category (it is normally part of the housing . . . category).

fuels. Positive income effects are prominent in the areas of furnishings, household equipment and maintenance, health and transport.

Demographic effects play an especially important role in the fields of health and education. The altered demographic structure raises the expenditure on health by 9.6%. It thereby reinforces the income effect, which already amounts to 27.1%. In combination with the level effect, this leads to an increase in health expenditure by 71.4%. Concerning education, the demographic effect is even stronger, albeit in the opposite direction – it leads to a reduction of 21.0%. Nevertheless, expenditure on education still rises by 14.4% due to the level effect of 34.4% and a slightly positive income effect of 0.8%.

The areas of central interest for InfraDem are transport and electricity, gas and other fuels. In these areas, an interesting pattern can be observed. While a negative income effect works against a positive demographic effect for household energy expenditures, the opposite is true for transport. In both cases, the income effect is stronger. It raises transport expenditure by 25.8%, while the demographic effect lowers it by 4.3%. Concerning energy expenditures, a negative income effect of 23.6% clearly overpowers a positive demographic effect of 2.8%. In sum, energy expenditure rises by 13.8%, while transport expenditure grows by 56.2%. Due to their central importance for InfraDem, the consumption categories related to energy and transport will receive more attention in the following. Note that the level effect, which amounts to an increase of 34.7% in each consumption category, is not displayed in the following figures because doing so would not add any new information.

Figure 4.3 shows the impact of demographic change and income growth on the individual components of the consumption category "electricity, gas, and other

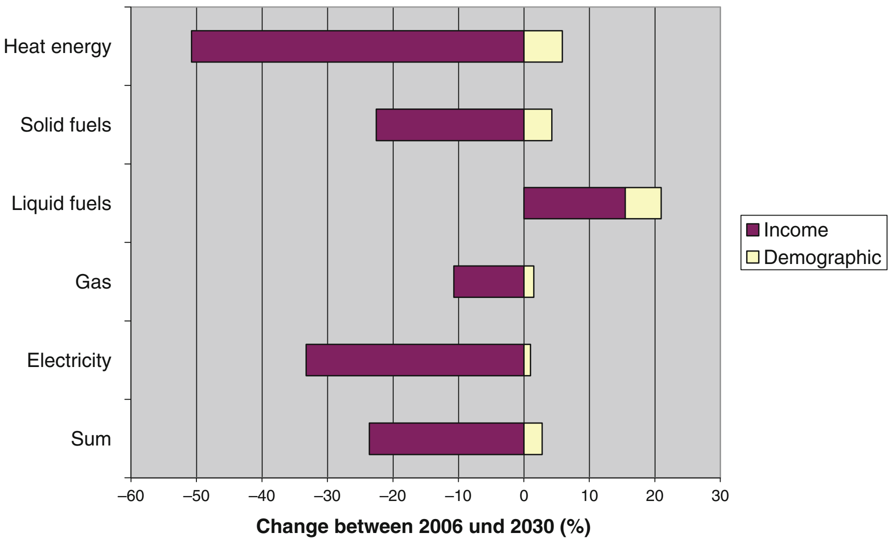

Fig. 4.3 Income and demographic effects on energy expenditure

fuels". It should be noted that this category does not include fuel for motor vehicles (this is included in transport expenditure, which is discussed below). In Fig. 4.3, the demographic effect is positive for all energy carriers, although it differs in terms of size. With respect to electricity and gas it is relatively unimportant. For the other energy carriers, by contrast, there is a significant positive demographic effect, increasing the expenditure on heat energy (+5.9%), liquid fuels (+5.5%), and solid fuels (+4.3%).

The income effect is negative for most energy carriers with the exception of liquid fuels, where it causes an increase of 15.5%. The heaviest income effect (−50.8%) is observed with respect to heat energy. Due to this strong income effect, the expenditure on heat energy falls by 10.3% in spite of the positive level effect of +34.7%. The expenditure on electricity is also affected by a sizeable negative income effect. However, this effect is not quite strong enough to overcompensate the level effect, so total expenditure on electricity still rises by 2.4%.

In Fig. 4.4, the income and demographic effect in the field of transport expenditure are shown in more detail than in Fig. 4.2, including the expenditure on fuels and lubricants for motor vehicles. A remarkable income effect can be observed with respect to the purchase of vehicles (+68.3%). Expenditures on the operation and maintenance of vehicles are also positively affected by growing income. The income effect causes a reallocation toward transport services by air (+33.7%) at the expense of other transport services (–9.6%).

The demographic effect, interestingly, works against the income effect in many cases. It is, however, generally smaller. For example, the negative income effect on transport services other than air is partly compensated by a positive demographic

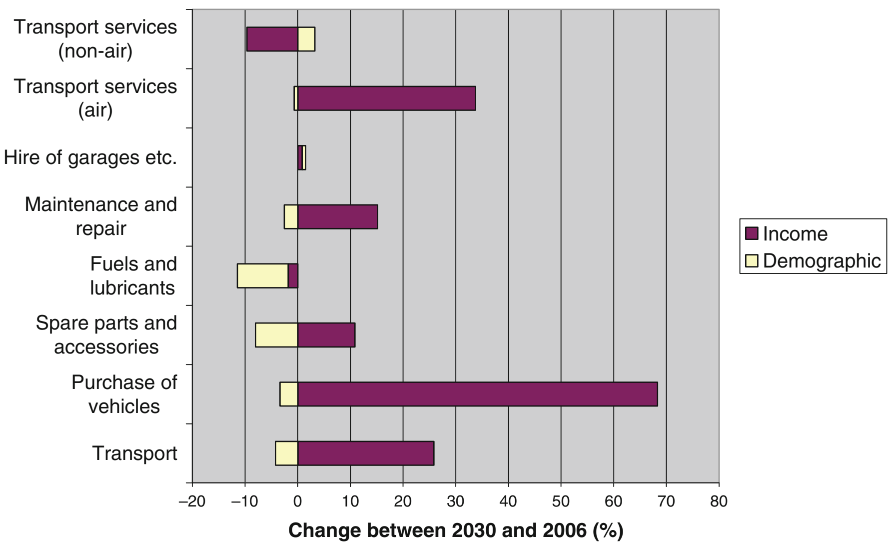

Fig. 4.4 Income and demographic effects on transport expenditure

effect of +3.2%. Expenditures on the purchase, maintenance and repair of vehicles, which are generally increased by growing income, are also reduced to a certain extent by the demographic effect. Expenditure on fuels and lubricants is an exception: here, a substantial demographic effect (–9.6%) is reinforced by a relatively weak income effect (–1.8%). However, even in combination, these two effects are not nearly strong enough to compensate for the level effect.

To sum up, the projection of consumption expenditure shows that demographic effects as well as income effects lead to significant shifts in the structure of private consumption expenditure. In general, demographic effects are of less importance than level and income effects, but they are by no means negligible. In certain consumption categories, they can have considerable consequences, reinforcing the income effect in some cases and partly compensating it in others. For InfraDem, the most notable finding is that demographic change tends to increase expenditures on energy in households and to reduce expenditure related to transport. However, within the transport category, it leads to an increase in expenditure on transport services by transportation means other than air.

4.4.2 Effects on Sectoral Production

Although the input–output model produced a projection of production by 71 homogeneous branches, it would not be very enlightening to discuss the impact on production of all those industries. Therefore, the following presentation focuses on the industries that are most relevant to InfraDem.

Figure 4.5 shows how changes in income and demography affect the output of industries related to the production and distribution of energy. In four of the five

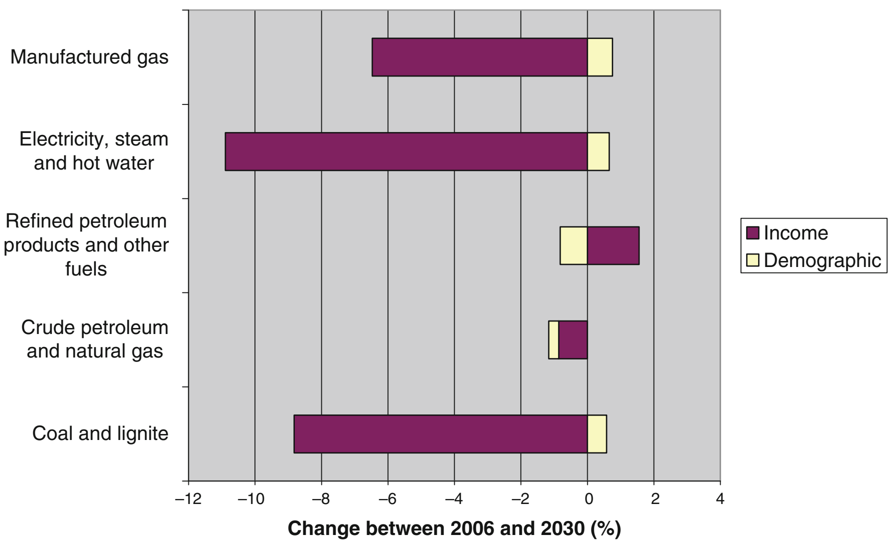

Fig. 4.5 Income and demographic effects on energy production

industries, the income effect is negative, especially in the case of electricity, steam and hot water, where it reduces output by more than 10%. The output of “coal and lignite” (–8.8%) and “manufactured gas” (–6.5%) is also seriously affected by the income effect. The only industry whose output is increased is “refined petroleum products and other fuels”, where a positive income effect of +1.6% can be observed. This industry consists mostly of refineries which produce, on the one hand, motor vehicles fuels such as gasoline and diesel and, on the other hand, heating oil. According to the consumption projection, the income effect on motor vehicle fuels is negative (Fig. 4.4), but the income effect on heating oil (in COICOP terms: liquid fuels) is positive. In sum, this amounts to a small positive income effect on this industry’s output.

The demographic effect is positive in three of the five energy-related industries. It tends to raise the output of “manufactured gases”, “electricity, steam and hot water” and “coal and lignite”. At the same time, it tends to reduce the output of “refined petroleum products and other fuels” and “crude petroleum and natural gas”. However, the absolute value of these effects always remains below 1%. Compared to the income effect, the demographic effect therefore plays a minor role.

Figure 4.6 shows how income and demographic effects manifest themselves in the industries producing transport services. Here, the picture is much clearer than in the energy-producing sectors. The demographic effect tends to increase the production of transport services, especially in the case of railway transport (+1.3%). The only exception is water transport, where the demographic effect is slightly negative but effectively equal to zero. The income effect is positive for all the industries shown in Fig. 4.6. This finding is quite remarkable, as the negative income effect on

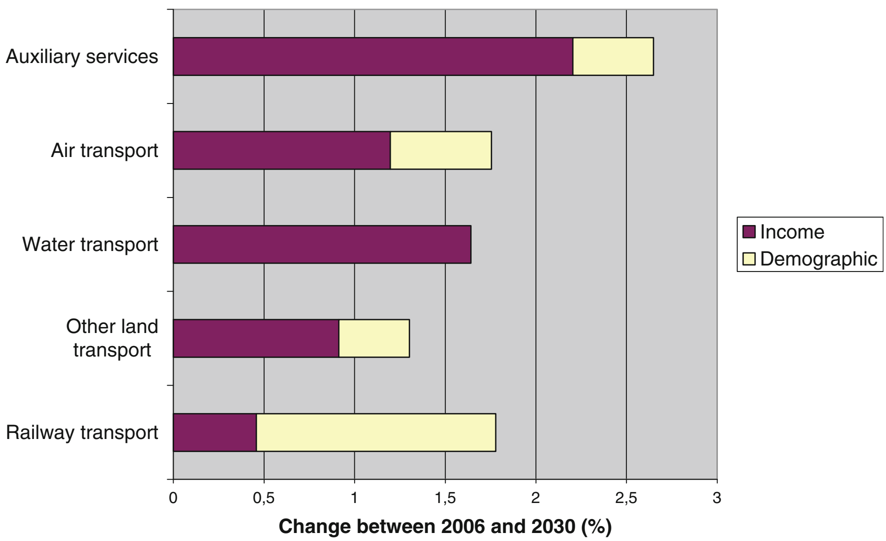

Fig. 4.6 Income and demographic effects on the output of transport services

the consumption of transport services (Fig. 4.3) would lead to the expectation that there should be a negative effect of income on the production of these services as well. However, it should be remembered that transport services are not only consumed by end users. A major share of transport services is “consumed” by other industries which haul intermediate goods across the country. As it happens, growing income has a negative effect on the consumption of transport services, but it has a positive effect on the consumption of other goods, whose production in turn requires additional transport services. In sum, the income effect on the output of transport services turns out to be positive.

4.4.3 Effects on Energy Use and Emissions

From a sustainability perspective, we would like to know how the aforementioned shifts in consumption expenditure and sectoral production affect energy use and emissions. In this section, the results of the EIO model with respect to these sustainability indicators are presented. In order to gain a good understanding of the total effect, the sustainability indicators are broken down between the household sector and industry (production sectors).

Figure 4.7 shows how growing income and demographic change affect the energy use of households, firms, and the economy as a whole. The income effect reduces the energy use of households by 8.1% and is being reinforced by a negative demographic effect, which causes a reduction of another 0.9%. In sum, the two effects reduce the energy use of households by 9.0%. However, they are clearly not strong enough to compensate the level effect of +34.7%. As a result, the energy use of households grows by 25.6%. The shift in consumption expenditure also affects the energy use of firms. Here, the income effect brings about a reduction of 2.6%. The demographic effect is negative, but its size is negligible.

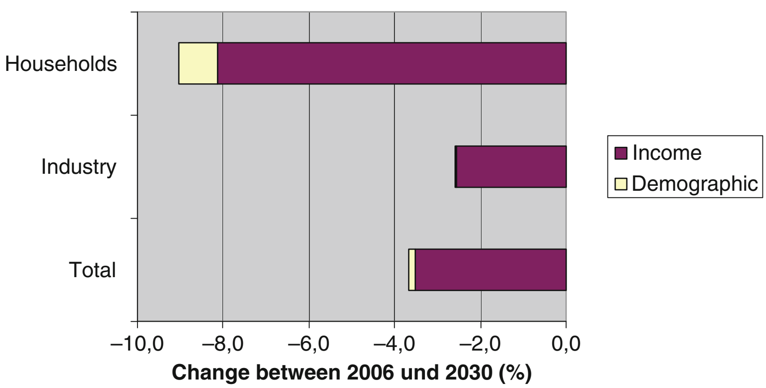

Fig. 4.7 Income and demographic effects on energy use

Total energy use (households and firms) is reduced through income and demographic effects by 3.7%. However, this reduction must be seen in relation to the level effect of +34.7%, which means that total energy use grows by 31.0%. In other words: the mechanism discussed in this chapter (altered consumption patterns due to income growth and demographic change) contributes to reducing the energy intensity of GDP, but it is not strong enough to achieve a decoupling of GDP growth and energy use. In order to achieve this decoupling, the other effects that were not explicitly modelled (substitution, preference, and technology effects) will have to produce a further reduction of at least 31.0%.

Figure 4.8 shows the results of the EIO model calculations with respect to CO_2 emissions. As in Fig. 4.7, a distinction is made between households and firms. The demographic effect leads to a reduction of 1.9% in the household sector, whereas in the industry sector it causes an increase of 0.4%. As a result, it reduces total CO_2 emissions by a negligible 0.1%. The income effect produces a reduction of 1.5% in the household sector and a remarkable reduction of 5.7% in the industry sector, which amounts to a reduction in total CO_2 emissions of 4.7%.

These findings suggest that demographic change does not contribute noticeably to a reduction in CO_2 emissions. It does lead to a reduction of these emissions by households, but the simultaneous increase in the industry sectors cancels this reduction almost completely. The income effect does contribute significantly to a reduction in CO_2 emissions, but it is far too weak to compensate the level effect of +34.7%. As the combination of demographic and income effects leads to a reduction of only 4.8%, the non-quantified effects would need to achieve an additional reduction of 29.9% in order to keep CO_2 emissions constant.

Figure 4.9 shows the equivalent of Fig. 4.8 for emissions of NO_X. As with CO_2, a negative demographic effect of considerable size (–2.5%) can be observed in the household sector. This is partly offset, however, by a positive demographic effect of +0.2% in the industry sector. In sum, the negative impact is slightly stronger; total NO_X emissions are reduced as a result of the demographic effect by 0.2%. The

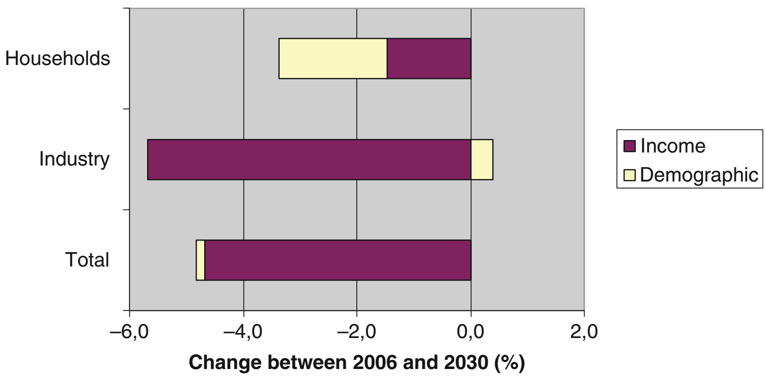

Fig. 4.8 Income and demographic effects on CO_2 emissions

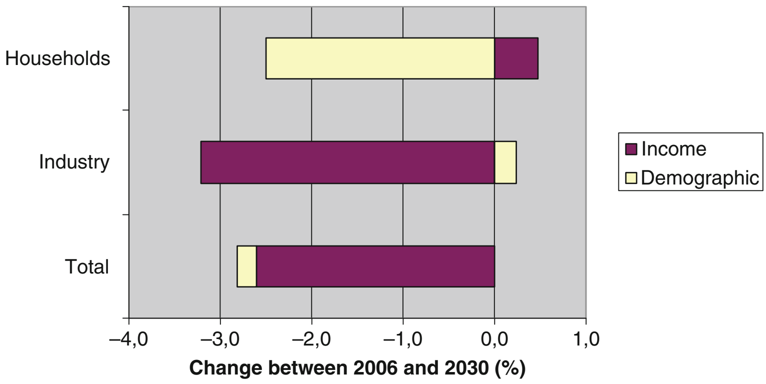

Fig. 4.9 Emissions of NO_X

income effect leads to a slight increase (+0.5%) in NO_X emission by households. However, as it causes a reduction of 3.2% in the industry sector, it reduces total NO_X emissions by 2.6%.

The combination of income and demographic effects tends to reduce NO_X emissions by 2.8%. From a sustainability perspective, this is a welcome prospect. However, as in the case of CO_2, a decoupling of GDP growth and emissions will require considerable changes in technology, preferences, or relative prices.

4.4.4 Results for Germany with a "High" Population

The EIO model was applied to the "low" and "high" population variants. Table 4.4 reports the results concerning consumption expenditure for both population variants. The "low" variant was already discussed in detail above, so in the following we will focus on the differences between the two variants.

According to Table 4.4, the most notable difference between the two variants lies in the size of the level effect, which amounts to +34.7% in the "low" variant compared to +39.5% in the "high" variant, a difference of almost 5 percentage points. This difference follows directly from the different GDP projections derived in Chapter 2.

In the "high" variant, the income effect is generally larger than in the "low" variant. For food and non-alcoholic beverages, whose expenditure share reacts strongly to income growth, the difference between the two variants amounts to 1.4% points. The reason for this is the fact that in the "high" variant, GDP per capita grows faster.

The demographic effect is slightly more pronounced in the "low" variant than in the "high" variant. This was to be expected, because population ageing proceeds faster in the "low" variant due to lower net migration of young people. However, the implications for infrastructure use or sustainability are virtually the same. The demographic effect differs by only 0.1 percentage points for energy expenditures

Table 4.4 Effects on German consumption expenditure in two population variants

	"Low" population				"High" population			
	Level effect	Income effect	Demographic effect	Sum of these	Level effect	Income effect	Demographic effect	Sum of these
Total	34.7	0.0	0.0	34.7	39.5	0.0	0.0	39.5
Food and non-alcoholic beverages	34.7	–26.5	–1.0	7.1	39.5	–27.9	–1.1	10.5
Alcoholic beverages and tobacco	34.7	–18.3	–5.9	10.5	39.5	–19.3	–5.5	14.7
Clothing and footwear	34.7	2.4	–3.1	34.0	39.5	2.6	–2.9	39.1
Housing and water	34.7	–13.3	2.3	23.6	39.5	–14.0	2.2	27.7
Electricity, gas and other fuels	34.7	–23.6	2.8	13.8	39.5	–24.9	2.7	17.3
Furnishings, household	34.7	21.7	0.1	56.5	39.5	22.9	0.1	62.4
Health	34.7	27.1	9.6	71.4	39.5	28.6	9.1	77.1
Transport	34.7	25.8	–4.3	56.2	39.5	27.2	–4.1	62.6
Communication	34.7	–19.8	–7.2	7.6	39.5	–20.9	–6.7	11.9
Recreation and culture	34.7	10.0	1.0	45.6	39.5	10.5	0.9	50.9
Education	34.7	0.8	–21.0	14.4	39.5	0.9	–20.1	20.2
Restaurants and hotels	34.7	12.0	0.6	47.2	39.5	12.6	0.6	52.7
Miscellaneous goods and services	34.7	5.8	2.3	42.7	39.5	6.1	2.2	47.8

Source: author's calculations. The numbers report changes in percent between 2006 and 2030.

and by 0.2 percentage points for transport expenditures. The greatest difference is observed for health expenditures, where the “low” variant gives rise to a demographic effect of +9.6%, whereas the corresponding figure for the “high” variant is +9.1%, a difference of 0.5 percentage points.

The different consumption projections were entered into the EIO model for both variants, and results for sectoral production, energy use and emissions were obtained in the same way as described above. However, with respect to infrastructure use and sustainability aspects, the differences between the two scenarios were negligible. The differences between the “low” and “high” population variants are driven mainly by the level effect, which differs by 4.8%. The structural effect due to demographically induced changes can therefore be considered robust to changes in net migration.

4.4.5 Results for Mecklenburg-Western Pomerania and Hamburg

Table 4.5 reports consumption projections in both population variants for Mecklenburg-Western Pomerania. As in the case of Germany, differences between the two variants are mainly driven by the level effect, which amounts to 18.0% in the “low” variant and 23.1% in the “high” variant. The structural effects are of a similar quality in both variants, although the numbers differ upon closer inspection. Generally, the demographic effect is more pronounced in the “low” variant (due to faster ageing) and the income effect is more pronounced in the “high” variant (due to faster GDP growth).

Comparing Table 4.5 to Table 4.4 shows that the demographic effects are generally more pronounced in Mecklenburg-Western Pomerania than in Germany. For example, the demographic effect on health expenditure amounts to roughly 9% in Germany compared to roughly 16% in Mecklenburg-Western Pomerania. However, the general observation does not hold for each individual consumption category. Interestingly, the positive demographic impact on energy expenditure is less pronounced in Mecklenburg-Western Pomerania. This can be explained by the fact that the *remanence effect*, which is largely responsible for the positive relationship between age and energy consumption, is not observed in Mecklenburg-Western Pomerania.[8]

Table 4.6 reports the results of the consumption projection for Hamburg. The picture that emerges is generally similar to the patterns observed above for Germany and Mecklenburg-Western Pomerania. Income effects are strongly negative for necessary goods such as food, beverages, tobacco, housing, water, and energy.[9] They are strongly positive for luxury goods such as furnishing, household equipment and maintenance, health, transport, recreation and culture and restaurants and hotels.

[8] The remanence effect receives more attention in Chapter 10.

[9] Alcoholic beverages and tobacco are necessary goods according to the economists’ definition.

Table 4.5 Effects on consumption expenditure in Mecklenburg-Western Pomerania

	"Low" population				"High" population			
	Level effect	Income effect	Demographic effect	Sum of these	Level effect	Income effect	Demographic effect	Sum of these
Total	18.0	0.0	0.0	18.0	23.1	0.0	0.0	23.1
Food and non-alcoholic beverages	18.0	–18.8	1.0	0.3	23.1	–20.1	0.9	4.0
Alcoholic beverages and tobacco	18.0	–11.9	–10.8	–4.6	23.1	–12.8	–10.5	–0.1
Clothing and footwear	18.0	3.9	–1.8	20.2	23.1	4.2	–1.8	25.6
Housing and water	18.0	–15.1	2.4	5.4	23.1	–16.2	2.4	9.4
Electricity, gas and other fuels	18.0	–20.3	2.3	0.1	23.1	–21.8	2.4	3.7
Furnishings, household	18.0	20.1	–1.9	36.3	23.1	21.6	–2.1	42.6
Health	18.0	21.1	15.9	55.0	23.1	22.6	15.5	61.2
Transport	18.0	26.1	–7.5	36.7	23.1	28.0	–7.5	43.7
Communication	18.0	–15.0	–7.8	–4.8	23.1	–16.1	–7.3	–0.3
Recreation and culture	18.0	13.9	5.0	37.0	23.1	14.9	5.0	43.0
Education	18.0	3.7	–25.6	–3.8	23.1	4.0	–24.2	2.9
Restaurants and hotels	18.0	8.8	–4.1	22.8	23.1	9.4	–3.9	28.7
Miscellaneous goods and services	18.0	5.4	4.3	27.7	23.1	5.7	4.2	33.1

Source: author's calculations. The numbers report changes in percent between 2006 and 2030.

Table 4.6 Effects on consumption expenditure in Hamburg

	"Low" population				"High" population			
	Level effect	Income effect	Demographic effect	Sum of these	Level effect	Income effect	Demographic effect	Sum of these
Total	50.9	0.0	0.0	50.9	71.9	0.0	0.0	71.9
Food and non-alcoholic beverages	50.9	−37.6	0.0	13.3	71.9	−45.9	−0.6	25.4
Alcoholic beverages and tobacco	50.9	−24.1	−1.0	25.8	71.9	−29.4	−0.5	41.9
Clothing and footwear	50.9	10.7	−2.4	59.2	71.9	13.1	−1.3	83.7
Housing and water	50.9	−21.2	2.2	32.0	71.9	−25.8	1.9	48.0
Electricity, gas and other fuels	50.9	−36.8	2.0	16.1	71.9	−44.9	1.6	28.5
Furnishings, household	50.9	32.0	−1.8	81.2	71.9	39.0	−2.3	108.6
Health	50.9	42.5	4.7	98.2	71.9	51.9	2.5	126.2
Transport	50.9	38.3	−2.6	86.6	71.9	46.7	−2.1	116.5
Communication	50.9	−27.1	−4.9	18.9	71.9	−33.0	−1.7	37.2
Recreation and culture	50.9	17.5	−0.2	68.2	71.9	21.3	−0.5	92.6
Education	50.9	2.6	−14.8	38.8	71.9	3.2	−11.6	63.5
Restaurants and hotels	50.9	29.1	−0.4	79.6	71.9	35.5	0.4	107.7
Miscellaneous goods and services	50.9	11.2	1.7	63.8	71.9	13.6	1.5	87.0

Source: author's calculations. The numbers report changes in percent between 2006 and 2030.

Table 4.7 Effects on energy use and emissions in Mecklenburg-Western Pomerania and Hamburg ("low" population variant)

	Mecklenburg-Western Pomerania				Hamburg			
	Level effect	Income effect	Demographic effect	Sum of these	Level effect	Income effect	Demographic effect	Sum of these
Energy use								
Households	18.0	–3.8	–3.5	10.7	50.9	–3.7	–1.2	46.1
Firms	18.0	–4.4	1.4	15.0	50.9	–0.3	–0.1	50.6
Total	18.0	–4.2	–0.4	13.5	50.9	–0.5	–0.1	50.3
CO_2								
Households	18.0	4.2	–6.4	15.9	50.9	11.2	–2.7	59.5
Firms	18.0	–4.9	1.4	14.6	50.9	–6.4	0.3	44.8
Total	18.0	–1.8	–1.2	15.0	50.9	–3.7	–0.2	47.1
NO_X								
Households	18.0	3.5	–7.6	13.9	50.9	15.0	–2.2	63.7
Firms	18.0	–0.7	1.4	18.8	50.9	–1.3	0.0	49.6
Total	18.0	0.0	–0.1	17.9	50.9	0.1	–0.2	50.8

Source: author's calculations. The numbers report changes in percent between 2006 and 2030.

Since the “high” population variant leads to a higher income per household, it is characterised by larger income effects.

As should be expected, the demographic effects are usually more pronounced in the “low” population variant due to the faster pace of population ageing. They are generally in line with our findings for Germany and Mecklenburg-Western Pomerania. Demographic effects tend to reduce expenditure on transport and to increase expenditure on energy. This trend should be taken into account by decision makers who are responsible for planning the local infrastructure.

However, in both population variants the level effect is clearly the most important driving force. In the “high” variant, for example, a very strong income effect would reduce expenditure on food and non-alcoholic beverages by 45.9%, but the level effect of +71.9% overshadows that effect. As a result, total expenditure on this consumption category still grows by 25.4%.

Finally, Table 4.7 shows the implications for sustainable development in the two federal states (focussing on the “low” variant because the differences between the two variants are negligible). Although the numbers differ, the general picture that emerges is consistent with the results for Germany. In all cases, the demographic effect tends to reduce energy use and emissions in the household sector. In Mecklenburg-Western Pomerania, this effect is quite sizeable; it reduces CO_2 emissions by 6.4% and NO_X emissions by 7.6%. However, the reduction in the household sector is largely offset by an increase in energy use and emissions in the industry sector. In Hamburg, the picture is slightly different, as the energy use of firms is also reduced and NO_X emissions by firms are basically unaffected. However, in all cases, the overall result is the same as that for Germany. Demographic change tends to reduce energy use and emissions of CO_2 and NO_X, but this tendency is not strong enough to overcome the level effect.

4.5 Conclusion

Using the methodology outlined in Section 4.3, we have calculated results, the most important ones of which have been reported in Section 4.4. Using the decomposition approach described in Section 4.2, these results can now be interpreted in order to identify their implications for infrastructure planning and sustainable development. For a proper interpretation, the assumptions underlying the EIO model approach should be kept in mind at all times. Most notably, the approach assumed no changes in preferences or technology. These assumptions made it possible to isolate the level effect (due to growing GDP) and two structural effects (due to changes in income and demographic structure).

The results show that the level effect is the most important driving force. Therefore, estimating future infrastructure use on the basis of GDP projections is in general a valid approach. However, even though the structural effects of growing income and demographic change are of a smaller magnitude, they are by no means irrelevant. Our results show, for example, that the expenditure on transport services (other than air) may grow at a significantly lower rate than GDP, because of a negative income effect. On the other hand, that negative income effect is partly offset by a positive demographic effect.

Furthermore, the results show how important it is to assume a macroeconomic perspective in order to take into account the complex relationship between households and the multitude of different industries. For example, even though rising income may induce households to spend relatively less on transport services, the overall effect of growing income on transport service demand is positive. The reason for this is that if households spend a smaller share of their income on transport services, they will spend a larger share on other goods. The production of those goods, in turn, requires transport services. According to our results, the net effect on overall transport service demand is positive. Thus, we might conclude that the use of transportation infrastructure grows faster than GDP.

Although the macroeconomic perspective is important, however, a high level of sectoral detail needs to be maintained during the analysis. For the purpose of this chapter, a consumption projection was constructed for 133 consumption purposes, and the EIO model was operated at a disaggregation level of 71 sectors. Maintaining a high level of disaggregation is important because aggregation invariably leads to a loss of relevant information. For example, the distinction between gasoline consumption and the use of public transport is crucial because the implications for infrastructure planning and sustainable development are quite different. At the two-digit level of COICOP, these consumption purposes are lumped together in the category "transport". Therefore, it is absolutely necessary to go beyond the two-digit level.

From a sustainability point of view, the most important results of this chapter are the estimated effects on energy and emissions of CO_2 and NO_X. Our findings suggest that demographic change should not be expected to contribute significantly to environmental and climate protection between 2006 and 2030. Demographic change does tend to reduce CO_2 and NO_X emissions by households, but at the same time it tends to raise emissions in the industry sector. Its net effect on overall emissions is small and almost negligible. One might say that the demographically induced structural effect leads to a reallocation of emissions but not to a significant reduction.

However, pressure on the climate and the environment slightly relaxes as growing income per household leads to a reallocation of consumption expenditure from relatively "dirty" to relatively "clean" goods. The results of the EIO model show that this effect reduces energy use by 3.5% and CO_2 emissions by 4.7%. In combination, the two structural effects reduce energy use in Germany by 3.7% and CO_2 emissions by 4.8% (in the "low" population variant).

On the other hand, German GDP is projected to grow by roughly 35–40% between 2006 and 2030 (Chapter 2). This means that the structural effects discussed in the present chapter are clearly not strong enough to achieve a reduction in total CO_2 emissions per year. With respect to emissions of NO_X, the results are quite similar. From a sustainability perspective this leads to the conclusion that the structural effects of growing income and changing household structure contribute slightly to sustainable development, but they do not achieve a decoupling of GDP and emissions. This goal will only be feasible if other structural effects (through substitution, altered preferences and technological change) reach a magnitude of roughly 30% or more. Therefore, the following chapters will discuss how technological progress and change in consumption patterns within each age group may affect the prospects for sustainable development in the context of demographic change.

Appendix

In regional economics, it is often necessary to construct an input–output table for the regional economy by means of a nonsurvey method, because the limited availability of time and money makes the construction of a survey-based table impossible. Traditional nonsurvey methods, however, generate biased results because they underestimate the importance of interregional trade. This problem can be solved by using the more advanced techniques developed by Flegg, Webber, & Elliott (1995) and Flegg and Webber (2000). However, these techniques require the modeller to select a certain value for a key parameter. Although recent work (Bonfiglio, 2009) has provided a range of "good" parameter values, the choice of this value remains to a large extent arbitrary. Therefore, an alternative approach was selected.

The CHARM approach (Kronenberg, 2009a) follows the recommendation by Richardson (1985) "to develop improved nonsurvey adjustments that correct for the effects of cross-hauling". It is based on the observation that cross-hauling is more common when products are highly heterogeneous. For practical purposes, it is assumed that for each product i the amount of cross-hauling q_i depends on the product's degree of heterogeneity h_i, regional production x_i, regional intermediate use z_i and regional final use d_i in the following fashion:

$$q_i = h_i(x_i + z_i + d_i) \tag{4.4}$$

At the national level, the quantities q_i, x_i, z_i, and d_i can be calculated from the national input–output table. This means that h_i, a theoretical construct indicating the degree of product heterogeneity, can be calculated from the national data. At the regional level, the quantities x_i, z_i, and d_i can be estimated using the traditional nonsurvey methods (or, with some luck, they could be obtained from official statistics). Assuming that the value of h_i is the same in all regions, Eq. (4.1) can then be used to calculate the regional q_i. Thus, the CHARM method provides an estimate of regional cross-hauling. Incorporating this into the regional input–output table leads to more realistic estimates of regional trade and output multipliers than the traditional nonsurvey methods.

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Part II
Specific Types of Infrastructures

Chapter 5
Demographic Effects on Passenger Transport Demand

Markus Mehlin, Anne Klein-Hitpaß, and Rita Cyganski

Abstract Demographic change in Germany will lead to a remarkable change in the composition of the population, particularly in terms of the ageing of society with the prospect of a population decrease. These factors are the main determinants for future travel demand. This chapter describes the procedure of modelling transport for 2030 and illustrates the results with regard to the infrastructure. The findings of the Rostock Center serve as the main basis for the data in the transport model, belonging to the family of microscopic activity-based demand models. The future passenger transport demand will decrease in most areas. The workload of the road infrastructure will decrease correspondingly. Differences of the impact between the two demographic scenarios are low. Findings show significant spatial differences. The western part of Mecklenburg-Western Pomerania, for example, will experience some trip increases, but most of the regions will face a decrease in transport demand. Public transport in Mecklenburg-Western Pomerania will not gain any more passengers in the future. We therefore conclude that the planning process for infrastructure should include a proper approach that assesses the options of disassembling streets and restructuring them. Criteria for making this decision should not be the workload of the road, but rather accessibility questions. Future land use management will also play an important role.

Keywords Passenger transport demand · Travel behaviour · Activity-based · Demand modelling · Trip generation · Demographic change

5.1 Introduction

Demographic change in Germany will lead to a remarkable change in the composition of the population, particularly in terms of the ageing of society with the prospect of a population decrease. Furthermore, economic development will cause changes in the work force, contributing further to the demographic change.

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These aspects are major determinants of trends in the transportation sector. The task of the DLR – Institute of Transport Research in this project was to prepare future trends of travel demand by applying a method suitable for the relevant aspects of InfraDem. The findings of the Rostock Center regarding the demographic and economic projections had to be integrated into our transport model.

Changes in the composition of the population lead to a change in transport demand, as each population group is characterised by a specific mobility demand. Here, we concentrate on school and university students, the work force, and elderly people. This chapter focuses on changes in these groups and discusses the respective future transport demand in two model regions. We conclude with the subsequent workload and demand of transport infrastructure.

The extent and manner of the impact of demographic change will not be the same throughout Germany. The InfraDem project selected the federal states of Hamburg and Mecklenburg-Western Pomerania as examples of two diverging regions. Hamburg (HH) is a densely populated city with a comparatively young population. Its population is expected to continue growing over the coming years. In contrast, the already sparsely populated federal state of Mecklenburg-Western Pomerania (MV) with a comparatively old population is expected to experience a further decline in population in the future.

Transport demand is the essential determinant of future infrastructure planning. Increasing or declining transport demand has to be considered when restructuring old roads or dimensioning new roads, and hence, when designing the road network. Renaturalization may be another option in regional planning, as the burden of maintaining the network is not viable considering the few people who will use it.

We have estimated future transport demand in the two model regions by applying the microscopic activity-based demand model TAPAS (Travel Activity Patterns Simulation). Furthermore, these demand projections will be used to outline recommendations for future infrastructure planning.

This chapter comprises four main parts. 5.2 elaborates on the relevance of demographic change for transport demand. A description of the applied transport demand model TAPAS is then given in 5.3. The results of the transport model are presented in 5.4. The chapter closes with a conclusion of the findings with respect to future infrastructure usage.

5.2 The Relevance of Demographic Change for Future Transport Demand

Changes in the composition of the population within a certain area can cause significant changes in the demand for transport. Two dominant processes that influence the transport demand must be distinguished (see Fig. 5.1): the shrinking of the population in general and the change in the age structure, or more precisely the proportional increase of the older population (see Chapter 9). The first process, the "shrinking" of the population, primarily leads to "quantitative" changes in transport demand, assuming a stable proportional composition of the population, as well as persistence in travel behaviour on a general level: less people use the existing infrastructure

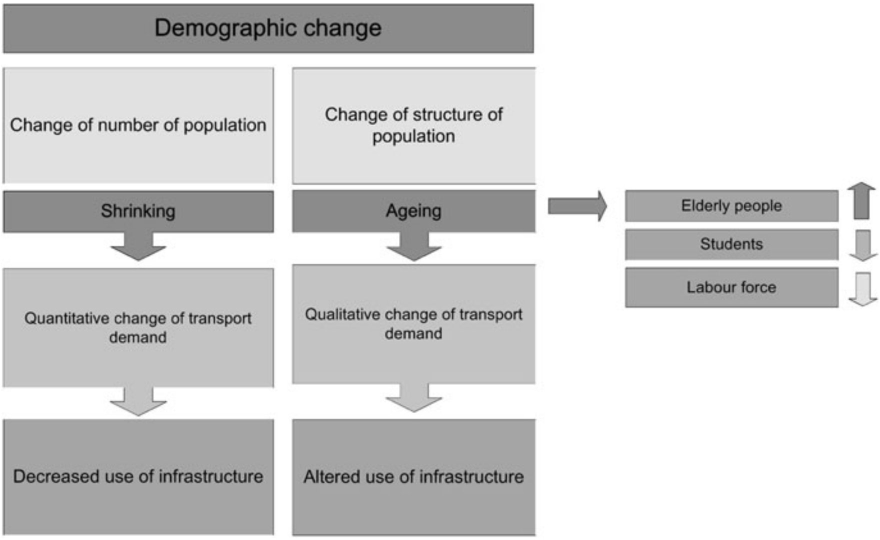


Fig. 5.1 Relevance of demographic change for transport demand and its impact on transport infrastructure

to an overall lower extent. The ageing of a population, on the other hand, goes along with a "qualitative" change in transport demand caused by a changed population structure that is potentially accompanied by a change in travel behaviour on the individual level. The main aspects of the ageing of the population comprise the increasing proportion of elderly people, as well as the proportional decline of the labour force and young people.

In recent decades, the development of the passenger transport demand can be summarised and characterised by a relatively stable volume of transport considering the number of trips per person, as well as by a relatively constant time budget for mobility per person. Furthermore, a modal shift from non-motorised means of transport to motorised individual transport and increasing lengths of trips travelled is noticeable.

For the upcoming decades, expectations are different. The German Plan for Federal Traffic Routes includes a traffic forecast for 2015. The prognosis presumes that previous developments will continue in the future with already familiar tendencies; motorised individual transport will continue to rise (Scheiner, 2006). Other empirical findings and the analysis of surveys and model calculation methods show that in the long run the transport demand will stagnate and even decline in shrinking regions. Even the German automobile association ADAC assumes that the average annual mileage will remain constant after 2010 before decreasing after 2015 (ADAC, 2003; Zumkeller, Chlond, & Manz, 2004).

All studies on future travel demand consider certain assumptions on general economic and demographic development, as well as the transport-related framework such as transportation costs or the availability of public transportation. The focus in InfraDem lies on the impact of the demographic aspects mentioned above. Changes in transport costs that go beyond the business-as-usual assumptions (e.g. due to new taxes) are not included in the modelling. Detailed descriptions of the demographic changes can be found in Chapter 2, as well as in Chapter 9 with specific emphasis on the mobility of the elderly. Concerning the modelling of the overall travel demand, the following aspects are crucial in the two model regions:

The elderly as a group is, as already mentioned, growing. With respect to traffic development, this increase has different impacts. This group will have more driving licences than seniors in the past. The share of households with a car will also increase. Each individual, reaching retirement age, will be better equipped with cars and driving licences and will thus influence passenger transport demand (Beckmann, Holz-Rau, Rindsfüser, & Scheiner, 2005; Scheiner, 2006).

Connected with these demographic developments, changes in the household structure with a growing share of one-person households are also expected. The increase in one-person households will bring with it an increase in car ownership, even if mobility budgets remain more or less stable. This will lead to a decreasing number of passengers per car. More and longer trips might therefore compensate for population losses (Ahrens, 2005).

The decreasing number of employed people will lead to a diminishing number of work and business trips. Employed persons make the most trips and travel the highest number of kilometres per day.

Scheiner (2006) analysed the daily variation of transport according to age and proved that the problematic peak during the afternoon rush hour is mainly caused by persons of working age. In future, when these people retire from 2020 to 2050, this peak will diminish, as will the morning peak. Therefore, with a stagnating or slightly growing transport demand, further expansion of the infrastructure should be reconsidered critically.

Another undesirable consequence is caused by the shrinking of the group of children and adolescents. This leads to a decreasing demand for public transport. In many areas of Germany, up to 90% of local public transport is to and from schools. Local public transport is hence mainly dependant on school students.

The impact on infrastructures differs according to the regional characteristics. For a stable or even slightly growing metropolitan area like Hamburg, no relief is expected on the urban infrastructure. In addition, suburbanisation processes might compensate for the diminishing transport demand of the shrinking group of employed persons (Scheiner, 2006). Sparsely populated Mecklenburg-Western Pomerania is fundamentally different. Characterised by a larger population loss, shrinking populations pervade throughout the whole federal state. Cities and municipalities suffer from bad public finances and the development of infrastructures is – compared to the number of inhabitants – over proportionately expensive (ibid.).

5.3 Estimating the Passenger Travel Demand 2030

In order to evaluate the impact of demographic change on travel demand, an activity-orientated demand modelling approach was pursued for the two regions under evaluation within InfraDem. The model applied was developed by the DLR Institute of Transport Research and originally emanated from a thesis written by Hertkorn (2005). Known as TAPAS (Travel Activity Patterns Simulation), the model belongs to the family of microscopic activity-based demand generation approaches in transport modelling.

Activity-based demand generation (ABDG) is based on the perception of travel behaviour resulting from an interdependent sequence of activities and trips. Interest has grown in this method over recent years. Currently, a lot of different ABDG implementations exist, sharing the common conceptual understanding of activity-based analysis but pursuing quite different methods and approaches (see Balmer, Axhausen, & Nagel, 2005; Bowman & Ben-Akiva, 2000; Jonnalagadda, Freedman, Davidson, & Hunt, 2001; Punjari, Eluru, Srinivasan, Guo, Copperman, & Sener, 2008; Rilett, 2001; Timmermans, 2001).

Other than the widely used traditional 4-step models (e.g. Emme/3, Viseva/Visum, see Lohse, Teichert, Dugge, & Bachner, 1997; Vrtic, Lohse, Teichert, Schiller, Fröhlich, & Schüssler, 2006), research and model development with an ABDG approach are not as standardised or well-established. They are based on a very detailed representation of the population within the region of interest and can account for a more individual- and household-centred perspective on demand emergence. TAPAS provides a detailed daily spatiotemporal activity programme for each individual in the population within the region analysed. Furthermore, especially temporal aspects and budget restrictions of individuals, both with respect to time and money, seem to be better addressed by the more detailed approach provided by ABDG.

TAPAS focuses on the complex process of demand generation, comprising the steps of trip chain generation for individuals in a synthetic population, trip distribution and destination choice. Route assignment is not yet part of TAPAS, therefore state-of-the-art software is used (e.g. PTV VISUM).

5.3.1 Modelling Approach of TAPAS

An overview of the main elements of the passenger transport demand model TAPAS is given below (see also Fig. 5.2). A more comprehensive description can be found in Justen and Cyganski (2008).

5.3.1.1 Generation of a Synthetic Population

As the modelling approach focuses on individuals, one of the major prerequisites for precise modelling results is the detailed representation of the people living in the area under investigation with respect to their demographic and socioeconomic characteristics.

The generation of this input was primarily based on the established and documented procedure known as the creation of a synthetic population (see Beckman, Baggerly, & McKay, 1996; Hobeika, 2005; Simpson & Tranmer, 2005).

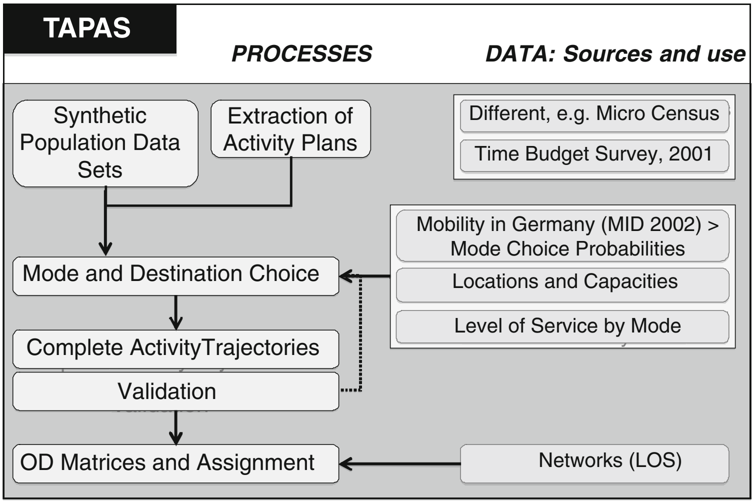


Fig. 5.2 Data sources and structure of the travel demand model TAPAS

By combining official statistics on demography and socioeconomics, multiple-attributed individual and household data sets were created, which match the distributions given by official statistics. The InfraDem project considers two different population forecasts based on the work packages of the Rostock Demographic Center (see Chapter 2, for further data used, see Table 5.1). A synthetic population was created composed of individuals equipped with different attributes such as sex, age, employment status (full or half-time), driving licence and the possession of an annual public transport ticket. As travel behaviour is strongly influenced by constraints imposed by the household context, individuals were aggregated to households. Hence, income, monetary budget for travel-related expenditure, car availability, household type (e.g. presence of children) were attributed on a household level. Last not least, a geocoded place of residence was assigned. Urban blocks were used to the greatest possible extent as spatial resolution for the place of residence and other locations used in the simulation. When this was not possible, traffic analysis zones (TAZ) were used as spatial units of reference.

5.3.1.2 Generation and Assignment of Activity Plans

Another prerequisite of an activity-based analysis of transport demand is the consideration of the interdependent choices of activities and trips during a day. Hence, a set of activity plans (referring to number, type, order, start and duration of activities) had to be provided for each individual in the synthetic population. The activity plans used in TAPAS were based on an analysis of a time budget survey conducted in Germany in 2001/2002 (Federal Statistics Office, 2004). For InfraDem, activity diaries were selected that were reported on workdays during the week (Tuesday to Thursday) and within the corresponding settlement structures of the

Table 5.1 Database for travel demand modelling in InfraDem

Category	Data source	Function	Characteristics
Demographics	Land use planning 2025 (study of the Federal Office for Building and Regional Planning (BBR); Rostock Center for the study of demographic change (InfraDem); Different public statistics	Number of inhabitants by sex and age/projections for population and household	Information of BBR e.g. concerning number of households by size for 2025
Persons and household characteristics	Rostock Center for the Study of Demographic Change (InfraDem); Infas Geodaten; Specific data provided by the Federal Office for Building and Regional Planning (BBR)	Calculation of cross-tables, e.g. concerning household structure and income or employment status	German-wide household surveys
Household budget for mobility	Income and consumption sample 2003 (Federal Statistical Office)	Calculation of household expenditures for mobility issues (public transport, fuel and vehicles)	German-wide household survey with 60,000 households
Travel behaviour	Mobility in Germany 2002 (Infas & DIW, 2004)	Generation of parameters for model calibration, e.g. travel distances and modal split/number of cars per household	German-wide household and travel survey with approximately 25,000 households, 62,000 persons and 167,000 trips
	Time Budget Survey 2001/2002 (Federal Statistical Office, 2004)	Generation of activity plans/variances of activity time durations and starting times	German-wide household survey with approximately 5,400 households, collecting about 38,000 diaries
Transport development	Transportation Forecast 2025 (Federal Ministry of Transport, Building and Urban Development)	Analysis of the general transport development concerning trip generation rates, average distances travelled	Forecast for transportation performance in passenger and commercial transport (e.g. vehicle miles travelled, modal split)

region according to the categories defined by the Federal Office for Building and Regional Planning (BBR).

To relate activity plans to travellers in the area, a concrete diary was assigned to each of the individuals in the demographic data set. To do so, a combination of sequenced and cluster analysis was applied, thus grouping plans with similarities in number, type, durations and order of activities. With this procedure, 23 different groups of diaries with internal structural similarities were identified, while each “diary group” contained a different number of activity plans. According to the individuals’ attributes (primarily age, sex, employment status and car availability), the population was divided into 32 groups. For each group, the choice probabilities were calculated und used to first assign a diary group and finally a specific diary to each of the individuals. To account for the increasing mobility of the elderly, the selection of diaries for persons aged 75 and older was modified so that the diary probabilities of the younger retirees (aged 65–74) were used.

5.3.1.3 Destination and Mode Choice

Subsequently, a destination and a mode had to be chosen for each of the activities contained in a selected diary. Both decisions were strongly interrelated in TAPAS. Destination choice was based on the model of intervening opportunities[1] and accounts for the preceding location of stay, as well as for the attractiveness or capacity of the available alternatives. Mode preferences of the individual with respect to the type of activity, the accessibility of the location of each mode, and the respective travel times and expenditures were also considered. Destinations were determined hierarchically in correspondence to the importance of each activity. Thus, interdependencies of choices within trip chains were considered.

Mode choice probabilities were based on a CHAID[2] decision tree built from regional adequate subsamples of the German National Mobility Survey “Mobility in Germany – MiD 2002” (see Table 5.1; Infas & DIW, 2004). The decision tree was defined using the sociodemographic attributes of the trip maker (e.g. age, sex, car availability), as well as attributes of the trip (e.g. purpose, distance). Respectively, the empirical mode choice probabilities at each leaf on the decision tree represented the basis for estimating an incremental multinomial logit model (see Ortúzar & Willumsen, 2006) to predict variances of mode choices due to changes in cost structures. Estimation parameters of the utility function were adopted from a study based on the analysis of a 6-week travel survey: the Mobidrive data set (König & Axhausen, 2001).

[1]The concept of *intervening opportunities* assumes that an alternative to all decision options is refused with a certain probability, e.g. because the location is not known or not preferred by the individual.

[2]Chi-Squared Automatic Interaction Detectors.

5.3.2 TAPAS: Summing up

Within the simulation process, a full activity trajectory was calculated for each of the individuals. This trajectory or day plan comprised information on the number, type, start, end and duration of each of the activities performed, as well as the mode and destination of all trips. Each day plan was finally evaluated with respect to financial and temporal feasibility and iteratively improved where necessary.

A statistical analysis of the resulting plans allows the derivation of the number of departures and arrivals per spatial analysis area, as well as the distribution of travel distances, modes chosen and the number of trips undertaken. Route assignment of the resulting origin-destination matrices for the car mode permits the calculation of the vehicle kilometres travelled according to the day plans. Each of the statistical parameters can hereby be differentiated by person group when appropriate.

5.4 Results of Travel Demand Modelling

In order to describe and assess the effects of the demographic development on transport demand, three indicators have been selected:

- Originating trips: The number of trips with an origin in a certain cell made by the inhabitants. Trips by tourists or other people from outside the area are not included. The effect of demographic change in this region is therefore dominant and it can be attributed to a local area.
- Kilometres travelled by car: All trips for which cars are used linked to destinations and assigned to the network result in the total traffic volume, described by vehicle kilometres travelled.
- Workload of the road network: Here, the vehicle kilometres are set in relation to the road capacity.

To model future transport demand, general assumptions have been taken over from the Federal Transportation Forecast 2025 (BVU, 2007), except in the case of assumptions on demographic development, which have been provided by the Rostock Center (Kühntopf & Tivig, 2007). The general assumptions in the Federal Forecast 2025 are a constant budget for travelling according to household income, increasing motorisation and increasing transportation costs of 1% per year (without inflation).

The results of the transport modelling will provide general information about trends of future transport demand. The project does not intend to give recommendations with regard to individual road sections, bridges or other infrastructure facilities. Therefore, a general trip assignment was performed for passenger car traffic to gain the indicator values only. A comprehensive and balanced trip assignment for the total network was not carried out in this project. For public transportation only the number of daily trips was calculated.

5.4.1 Expected Changes in the Origin of Passenger Trips

The origin of trips reflects the number of inhabitants in a certain area and their activities. If the number and structure of the population changes, the activities will also change because the travel patterns are closely linked to the age and the phase of life of the people. Therefore, the average number of trips per person will not stay the same as for 2005, but will develop in line with the assumptions made in the population scenarios.

5.4.1.1 Mecklenburg-Western Pomerania

The development of the number of trips shows a large spread in general, as well as large differences within the state. Areas can be found in the western part of Mecklenburg-Western Pomerania between Wismar and Lübeck with a high increase of trips of about 20% and more (Fig. 5.3). A few smaller areas in the southwest also have high rates of increase. However, according to our modelling, the majority of Mecklenburg-Western Pomerania will experience heavy decreases of 20–30% in the number of trips made between 2005 and 2030.

In the high scenario (Fig. 5.4), some more areas displayed a high increase in trips during the 25 years investigated. In the western area, more trips were made, especially in the district of Ludwigslust (5–20%) and the coastal region around Wismar and Rostock, as well as some eastern parts near the city of Anklam. The districts of Güstrow, Demmin, Mecklenburg-Strelitz and Uecker-Randow do not benefit from

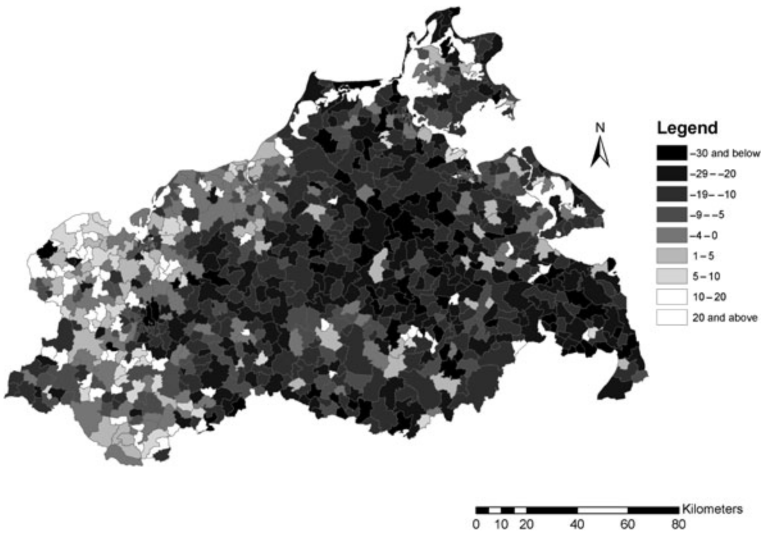


Fig. 5.3 Development of trips originating in Mecklenburg-Western Pomerania from 2005 to 2030 in the low scenario. Source: author's design based on Kühntopf, S., & Tivig, T. (2007)

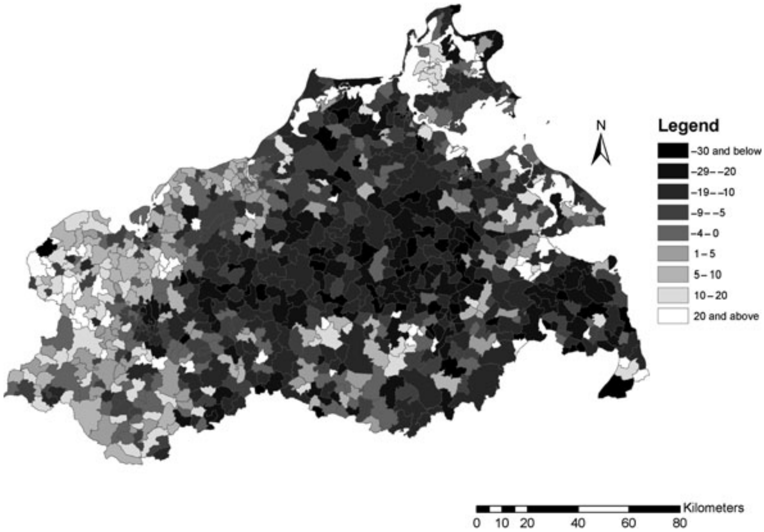


Fig. 5.4 Development of trips originating in Mecklenburg-Western Pomerania from 2005 to 2030 in the high scenario. Source: author's design based on Kühntopf, S., & Tivig, T. (2007)

the different assumptions in the high scenario, and show nearly the same decrease rates as in the low scenario.

Looking at the trip development of age groups, very large differences were revealed. Trip increases can be reported for students and those retired. The number of trips made by people aged 74 years and older nearly tripled in the time period investigated. In all other age groups, the number of trips decreased.

In addition to some general assumptions, e.g. those concerning mobility costs, the number of trips is mainly influenced by the underlying population scenario. As Mecklenburg-Western Pomerania will lose 9.5% of its population in the low scenario and 12.9% in the high scenario, which will simultaneously age by about 7 years, the results of the transport model are not surprising. Furthermore, the 30% decline in the labour force must also be considered, as the specific trips per day made by this group differ from those made by the other groups.

5.4.1.2 Hamburg

In the case of Hamburg, a very uniform picture was revealed by the calculation of the future transport demand. The number of originating trips will grow in all districts until 2030 by 13–15% in the high scenario (Fig. 5.5). The low scenario results in slight changes, but the number of trips stays more or less the same.

These findings are not unexpected when considering the weak demographic changes in the low scenario for Hamburg. The high scenario includes a population growth of approximately 15%, which is reflected by the higher mobility demand. The labour force will increase by 13%.

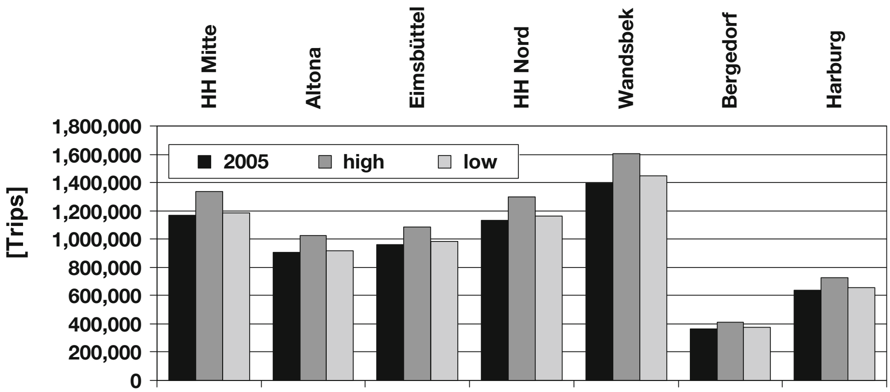


Fig. 5.5 Average daily trips originating in Hamburg 2005 and 2030

5.4.2 Expected Changes in Kilometres per Year

In order to determine the total transport demand and hence the resulting workload of the infrastructure, the originating trips were supplemented with the arriving trips. For the origin-destination matrices, the routes were assigned to the network. By adding up all assigned trips, the kilometres travelled per year were calculated.

In contrast to other projects, the passenger kilometres (pkm) which include the number of passengers per car, is irrelevant for the purposes of this project. As the workload of the infrastructure is a key indicator, the kilometres driven per year are important.

In Mecklenburg-Western Pomerania (Fig. 5.6), the vehicle kilometres decline significantly in both scenarios by about 16%. This means that the difference between the two scenarios only has a minor influence on the vehicle kilometres. Moreover, the increase in the activities of retired people in 2030 compared to 2005 cannot compensate for the general decrease in mobility demand in that state.

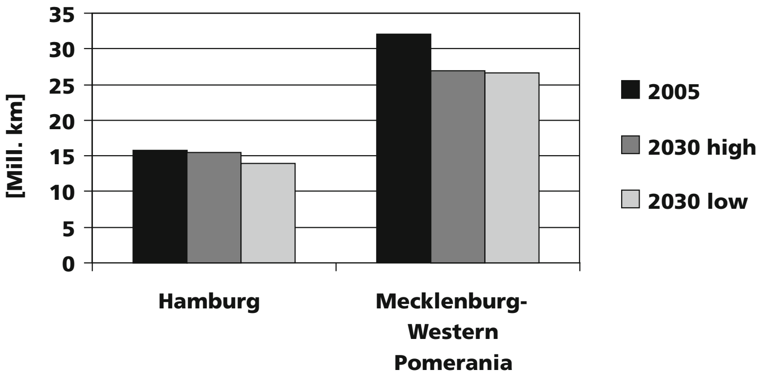


Fig. 5.6 Average daily trips originating in Hamburg and Mecklenburg-Western Pomerania

In Hamburg, constant or even decreasing vehicle kilometres (up to 12%) are expected in 2030 compared to 2005. As this accompanies the stable or increasing number of total trips caused by the increasing use of public transport, the modal split shares in Hamburg clearly change from car to public transport.

Having calculated the kilometres driven per year, the assignment of the trips to the road network will be of interest, especially for Mecklenburg-Western Pomerania, in order to gain information on the usage of the infrastructure in the future. This is carried out in the following section.

5.4.3 Resulting Workload of the Road Infrastructure

The emerging traffic as described above is set in relation to the road capacity in this step. The capacity is determined by factors such as the number of lanes, the width of lanes and the speed limit. The daily average workload will not provide information on congestion at certain places. However, the daily figures allow for a general assessment of the suitability of the infrastructure.

5.4.3.1 Mecklenburg-Western Pomerania

The state shows a decrease in the workload in nearly all districts (see Fig. 5.7). The workload, which is low to start with, will fall further by approximately 5% on average. A constant workload was found for very few districts. The whole state was divided into two parts: the very rural areas with a workload between 5 and 10% and the cities of Greifswald, Neubrandenburg, Schwerin, Stralsund, Wismar and Bad Doberan with a workload of about 15–20%. As an exception, Rostock shows a stable workload of nearly 40% in all scenarios.

5.4.3.2 Hamburg

In the area of Hamburg, the workload of the road infrastructure is not significantly affected by demographic change. The trend shows a slight decrease from 2005 to 2030. In 2030, Bergedorf and Harburg will have a workload of 20% on average, Mitte and Altona about 40% and Eimsbüttel, Nord and Wandsbek about 50%.

5.4.4 Public Transportation

For public transport in Mecklenburg-Western Pomerania, a remarkable decrease of about 20% was ascertained in daily trips from 2005 to 2030 (see Fig. 5.8). This reflects the lower numbers of school and university students, as well as the growing motorisation of older people. The differences between the two scenarios have just a minor influence. Since the public transport service in this rural area is only moderate, more passengers are not expected in the future.

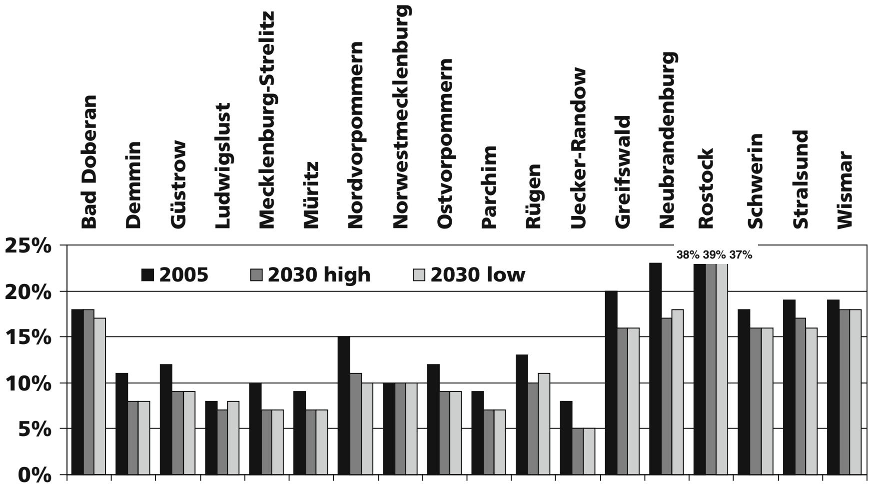
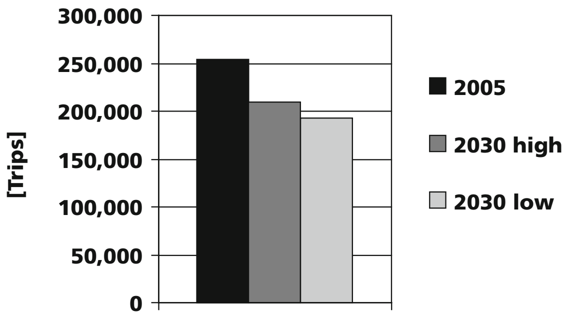


Fig. 5.7 Average workload of the main road network in Mecklenburg-Western Pomerania

Fig. 5.8 Average daily trips by public transport in Mecklenburg-Western Pomerania



In Hamburg, trips by public transportation will increase in both scenarios: by 24% in the high scenario and 11% in the low scenario. These results are not only influenced by demographic change. The general trend of increasing transportation costs also has a significant impact. People have the choice of using their own car or using a well-developed public transportation system in Hamburg. Therefore, increase rates were ascertained for public transportation that were well above the population growth.

5.5 Conclusion

When calculating the future passenger transport demand under the given demographic assumptions, a demand decrease can be found for most areas. The workload of the road infrastructure will decrease correspondingly. Therefore, the available infrastructure is satisfactory in general. However, in a few tourist and urban areas, congestion may occur during the peak hours. This is more a matter of traffic organisation than of infrastructure in general. Hamburg in particular has streets with very dense traffic; however, this initial situation will not be affected by the demographic change in the future.

Moreover, the following results can be concluded:

- The differences between the two demographic scenarios in terms of impact on passenger transport demand are low. A higher impact was observed in general for the development from 2005 to 2030.
- Findings with regard to the transport demand show significant spatial differences. The western part of Mecklenburg-Western Pomerania, in particular, will experience some trip increases, but most of the regions will face a decrease in transport demand.

Concerning public transportation in Mecklenburg-Western Pomerania, the situation will become more problematic. New affordable approaches for public transportation must be introduced.

In Hamburg, public transportation will face an increasing passenger volume due to demographic change. Here, a thorough analysis is necessary to assess the sufficiency of available capacities.

Bearing the forecast results in mind, the planning process for infrastructure must be questioned. The establishment of an approach that assesses the options of disassembling streets and restructuring them in a proper way will become very relevant. Criteria for the decision to invest in infrastructure may not necessarily be the workload of the road, but rather the accessibility of all houses. Lots of minor streets connect the destinations directly, but not all of them can be restructured and maintained. The question in the future will therefore be: how big is the imposition for the inhabitants, i.e. how long a detour will they have to make when direct connections are no longer available? Future land use management will also play an important role here.

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Chapter 6
The Demand for Air Transport and Consequences for the Airports of Hamburg and Rostock

Michael Hepting, Henry Pak, and Dieter Wilken

Abstract In the following, we discuss the question of whether or not demographic change will have an impact on the infrastructure needed in the air transport sector. For this purpose, the population and economic scenarios for the year 2030, described in Chapter 2, are used as the basis to estimate the future German air transport demand. The consequences of demographic change on the passenger demand and its structure are discussed. For the airports of Hamburg and Rostock, the number of aircraft movements is derived from the estimated airport passenger demand. The current and planned infrastructure capacities at Hamburg and Rostock airports are compared with the predicted aircraft movements. The results show a significant change in the level and structure of air passenger demand. While the total population will decrease over the next few decades, it is expected that the specific demand (trips per capita) will rise. As a consequence, the total air transport demand will continue to grow. It is also estimated that the current high capacity utilisation at Hamburg Airport will further increase in spite of the capacity utilisation of Rostock Airport which will remain low.

Keywords Air transport demand · Relation between air transport and social change · Air traffic forecast · Flight movements · Airport capacity

6.1 Introduction

Airports are the most important part of the air transport infrastructure, with high investment costs effective over a long time period. Currently, a discrepancy exists between regional airports with typically low utilisation and metropolitan airports with typically high utilisation. While the former are often favoured by regional politics, the latter face difficulties in expanding their capacity. Therefore, the question arises as to whether the future demographic development will help to

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relieve the situation at congested airports, and whether future investments in existing and planned regional airports are worthwhile.

A second – more theoretical – aspect arises from the question of which differences result from the demographic development regarding necessary infrastructure in the sectors of air transport, energy and land transport.

In terms of gross value added (GVA), the air transport sector is of rather secondary importance for a national economy. Thus, the contribution of airlines to the German GVA amounted to merely 0.3% in the year 2004 (Keimel, 2007). However, for the functioning of a modern society, air transport is of considerable importance, the quantification of which seems to be rather difficult. In realising international trade, air transport plays a vital role in the total transport system. Even though its transport significance is rather modest in terms of traffic performance, it is obvious that international passenger travel in order to visit business partners and exchange goods across continents could not be managed without the option of using the plane. For private travel, air transport also plays an important role: although aircraft are not an everyday transport mode, they are used more and more for holidays, which do not only have a major recreational function but are increasingly considered as an essential part of lifestyle in modern societies. Furthermore, intercultural exchange is an additional fundamental reason for travelling in general. Air transport enhances opportunities by offering short travel time connections over long distances.

Corresponding to the importance of air transportation for international trade, a strong relationship can be found between the development of air transport and the economy. As can be seen in Fig. 6.1, the demand for air transport services has grown

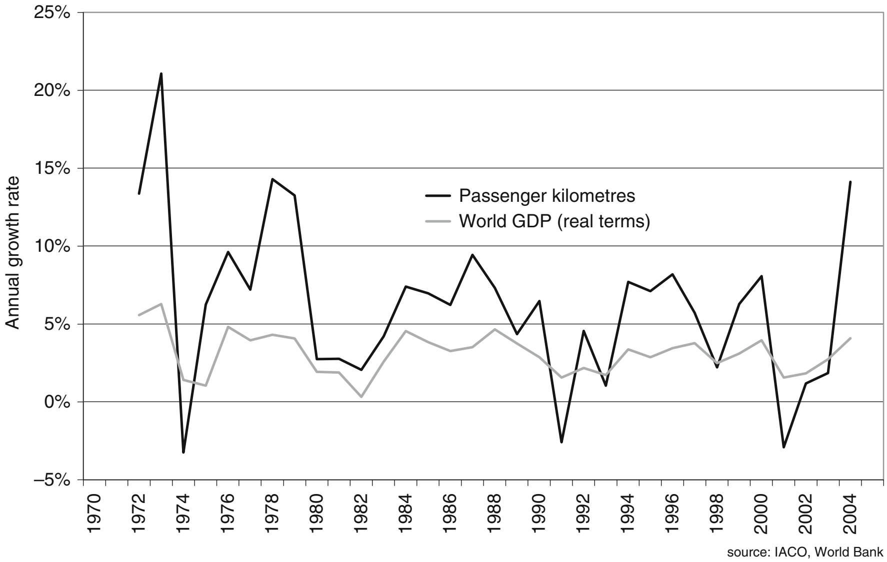

Fig. 6.1 Global economic and air transport trends (1972–2004)

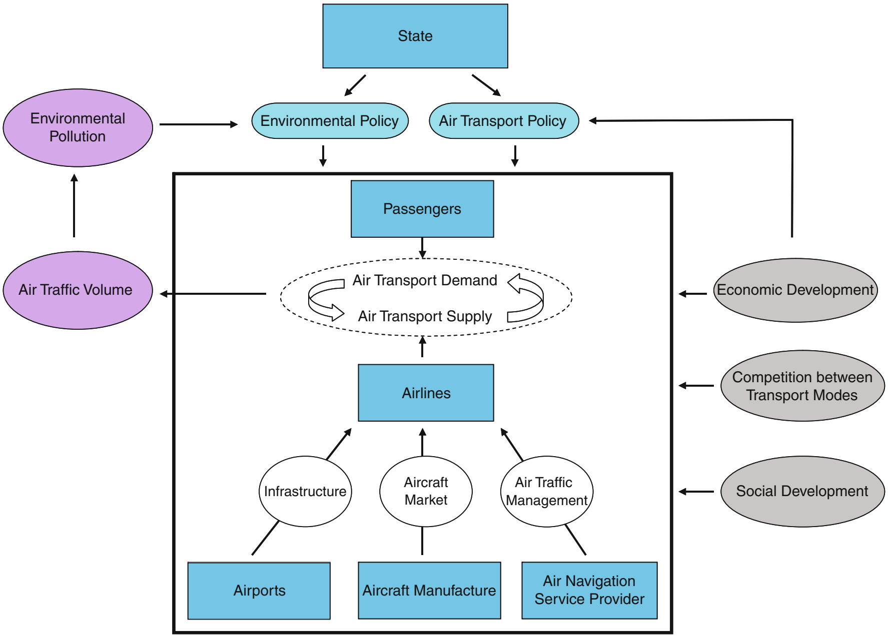

Fig. 6.2 Important actors in the air transport system

simultaneously with the gross domestic product (GDP) over a long period of time. In years with higher GDP growth, the air transport demand grew even more, whereas in times of recession, the air transport demand also grew less or even decreased.

The air transport system consists of several actors and depends on influencing factors, e.g. the development of population and economy, society, government and policies. An overview of these interrelationships is given in Fig. 6.2. In general, the air transport market is determined by the demand for air transport services and the supply side represented by flights offered by airlines. Further important system components are airports and air traffic control. Airports realise the interfaces to complementary traffic subsystems like road and rail. In the past, airports were mainly planned, built and managed by public institutions. However, in recent times, major airports, particularly in Europe, have been privatised. Consequently, the public sector partially withdrew from the provision of infrastructure.

In the following section, we first present the methodology of the elaboration of air transport forecasts, which was developed by the German Aerospace Center. The estimate of the German air transport demand up to the year 2030 is discussed taking into account InfraDem input data. In a further step, the total demand is broken down to the airport level. For the airports of Hamburg and Rostock, aircraft movement development was estimated and the current and planned infrastructure capacities of these airports are discussed with regard to the estimated aircraft movements. The chapter ends with some conclusions on the possible future demand and infrastructure development.

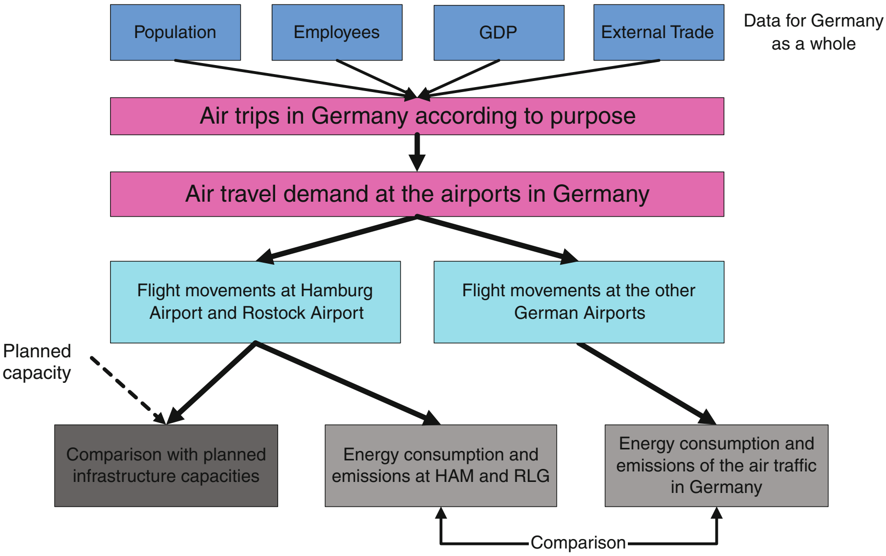

Fig. 6.3 Workflow of the air transport work package within InfraDem

6.2 Methodology of Forecasting the German Air Transport Demand

The DLR method of forecasting air transport development in Germany (Pak, Claßen, Hepting, & Wilken, 2005) was used to forecast the total air passenger demand for Germany for the forecast period, depending on the framework data of the economic and demographic development of the InfraDem project (see Chapter 2). To reflect regional differences of factor trends, total demand has been allocated to the major airports. Based on empirical analyses, flight movements at individual airports have been derived from local passenger volumes. In a further step, the forecasted flight movement volumes are discussed in relation to available or planned infrastructure capacity. Finally, the expected energy consumption and selected gaseous emissions for Germany were identified for the airports under examination. This last step, however, is not further discussed here. An overview on the used forecast process is given in Fig. 6.3.

6.2.1 Structuring Air Transport Demand

Analyses of the trip purposes of the German air transport demand, carried out over several years, have shown that the structure is composed of only a few segments, the relative size of which has changed only marginally over time. In a high level differentiation of demand segments, we may distinguish between two major groups: business and holiday travellers. Short-stay personal travellers form the third group, which is much smaller than the other groups. In the year 2006, the trip purpose structure of air transport demand in Germany was as follows (German Aerospace Center, 2007 and Deutsche Lufthansa AG, IFAK Institut GmbH & Co. KG (DLH/IFAK), without year.[1]

- Domestic travel: ca. 14%
- International business travel: ca. 26%
- International holiday travel: ca. 51%
- International short-stay personal travel: ca. 9%

For comparison, in the year 1995, air travel volume was composed of 39% business travellers, 56% holiday travellers and only 5% short-stay personal travellers. Travellers going on holidays formed and still form the biggest group for air transport demand, followed by business travellers. Journeys for short-stay personal reasons formed only a small fraction of about 5%. Only in the last few years has this group grown strongly due to the fact that low-cost carriers have gained in importance.

According to the World Tourism Organisation of the United Nations (UN-WTO), holiday journeys are defined as journeys with a personal purpose lasting 5 days or more, and accordingly short-stay personal journeys with a duration of less than 5 days. Behind these segments, we find many different specific trip purposes. Two holiday journeys may be similar in many aspects; however, they typically differ in many other aspects. To forecast holiday travel, it is important that the factors behind the trip for the purpose of holiday travel are similar, so that holiday journeys may be combined to one or several market segments with corresponding forecast methodologies.

The trip purpose structure varies with each travel route (or origin-destination link). Short haul domestic travel is made up primarily of business travellers (about 75%), whereas in inter-continental travel, holiday travellers form the biggest proportion, also with around 75%. The type of route may therefore be regarded as a criterion for segmenting the travel market. In addition, travel-influencing factors vary spatially with the traffic originating in or attracted to a region. They are to be found partly in Germany for the travel originating there, and they are correlated with the country or region of origin in the case of foreigners travelling to visit Germany.

The following demand segments have been defined on the basis of criteria such as trip purpose, trip origin and type of travel route (or relation), after having analysed the availability of data relevant to forecasting:

- Domestic air journeys
- International business journeys by air
- International holiday journeys
- International short-stay personal journeys by air.

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[1] Handbuch Internationale Fluggastbefragung 2003. Unpublished internal script.

The domestic origin to destination (O-D) journeys by air (not counting passengers corresponding at German airports) form a separate segment, which consists mainly of business travellers and competes with high-speed ground modes. In the past, for a long time 85% of domestic air passengers used the air transport mode for business reasons. However, the low air fares offered by low-cost carriers have led to a recent demand for short-stay personal trips, so that the portion of business travellers has decreased to about 75%. Nevertheless, the domestic air travel market is still characterised by business trips. The domestic segment, quite in contrast to the border-crossing air travel, only forms a small part of the total air transport demand. In the year 2004, about 86% of all air journeys in German O-D travel either had a trip origin or destination in a foreign country. German air transport is thus primarily internationally oriented.

The strongest segment of air travel demand is the group of border-crossing holiday travellers, forming about 51% of the total O-D demand. Due to the relative size, this segment has been subdivided further into the group of travellers with a trip origin in Germany (primarily German travellers) and those with a trip destination in Germany (mainly foreigners visiting Germany). The former segment has then been broken down into age-specific groups, since the age of travellers plays a major role in the decision process of making holiday trips. The origin segment is relatively large compared to the destination segment. Germany is not a destination country strongly frequented by foreign holiday travellers in air transport. Over 90% of all holiday journeys by air are generated in Germany, less than 10% are foreigners coming to Germany for their holidays.

About a quarter of total air travel demand is border-crossing business travel. For the purpose of forecasting, this segment has been subdivided into origin travel (mainly by Germans) and destination travel (mainly by foreigners), and subsequently into groups by service and industry branch. This allows influential factors acting branch specifically to be reflected. In contrast to holiday travel, border-crossing business travel is not dominated by travellers originating in Germany but rather – varying by branch – balanced between inbound and outbound travel.

For a long time, just 4% of the total passenger demand for air transport of Germany belonged to the group of short-stay personal travel to and from international destinations. Recently, this portion has almost doubled due to the emergence of low-fare services of low-cost carriers. However, short-stay personal travel with 8% still forms a small segment of the total German air transport demand.

6.2.2 Methodological Forecast Approach

The methodological approaches of forecasting the demand segments differ primarily in that those related to business travel are of econometric nature and those of private travel demand are less functional and tend to be more extrapolations of trip characteristics, like trip intensity or frequency, by travel group. The groups refer to the demand originating in Germany and with a destination in Germany, on the one hand, and to subgroups of the population, especially age-specific groups, on the other hand.

For the domestic air transport demand, consisting mainly of business travellers, we can rely on an econometric function, which has been verified empirically for a long period of time (Pak et al., 2005). The function yields the propensity to fly, as expressed by the number of journeys in domestic O-D travel per person employed, in relation to the macro-economic productivity, expressed by the gross domestic product (GDP) per person employed. This relationship is explained by the fact that the factors causing and influencing trip-making in domestic air travel for business purposes can be derived directly from the complex acquisition, production and distribution processes of the German economy. A mutual relationship therefore exists between a change in the macro-economic production, which is again related to a change in the spatial division of labour and distribution processes, and the total demand for business travel as well as the specific demand for business travel by air. To exclude changes in GDP growth caused by a change in the work force or by business cycles, the function between demand and GDP relates the trip generation rate with the productivity, thus including the number of employed persons in the variables.

The demand for international business travel by air results from the economic activities of industry and services, including the international division of labour, and from international relations between public and private institutions. Business travel is as such a complementary demand for taking up, maintaining and intensifying business relations, the objective of which is the commerce of goods and services. Since border-crossing business travel is a necessary prerequisite for realising foreign trade, there is a methodological need to incorporate foreign trade into the forecast function as an explanatory variable.

A direct forecast of the total border-crossing business travel appears to be a suboptimal approach since we can assume that the relationship between foreign trade and business travel demand varies by economic sector, and in the case of service sectors, such a relationship may exist only indirectly or not at all. Unfortunately, demand data by economic sector do not exist, so that a sector-specific approach cannot be pursued for the time being. Instead and similar to the domestic demand, a functional relationship has been formulated between the trip generation rate of the demand originating in Germany and the export productivity, whereby both rates are related to the labour force in order to avoid the influence of variations in export caused by a change in the number of persons employed. Regarding the travel demand generated abroad with destinations in Germany, it has been observed that the proportions of either origin or destination demand in relation to the total demand of border-crossing business travel varied only marginally over time. The demand of visiting business travellers was thus forecasted in relation to the demand originating in Germany.

To forecast the business travel demand by air, input data are needed that describe the future development of the German GDP, foreign trade and the number of persons employed in Germany.

Similar to business travel, separate approaches for originating demand and destination demand are used to forecast cross-border holiday travel. Long time series are available for destination travel, whose share is about 10% of holiday trips by plane, and can be directly extrapolated. For originating travel, a model has been developed based on both population development and holiday travel behaviour as explicit input variables.

Unlike the rest of the demand segments, a multimodal approach was chosen to forecast the demand for holiday trips by plane for originating traffic. This approach considers the substitutability of destinations with other tourist destinations, which can be reached by other preferred means of transport (Italian Adriatic Sea by car instead of the Balearic Islands by plane). The available data allow the desired procedure: In a first step, the overall holiday trips are determined without considering the choice of transport means. In a further step, holiday trips by plane are extracted.

To forecast all holiday trips of originating demand, multiple data sources are available. Travel analyses of the association "Forschungsgemeinschaft Urlaub und Reisen (F.U.R.)", formerly known as "Studienkreis für Tourismus" (Institute for Tourism), offer the most detailed structural data for an extended period. This data is primarily used for the period since 1991 (since reunification) and is supplemented by the results of air passenger surveys. These surveys, based on a large sample size and an extrapolation on the basis of the air traffic statistics of the German Federal Statistical Office, provide reliable information on the actual volume of air trips (F.U.R., several years; Pak, 2007).

The demand analyses aim for a detailed representation of travel events and their background. Due to the design of these analyses, holiday trips of originating travel are determined only for the German resident population over 14 years of age, but differentiated by main holiday trips and additional holiday trips. The volume of holiday travel of the German population by age group is estimated using the parameters intensity of travel (percentage of population that take a holiday) and travel frequency (number of journeys per year per traveller). The main holiday trips and the additional trips are then distributed per age group to the destination area. Subsequently, the trips per destination area are assigned to air transport and other transport modes. Therefore, both travel decision and travel destination choice depend on the age and thus indirectly on the phase of life, position in the family and profession, and the age-specific mobility. The choice of transport mode is also influenced by these factors and additionally by the selected destination area. This category analysis has the advantage of a relatively high transparency of decisions, starting from the generation of travel to the point of choice of transport mode. However, detailed data material is required over a long period of time in order to model the changes in behaviour over time resulting from the phase of life. Furthermore, the age-group approach allows the explicit consideration of the demographic changes of the German population in terms of number and age in the future.

Since the travel surveys are limited to the German resident population over 14 years of age, assumptions are made regarding the holiday travel behaviour of children younger than 14 years. These assumptions are based on the travel behaviour of their parents' generation. Furthermore, it is assumed that the holiday travel behaviour of the foreign population living in Germany will develop similarly to that of the German population. Finally, methodological differences in the historical values of trips, resulting from both travel analyses and air passenger surveys, are included in the form of correction factors. These are taken into account in the forecast values.

Extrapolations are also applied for the smallest segment, namely the private short trips in international traffic. Especially in this segment, an expansion of the range of destination of the so-called low-cost carriers has been observed in recent years, which led to a sharp increase in demand. This observation is reflected in the forecasting methodology by assuming that there will be a strong growth in this segment in coming years. However, the annual growth will increasingly flatten as the generation of additional demand will become increasingly difficult.

6.3 Future German Air Transport Demand and the Impact of Demographic Change on the Demand

Applying the framework data described above, the presented forecast methodology predicted a growing air transport demand for Germany. The demand will grow from 60.7 million passengers in 2006 to 97.6 million passengers (+61%) in the high scenario (see Table 6.1) and 94.9 million passengers (+57%) in the low scenario (see Table 6.2) by 2030.

The ratio between domestic and border-crossing transport demand is not expected to change, with the share of intra-German air travel within total air travel being about 13–14% in both scenarios. However, within the cross-border traffic, the shares of business travel, holiday travel and private short trips are expected to change. Comparing both scenarios, these share shifts are almost identical. It is expected that the share of cross-border business travel in originating travel will rise

Table 6.1 Forecast of the air transport demand in the “high” scenario

Air trips in thousands	2006	(%)	2015	(%)	2030	(%)
Domestic air trips	8, 231	13.6	10, 092	12.5	12, 973	13.3
Air trips from Germany						
Business	9, 360	15.4	14, 281	17.7	19, 763	20.2
Holidays trips	27, 741	45.7	31, 100	38.5	31, 600	32.4
Leisure travel	3, 863	6.4	7, 000	8.7	9, 700	9.9
Air trips to Germany						
Business	6, 406	10.6	9, 402	11.7	11, 360	11.6
Holidays trips	3, 318	5.5	5, 600	6.9	7, 750	7.9
Leisure travel	1, 767	2.9	3, 200	4.0	4, 500	4.6
Total	60, 686	–	80, 675 +33%	–	97, 646 +61%	–

Table 6.2 Forecast of the air transport demand in the "low" scenario

Air trips in thousands	2006	(%)	2015	(%)	2030	(%)
Domestic air trips	8,231	13.6	10,023	12.5	12,561	13.2
Air trips from Germany						
Business	9,360	15.4	14,162	17.7	19,073	20.1
Holidays trip	27,741	45.7	30,813	38.5	30,452	32.1
Leisure trips	3,863	6.4	7,000	8.7	9,700	10.2
Air trips to Germany						
Business	6,406	10.6	9,324	11.6	10,963	11.5
Holidays trip	3,318	5.5	5,600	7.0	7,750	8.2
Leisure trips	1,767	2.9	3,200	4.0	4,500	4.7
Total	60,686	–	80,122 +32%	–	94,999 +57%	–

from about 15% in the year 2006 to approximately 20% in the year 2030. This represents almost a doubling of trips from 9.4 to 19.8 million in the high scenario. In comparison, the share of holiday trips in originating travel will become less important, shrinking from 45% in 2006 to 32% in 2030. Nevertheless, assuming the high scenario, the model estimates a rise in total holiday trips from Germany to destinations throughout the world. These trips are expected to increase from 27.7 million to 31.6 million by 2030. With regard to the segment of border-crossing private short trips, more than a doubling of the trips originating in Germany (3.9 million trips in 2006) is expected. Following the results of the forecast, the travel volume will be 9.7 million trips in 2030. Accordingly, the share of private short trips in total travel trips will rise from 6.4 to 9.9%.

Regarding air travel to Germany, a growth from 6.4 million business trips to 11.4 million are estimated in the business segment in the high scenario. Very strong absolute increases for both segments of private travel are additionally expected, albeit starting from a relatively low level. Therefore, the complete shares of both segments in total traffic will rise only moderately.

While the demand of cross-border business trips depends primarily on the expected economic development and especially on the development of exports from Germany into the world, private short trips are rather influenced by the offer of low-cost carrier connections. Since the demographic development has a significant impact on holiday travel demand, the forecast results for holiday travel originating in Germany will be explained in more detail in the following.

For the InfraDem project, the forecasting of holiday travel was conducted for two scenarios of population development and in addition for two travel behaviour variants, respectively. The first variant was based on the assumption of an unchanged age-specific holiday travel behaviour compared to 2006. This means that the following three behavioural characteristics were held constant for each age group:

- The share of the population that participates in holiday travel, as described by the travel intensity,
- the travel frequency of the holiday travellers,
- and the choice of destination and transport mode.

This leads to a forecast where changes in demand are only caused by population changes. The second variant takes into account changes in travel behaviour. Here, it was assumed that the travel intensity and frequency in the age group of over-60-year-olds will grow in the next ten years and then remain constant at the level reached. In addition and following the observations in the past, a growing preference for holiday trips by plane, mainly to destinations in the Mediterranean region, was assumed for all age groups. By comparing these two variants, the effects of the population development and of changed holiday travel behaviour in terms of the demand for holiday trips by plane can be separated.

Considering changes in travel behaviour, the forecast results initially show a further increase in demand for holiday trips by plane for both scenarios of population development (see Fig. 6.4). For the more optimistic population development of the high scenario, a maximum annual demand of 32 million holiday trips by plane was identified around the year 2025. Compared to the base year 2006, this represents an increase of 16% in demand. In the case of the population development of the low scenario, the maximum demand of 31 million holiday trips by plane is slightly lower and occurs five years earlier. The increase compared to the base year 2006, merely amounts to 13% in this case. The associated trip rates are almost identical. Initially, they grow significantly. However, around the year 2020, they remain constant

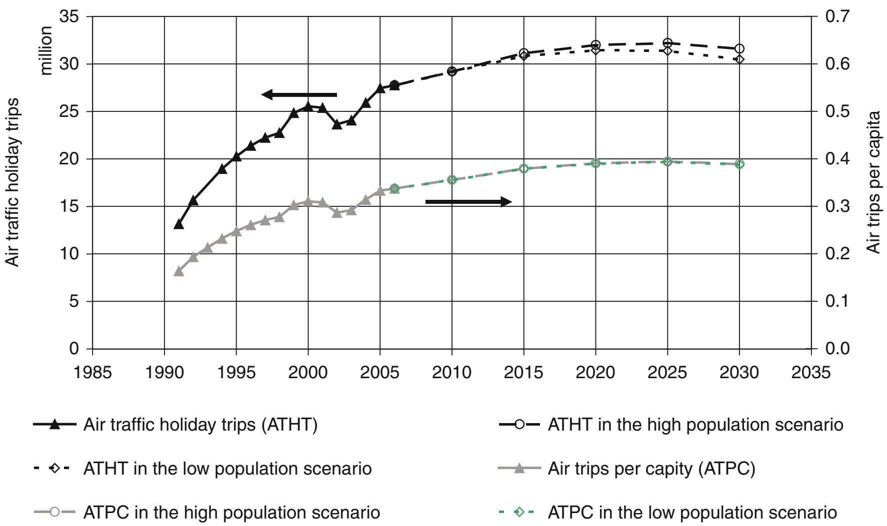

Fig. 6.4 Demand development of holiday trips by plane

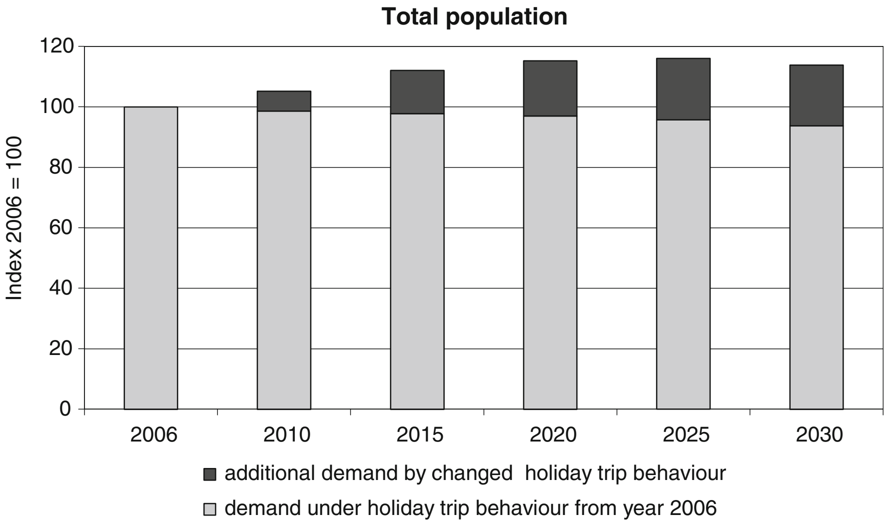

Fig. 6.5 Demand development of holiday trips by plane due to population development and changes in holiday travel behaviour of the German-speaking population (high population development)

at a level of 39 holiday trips by plane per 100 inhabitants. The two scenarios of population development therefore result in relatively small differences in the forecasted volume of holiday trips by plane and the associated trip rates.

As illustrated in Fig. 6.5, the predicted rise in demand for holiday trips by plane is essentially determined by the changes assumed in travel behaviour. Without changes in travel behaviour, the demand for holiday trips by plane would decline according to the demographic development and, in 2030, would be about 6% below the demand of the base year 2006.

The development of overall demand consists of partially varying demand developments in different age groups, which in turn result from various changes in group size and travel behaviour. The following figures show the demand development, in relation to 2006, for some selected age groups. The illustration is restricted to the high scenario of the population development, since only minor differences exist compared to the low scenario.

Concerning the age group of 14-to-19-year-olds, a variable demand development is predicted (see Fig. 6.6). It is assumed in this context that the holiday travel behaviour of this age group will exhibit a strong tendency to fly over the next few years. This will lead to an overcompensation of the fall in demand that results from the strong decline in the population of this age group caused by the abating impact of the second baby-boom generation in Germany[2]. Nevertheless, the

[2]The second baby-boom generation is mainly a result of the increasing birth rates after the Second World War.

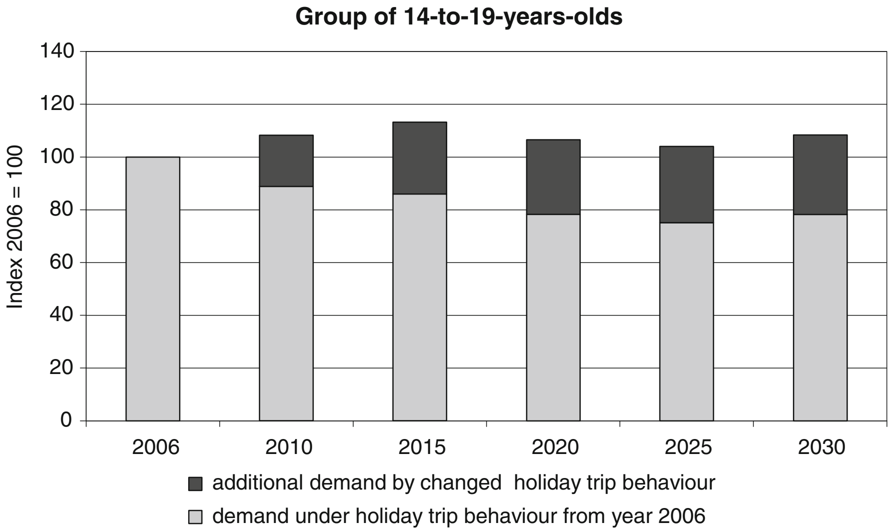

Fig. 6.6 Demand development of holiday trips by plane due to population development and changes in holiday travel behaviour of the German-speaking population aged between 14 and 19 years (high population development)

ongoing diminution of the age group of 14-to-19-year-olds will result in a falling demand during the period from 2015 to 2025, because this decline can no longer be compensated by changes in holiday travel behaviour. Concerning the long-term development after 2025, a slight increase in demand linked to a moderate growth of the concerned age group can be expected.

The demand development within the age group of the 20-to-29-year-olds is characterised by a slight increase until the year 2015, followed by a demand decrease in the time span afterwards (see Fig. 6.7). The potential of additional demand as a result of changing holiday travel behaviour is relatively small in this age group because both travel intensity and frequency have already reached a high level. In addition, the considered age group already has a high preference for flight trips today. This explains why a fall in demand in this age group, which is caused demographically, can be compensated only partially by changes in holiday travel behaviour. Nevertheless, in the near future, the group size will slightly increase, leading to a demand growth together with slight changes concerning holiday travel behaviour. This development will change in 2015, when the age group of the 20-to-29-year-olds will begin to shrink strongly. As a result, the demand for flight trips will be lower in the year 2025 than in the base year 2006.

Concerning the 60-to-69-year-old age group, the demand for holiday trips by plane will strongly increase (see Fig. 6.8). Reasons for this demand growth can be seen in both the demographic development and the changing patterns of holiday travel behaviour. In the year 2010, the considered age group mainly consists of the birth cohorts from 1940 to 1950. As a result of lower birth rates during the Second

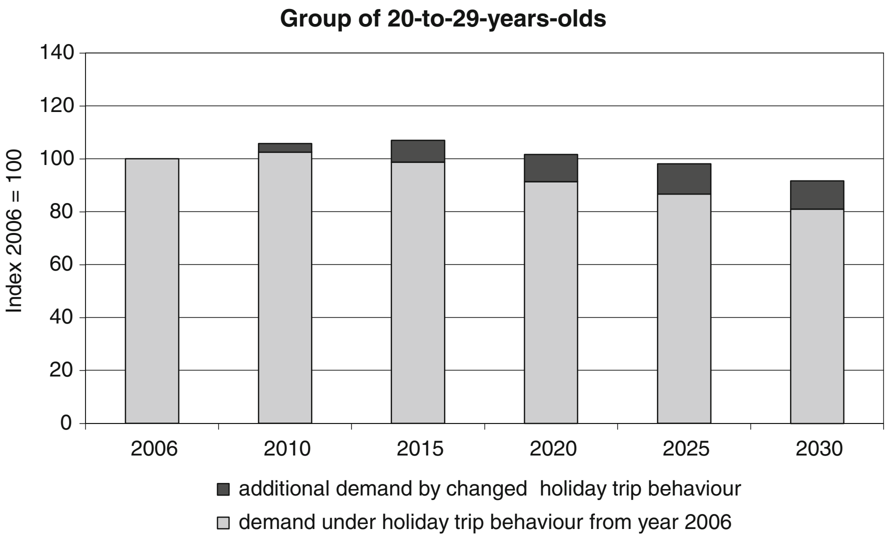

Fig. 6.7 Demand development of holiday trips by plane due to population development and changes in holiday travel behaviour of the German-speaking population aged between 20 and 29 years (high population development)

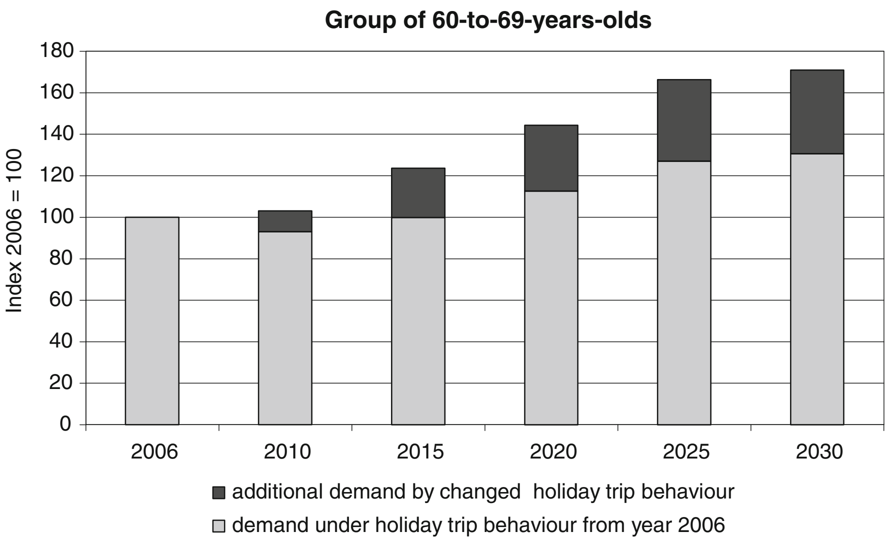

Fig. 6.8 Demand development of holiday trips by plane due to population development and changes in holiday travel behaviour of the German-speaking population between 60 and 69 years (high population development)

World War and afterwards, the population number of this age group will shrink in the first instance. Nevertheless, the resulting drop in demand will be balanced or even overcompensated by a stronger tendency of this group to go on holidays and use airplanes to travel. Concerning the years 2020 and 2025, the age group of 60-to-69-year-olds will mainly be formed by people of the baby-boom generation after the Second World War. These people, born in the years between 1951 and 1965, will contribute to a strong increase in the size of this age group. This alone causes a strong push in travel demand, which will additionally be supported by changed travel behaviour in favour of more flying. Looking at 2025, an increase of 70% in the demand for flight trips compared to 2006 can be expected for this age group. After this, demand growth will be only small because of the decline in birth rates after the middle of the 1960s, which will then start to influence the future development of the size of this age group.

6.4 Development of the Capacity Utilisation at the Airports of Hamburg and Rostock Until 2030

For the "high" InfraDem scenario, the potential demand at the airports of Hamburg and Rostock for 2030 was derived from the estimated total demand for air travel. These passenger volumes were primarily extrapolated using observed trends in recent years that were extracted from the German air transport statistics [DESTATIS, several years]. The key assumptions for allocating the nationwide travel demand to the German airports are listed below:

- The differences in demand behaviour of the population in East and West Germany will diminish more and more.
- Airports in the geographical "periphery" of Germany (e.g. Munich, Hamburg, Berlin) will gain above-average demand shares due to their location.
- The future Berlin Brandenburg International Airport will gain above-average market shares due to Berlin's function as capital and because of the anticipated increase in attractiveness.
- Medium-sized airports (e.g. Hamburg, Stuttgart, Berlin) will gain above-average demand shares in intercontinental traffic.
- The current fleet mix will continue to evolve.
- The current operation process will be maintained about the same.

The nationwide demand was allocated to the individual airports for the originating regions and the destination regions "inside Germany", "Europe", and "Intercontinental". Initially, the demand was allocated to six German regions and, in a second step, to the airports in these particular regions.

For Hamburg Airport, which handled approximately 5.1 million originating passengers in 2007, the number of originating passengers for the year 2030 was predicted as 8.5 million. This represents an increase of approximately 66%.

At Rostock Airport, which was used by about 79,000 originating passengers in 2007, the number of originating passengers was estimated as 126,000 for the year 2030 assuming dynamic growth mainly in European traffic. This represents an increase of 60%. Regarding the forecast for Rostock Airport, it is important to note that the growth starts from a relatively low base in 2006, and the absolute increase of less than 50,000 passengers remains a relatively small volume. It is well known, that the forecast uncertainties are rather high in the case of low levels of demand. Thus, the actual future development at Rostock Airport may look completely different depending on airline behaviour, e.g. if an airline operating at this airport expands or reduces its services.

In a further step, the passenger demand estimated for the airports of Hamburg and Rostock was converted into aircraft movements. For Hamburg Airport, the results of an existing empirical analysis of the relationship between passenger numbers and aircraft movements were used. Furthermore, it was assumed that aircraft movements of general aviation are increasingly being crowded out by scheduled services. In order to forecast the number of aircraft movements at Rostock Airport, the current average number of passengers per flight was used as a pragmatic assumption for an extrapolation into the future. Moreover, it was assumed that the number of flights performed by general aviation, which has a relatively high relevance at Rostock Airport, will increase by 3% p.a. For Hamburg Airport, the described procedure leads to a total number of movements of about 226,000 take-offs and landings in 2030, representing an increase of approximately 30% compared to 2007 (see Fig. 6.9). With the assumptions mentioned above, the number of aircraft movements at Rostock Airport will increase from 9,900 in 2007 to 18,400 in 2030, corresponding to a growth of 87% (see Fig. 6.10). This relatively high growth results less from scheduled services, and more from general aviation services.

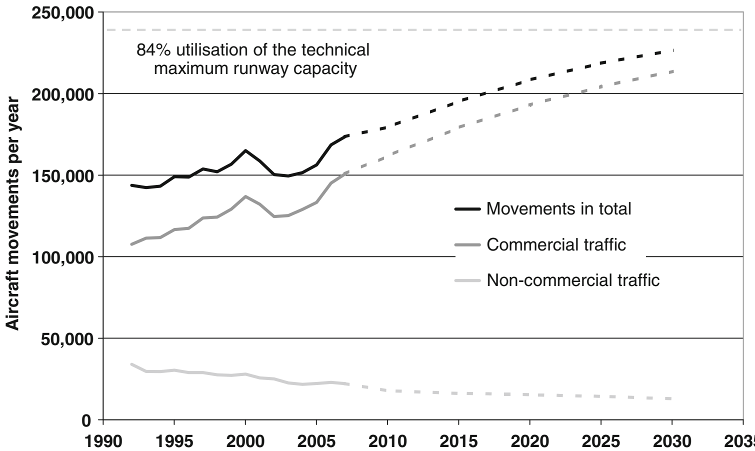

Fig. 6.9 Historical and estimated aircraft movement development at Hamburg Airport ("high" scenario)

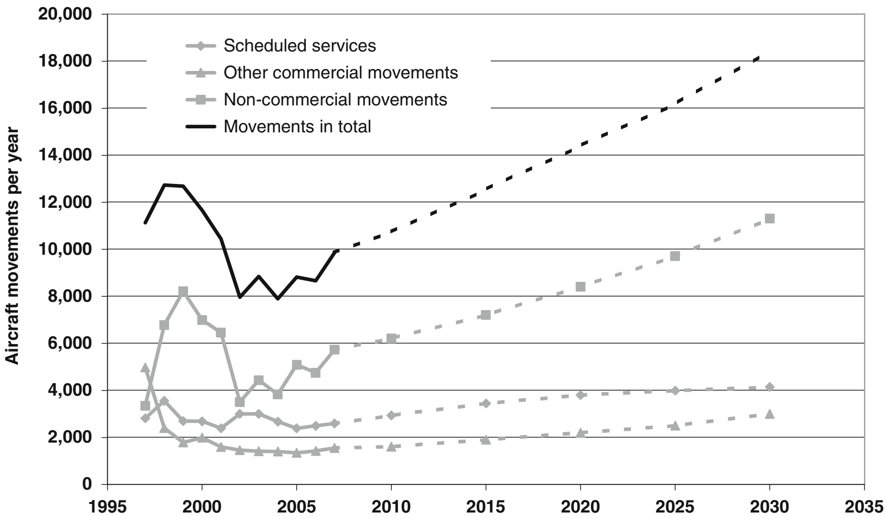

Fig. 6.10 Historical and estimated aircraft movement development at Rostock Airport ("high" scenario)

The degree of capacity utilisation of an airport cannot be determined precisely due to variations in demand both throughout the day and the months of a year. Thus, it is possible that the technically feasible utilisation of an airport is reached only on a few days of a year or during a few hours of a day. To illustrate the capacity utilisation of Hamburg Airport, it was assumed that a near-capacity utilisation is achieved at a level of 84% utilisation of the current runway capacity, which is determined by technical, operational and administrative constraints. This figure of 84% is derived from the annual utilisation rate of Frankfurt Airport, which operates at capacity limits. Based on this assumption, approximately 248,000 aircraft movements per year are feasible at Hamburg Airport (German Aerospace Center, 2008). Compared to the forecasted movements of 226,000 in the year 2030, the slot demand will approach but not exceed the described capacity limit. However, even today, capacity constraints exist during demand peaks. Therefore, it is already necessary to improve operating procedures.[3] Even though the terminals at Hamburg Airport were extensively modernised in recent years in order to handle approximately 16 million passengers,[4] the estimated 17 million passengers in 2030 would exceed the capacity limit. Nevertheless, terminal capacity can be optimised.

At Rostock Airport, the existing airside infrastructure capacity will not be reached by the estimated volume of aircraft movements over the entire forecast period (see Fig. 6.10). The expected 18,000 aircraft movements per year in 2030 can

[3]This predication bases on a DLR-internal analysis of time schedules data of the Official Airline Guide (OAG) for Hamburg Airport.

[4]http://de.wikipedia.org/wiki/Flughafen_Hamburg, retrieved April 21, 2009.

be handled easily by the existing runway. Since only about 4,000 out of these 18,000 aircraft movements are time-sensitive scheduled services, airside infrastructure bottlenecks will hardly occur even during periods of seasonal demand peaks. The terminal, established in 2005, is designed for about 300,000 passengers.[5] According to the estimation described above, the number of passengers is anticipated to reach 280,000 in 2030. Thus, the terminal capacity would be sufficient within this period. Also in the long run, Rostock Airport will be of importance for general aviation such as corporate jets, taxi services, and charter services with smaller aircraft.

6.5 Conclusions

Despite the expected demographic change, the estimated air travel demand in Germany will grow relatively strongly until 2030, primarily due to changes in travel behaviour and the further proliferation of low-cost services. For the two scenarios under consideration, the absolute increase in demand varies only marginally. Although a stagnation or slight decline in population can be anticipated for Germany until 2030, the further increase in specific air travel (the number of flights per capita) more than compensates this effect. Furthermore, there will be structural changes in demand due to different developments of market segments.

The analysis of the capacity situation at the airports of Hamburg and Rostock has shown that the current situation of low utilisation at Rostock Airport and the high utilisation at Hamburg Airport will persist or even aggravate in the case of Hamburg in the future. The airport concept of the Federal Government of Germany (BMVBS, 2009) takes into account the differences in utilisation between regional and metropolitan airports and sees the future potential of regional airports especially in the sector of general aviation and tourist scheduled services. Specifically for Rostock Airport, this implies the challenge to cover operating costs in a situation with insufficiently used infrastructure. For Hamburg Airport and other metropolitan airports, the situation is completely different. Hamburg Airport already shows a high load factor, and a further increase in demand, resulting amongst others from a population growth in this region, can be anticipated. In addition to the need to optimise operations, it seems appropriate to improve coordination of and maybe even merge existing airport capacity in the north-western part of Germany. To do so, the elaboration of a general infrastructural concept of air transportation, including the airports of Hamburg, Bremen and Lübeck, seems to be an objective worth pursuing. For example, Lübeck Airport already fulfils the function of a low-cost airport, serving partly the metropolitan region of Hamburg. Changes in air transport supply at this airport will clearly have an effect on Hamburg Airport. So, interdependencies between airports in the north-western region of Germany have to be taken into account.

[5] http://de.wikipedia.org/wiki/Flughafen_Rostock, retrieved April 17, 2009.

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Chapter 7
Impacts on the National Energy System

Thomas Pregger, Joachim Nitsch, and Wolfram Krewitt

Abstract A scenario analysis helps to determine the impact of an ageing and shrinking population on the energy sector in the context of pathways to sustainability. The scenario analysis in InfraDem follows the German "Lead Scenario" for the implementation of official targets for renewable energies and efficiency measures. This scenario points out an ambitious but realistic development towards a far more sustainable energy supply system by 2030 with long-term perspectives for a low-carbon energy system by 2050. The analysis takes into account the InfraDem population, GDP and household projections. The results show that demographic change will have a rather small impact on the national energy system compared to expected changes caused by political targets and strategies and the implementation of new energy technologies. The difference between the InfraDem high and low variant is between 3 and 4% for energy consumption and emissions. Although total population will decrease significantly until 2030, demographic change will tend to increase the residential power and heat demand due to an increasing floor space per capita and total household number as well as the higher specific energy demand of older people.

Keywords Energy scenario · Energy system · Energy demand · Demographic change · Renewable energy

7.1 Introduction

Demographic change is one factor that will affect energy demand and the development of the energy system in the future. Impacts of an ageing and shrinking

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population on the energy sector can be compared with other developments in an energy scenario analysis. The scenario analysis in InfraDem aims to describe and assess a possible pathway to a more sustainable energy system in Germany, taking into account the impacts of InfraDem projections on the energy demand. As the development of the energy system mainly depends on political framework conditions and the economic and technological potential of energy technologies, the analysis is based on a sophisticated and officially accepted energy scenario, which already includes all of the required detailed input data, such as technology characterisations, scenario constraints and policy targets. The ambitious but realistic Lead Scenario developed in the "Lead Study 2008" (Nitsch, 2008) commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) focuses on efficiency improvements and the strong role of renewable energies. Costs/benefits, time horizon and required structural changes for the medium and long-term expansion of renewable energies are discussed. The result is several policy recommendations regarding incentives, instruments and strategic actions for the implementation of renewable energy technologies. As the Lead Scenario 2008 is a realistic trajectory which enables the political goals of reducing energy demand, CO_2 emissions and the dependence upon fossil energy imports to be achieved, it is a suitable basis for the assessment of sustainability criteria focussed on by the InfraDem project, namely CO_2 emissions, NO_x emissions, energy demand and energy security.

7.2 Outline and Main Results of the Lead Study 2008

Methodologies, assumptions and results of the Lead Study 2008 were documented and published in Nitsch (2008). The "Lead Scenario 2008" and five further scenarios ("Efficiency" E1, E2 and E3 and "Shortfalls" D1 and D2) explore the probable future development corridors of the energy supply system, and explain the structural and economic effects that are to be expected in the energy sector. The study sets out in detail how the goals of the German federal government of expanding renewable energy production and improving energy efficiency can be attained by 2020. It also shows how the long-term targets of reducing greenhouse gas emissions by 2050 to approx. 20% of the 1990 level and boosting the contribution of renewable energies to the overall energy supply to about 50% can be achieved.

A number of matching sub-strategies are examined as key elements, and are implemented in all branches of the energy sector with their reciprocal structural interactions modelled over time. These sub-strategies are: "substantial expansion of renewable energies", "significantly improved efficiency of use in all sectors" and "improved efficiency of conversion by means of expansion of cogeneration". Final results for primary and final energy demand and the contribution of renewable energies are shown in Figs. 7.1 and 7.2. According to Nitsch (2008), the key findings of this analysis are:

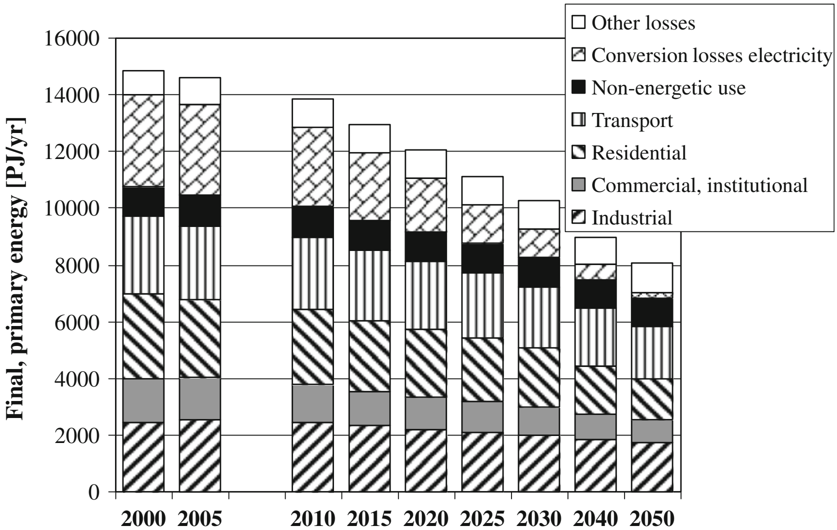

Fig. 7.1 Structure of final energy consumption, non-energy use and conversion losses in 2000 and 2005 (temperature adjusted) and according to the Lead Scenario 2008 (Nitsch, 2008)

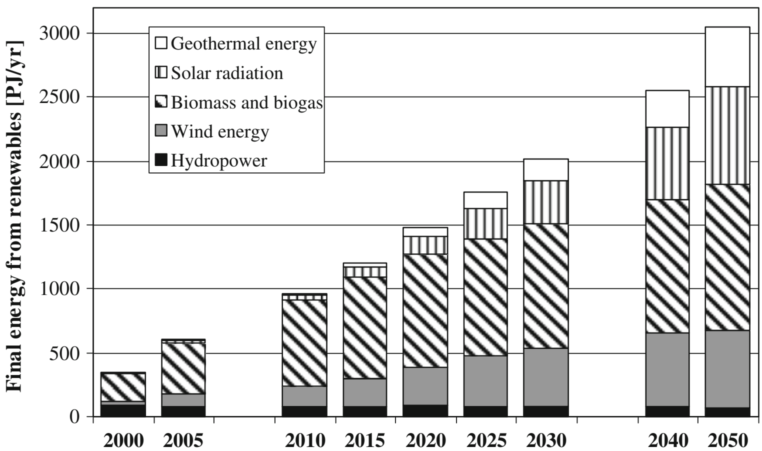

Fig. 7.2 Development of the contribution of renewables to final energy according to the Lead Scenario from 2008 to 2050 (Nitsch, 2008)

- The combination of continuous expansion of renewable energy production and substantial efficiency improvements in the Lead Scenario 2008 results in a reduction of primary energy consumption by the year 2020 by 17% compared to the 2005 level. The average growth rate of primary energy productivity is 3% per year, the average increase in electricity productivity was assumed to be 1.8% per year. The corresponding target of the federal government will be achieved. The share of renewables in final energy consumption rises to about 18%, and that of combined heat and power (CHP) production to almost 21%. This delivers a reduction in CO_2 emissions of 36% from the 1990 baseline. By 2050, primary energy consumption, according to the Lead Scenario 2008, will be 55% of that of 2005 with renewables meeting almost 50% of the remaining primary energy demand. Only 37% of the fossil energy deployed today will be required. Energy import requirements will amount to 40% of the presently imported quantity. The targeted 80% reduction in CO_2 emissions will therefore be barely achieved.

- According to the Lead Scenario 2008, the contribution of renewables to electricity supply by 2020 will grow to about 180 TWh/yr, which is 30% of the gross electricity consumption. In 2030 renewables will already cover 50% of the gross electricity consumption. Renewable generating capacity installed will total 70 GW in 2020, twice the figure of 2007. This figure will rise to about 100 GW by 2030. Renewable generating capacity newly installed since 2000 will produce more electricity each year than the quantity lost due to the phase-out of nuclear power up to the respective year.
- Under the precondition that 28 GW of existing fossil generating capacity will be decommissioned between 2005 and 2020, new fossil-fired power plants with a total capacity of 29 GW will be installed according to the Lead Scenario. Of that capacity, 9 GW should not be exceeded by coal-fired power plants, the remaining 20 GW must be operated with natural gas if the CO_2 reduction of 36% that follows from the Lead Scenario 2008 is not to be jeopardised. At least 12 GW of the new fossil generating capacity must take the form of CHP facilities, of which almost 3 GW must be in the form of small CHP units. The demand for natural gas will drop substantially after 2020.
- The heat sector must undergo major structural change by 2050. Demand for heat will drop to 82% of its present level by 2020 and to 50% by 2050. The contribution made by renewables will rise to 14% by 2020. In 2050, half of the remaining demand for heat energy will be met from renewable sources. In 2050, 25% of the present quantity of fossil energies consumed will still be required.
- CHP penetration and renewables expansion require considerable conversion of individual on-site heating systems to grid-connected heat supply systems. According to the Lead Scenario 2008, their share rises from its present level of 12% to 65% in 2050. The structural changes in the heat market required by the climate policy goals call for very precise monitoring of the effects of the present energy policy tools, and rapid adjustments where required.
- Due to a persistent strong growth trend in freight transport, the efficiency strategy only deploys limited effect over the medium term in the transport sector. The reduction in mean specific fuel consumption of the entire car fleet by 25% and of road freight by 20%, according to the Lead Scenario 2008, will only lead to a reduction of 10% in overall consumption by 2020. By 2050, total energy demand in the transport sector will drop to 73% of the 2005 level. Then, only 50% of the presently required quantity of fossil fuels will be consumed.
- Under the precondition that fuels will be used much more efficiently, a measured introduction of biogenic fuels is a recommendable transitional strategy if

the sustainability criteria set out in, among other things, the biomass strategy of the BMU are complied with. A contribution to total fuel consumption of 12% in energy terms (and of about 15% of consumption for road transport) will be achieved by 2020. The share of biofuels in fuel consumption that is achievable in the long term is 17% (for road transport 20%).

- There are highly attractive options to deploy cost-effective renewable electricity on a relevant scale in the transport sector. Electric traction and hydrogen engines are already available. Scenario E3 shows that if these options are deployed, by 2030 almost 25% of the final energy requirement of the transport sector can be met by biofuels, renewable electricity and renewable hydrogen. This share could rise to 56% by 2050. By then, only 30% of the presently deployed quantity of fossil fuel will be required.
- The expansion of renewables in accordance with the Lead Scenario 2008 continuously maintains an investment volume of approximately 12 billion EUR_{2005}/yr. Annual investments will rise to more than 15 billion EUR_{2005}/yr after 2020. Cumulative investments in renewable energy facilities between 2008 and 2020 will amount to 160 billion EUR_{2005} (of which 90 billion EUR_{2005} for electricity).
- With realistic energy price developments (Price Path A, see Table 7.2), the production costs of the renewable electricity mix according to the Lead Scenario 2008 are lower in 2020 than those of fossil electricity supply. If photovoltaic production is excluded from the calculation, this point is already reached by 2015. Further expansion of renewable generation leads to a stabilisation of electricity production costs at approximately 8.5 to 9 $€cts_{2005}$/kWh (medium-voltage level) with a trend towards further long-term cost reduction in accordance with the further cost degression potential of renewables.
- The step-by-step development of the Lead Scenario 2008 reveals that an insistent energy policy, which establishes a favourable setting over lengthier periods, can deliver substantial outcomes by 2050 in terms of climate change mitigation and fossil resource conservation. Considered in the light of the set of further scenarios, the actual Lead Scenario 2008 is a realistic trajectory. Renewables can moreover make contributions to energy supply by 2050 that go beyond those in the Lead Scenario (Scenario E3 with a renewable share of 65%).
- If a smaller impact of the efficiency measures and CHP expansion is assumed (i.e. an increase in average energy productivity of only 2.5% per year until 2020; CHP share 17%), the resulting higher energy demand will reduce the share of renewables in 2020 by 1.8% compared to the Lead Scenario 2008. The fossil energy requirement is then already some 1,000 PJ/yr higher in 2020 than according to the Lead Scenario 2008. In this case, total CO_2 emissions can only be reduced by 28% by 2020 from the 1990 baseline. This underscores the importance of a consistent policy aiming to improve efficiency in all fields.

Figures 7.1 and 7.2 show summarised scenario results for primary and final energy demand and the contribution of renewable energies. Primary energy demand drops between 2000 and 2050 from around 15,000 PJ to around 8,000 PJ. Final energy demand in all consumer sectors decreases from around 10,000 PJ to around 6,000

PJ. The contribution of renewables to final energy increases between 2000 and 2050 by factor of around 9.

The scenario analysis in the Lead Study 2008 shows the significant impact of policy targets and strategies as well as of the implementation of efficiency measures and new energy technologies on energy demand and CO_2 emissions. The structural changes required for these implementations will also need infrastructural investments for energy distribution and new communication and monitoring facilities. The implementation of carbon capture and storage technologies (CCS) and infrastructures were not included in the Lead Scenario as a policy target. CCS remains controversial, as this concept cannot guarantee safe and permanent underground storage of CO_2, has significant energy consumption and costs, and is not expected to be available before 2030.

Table 7.1 Key demographic and economic data for the Lead Scenario 2008 (Nitsch, 2008)

Key data	2004	2006	2010	2015	2020	2025	2030	2040	2050
Population (millions)	82.5	82.4	82.4	82.1	81.4	80.6	79.3	77.3	75.1
Working population (millions)	38.9	39.0	39.3	39.2	39.0	38.4	37.5	37.0	35.8
Private households (millions)	39.1	39.3	39.7	39.9	40.0	39.9	39.7	39.2	38.5
Housing units (millions)	39.4	39.5	40.3	41.0	41.3	41.1	40.8	39.5	38.5
Residential floor space (millions m^2)	3,369	3,421	3,534	3,692	3,850	3,950	4,000	4,000	3,900
Heated non-res. floor space (mill. m^2)	1,485	1,500	1,525	1,539	1,550	1,540	1,520	1,500	1,450
GDP (billions EUR_{2005})	2,106	2,183	2,335	2,540	2,763	2,960	3,130	3,420	3,600
Number of cars (millions)	45.0	45.7	47.0	47.8	48.0	47.7	47.5	47.0	46.3
Passenger transport vol. (billions pkm)	1,091	1,100	1,126	1,124	1,113	1,105	1,080	1,050	1,015
Freight transport volume (billions tkm)	565	600	675	742	804	835	855	880	890
Specific values	2004	2006	2010	2015	2020	2025	2030	2040	2050
Persons per household	2.11	2.10	2.08	2.06	2.03	2.02	2.00	1.97	1.95
Residential floor space per capita (m^2)	40.8	41.5	42.9	45.0	47.3	49.0	50.4	51.7	51.9
Resid. floor space per household (m^2)	85.5	86.6	87.6	90.0	93.2	96.1	97.9	101.3	101.3
Number of cars per household	1.15	1.16	1.18	1.20	1.20	1.20	1.20	1.20	1.20
Non-resid. floor space p. employee (m^2)	38.2	38.5	38.8	39.3	39.8	40.1	40.5	40.5	40.5
GDP per capita (1,000 EUR_{2005})	25.53	26.49	28.33	30.94	33.95	36.73	39.47	44.24	47.92
Passenger transport volume per capita (1,000 pkm)	13.23	13.35	13.66	13.69	13.67	13.71	13.62	13.58	13.51
Freight transport volume per capita (1,000 tkm)	6.85	7.28	8.19	9.04	9.88	10.36	10.78	11.38	11.85

Impacts of socio-economic developments affecting energy demand were taken into account on the basis of scenarios for key demographic and economic data (see Table 7.1). These time series are mainly based on EWI/Prognos (2005; 2007). As the assumed development of population, households, GDP and working population differ from the two InfraDem variants, an adoption of these assumptions and therefore a modification of the energy demand was performed before the Lead Scenario was used for the analysis (see section 7.2).

The development of energy prices has an impact only on the calculation of production costs and differential costs between fossil and renewable energy production. Energy prices are therefore an important factor for assessing future benefits of the structural change of the supply system. The Lead Scenario aims to achieve defined policy targets and therefore fossil fuel prices do not play a dominant role for the technology shares in the scenario at least until 2020. In reality fuel prices affect investment decisions and the implementation of energy efficiency measures in all demand sectors. Therefore, political measures will have to further promote new technologies as long as they are more expensive than conventional technologies based on fossil fuels. Table 7.2 summarises the fuel price path which was assumed

Table 7.2 Price path A "Significant Increase": real (value of money in 2005) and nominal import prices for crude oil, natural gas and hard coal, and CO_2 mark-ups assumed for the Lead Scenario 2008

Real 2005			2005	2007	2010	2015	2020	2025	2030	2040	2050
Crude oil import price, $\$_{2005}$/b			52.50	71.22	78.0	86.0	94.0	101.0	108.0	120.0	129.0
Crude oil import price, €$_{2005}$/GJ			7.51	9.19	9.79	11.19	12.70	14.19	15.67	18.17	19.70
Natural gas import price, €$_{2005}$/GJ			4.66	6.80	7.83	9.17	10.67	12.20	13.79	16.53	18.52
Natural gas import price, €cts$_{2005}$/kWh			1.68	2.45	2.82	3.30	3.84	4.39	4.96	5.95	6.67
Hard coal import price, €$_{2005}$/GJ			2.10	2.48	3.91	4.59	5.33	6.10	6.89	8.54	9.85
Hard coal import price, €$_{2005}$/t			61.7	72.7	114.7	134.4	156.3	178.8	202.1	250.2	288.7
Lignite, €$_{2005}$/GJ			1.05	1.10	1.12	1.20	1.25	1.30	1.37	1.50	1.65
Nominal			2005	2007	2010	2015	2020	2025	2030	2040	2050
Crude oil import price, $/b			52.5	74.0	86.0	104.7	126.4	149.9	177.0	239.8	314.2
Crude oil import price, €$_{2005}$/GJ			7.51	9.56	10.79	13.63	17.07	21.06	25.68	36.26	47.93
Natural gas import price, €$_{2005}$/GJ			4.66	7.07	8.63	11.17	14.34	18.11	22.60	33.00	45.05
Natural gas import price, €cts$_{2005}$/kWh			1.68	2.55	3.11	4.02	5.16	6.52	8.14	11.88	16.22
Hard coal import price, €$_{2005}$/GJ			2.10	2.58	4.32	5.59	7.17	9.05	11.3	17.04	23.97
Hard coal import price, €$_{2005}$/t			61.7	75.6	126.5	163.7	210.1	265.4	331.2	499.5	702.4
€/$ exchange rate			1.23	1.36	1.40	1.35	1.30	1.25	1.21	1.16	1.15
	Emission factors assumed:				2010	2015	2020	2025	2030	2040	2050
CO_2 – mark-ups €/t CO_2	t CO_2/GJ	kg CO_2/kWh			24	32	39	45	50	60	70
Hard coal, €/GJ	0.0920	0.331			2.208	2.944	3.588	4.140	4.600	5.520	6.440
Natural gas, €/GJ	0.0562	0.202			1.349	1.798	2.192	2.529	2.810	3.372	3.934
Lignite, €/GJ	0.1112	0.400			2.669	3.558	4.337	5.004	5.560	6.672	7.784
Crude oil, €/GJ	0.0745	0.268			1.786	2.384	2.906	3.353	3.725	4.470	5.215

for the Lead Study 2008 assessments and especially for the Lead Scenario 2008. These assumptions are based on the premise that global demand for exhaustible resources will continue to rise but supply capacities will be limited and peak in the future.

7.3 Approach for InfraDem Scenario Analysis

This section describes the approach for modifying the Lead Scenario and applying it to the sustainability analysis in the InfraDem project which also includes NO_x emissions. The assumptions used to estimate demographic effects based on specific parameter values from the literature are described in Section 7.4.2.

7.3.1 Modification of Demographic and Economic Data and Impact on Energy Demand

Figure 7.3 compares InfraDem projections on population, number of households, GDP and working population with the data in Table 7.1 referred to by the Lead Study (Nitsch, 2008). Whereas population development assumed by Nitsch (2008)

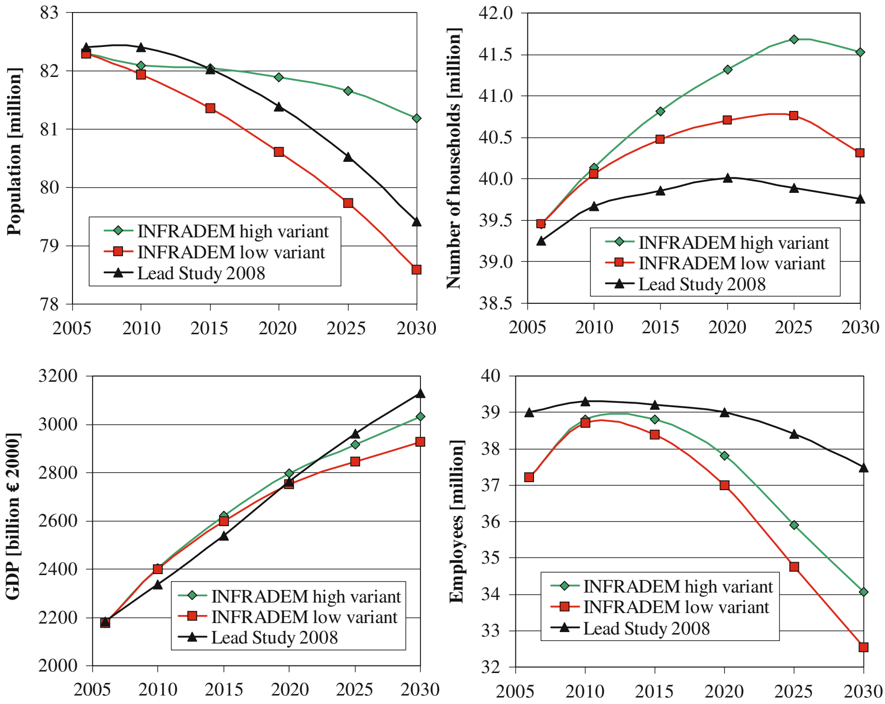

Fig. 7.3 Comparison of projections for households, population, GDP and working population – InfraDem versus Lead Study 2008

is between InfraDem high and low variants, the time series for number of households is higher for both InfraDem projections. An adjustment of this demand driver will therefore lead to a higher energy demand in the InfraDem scenarios compared to the Lead Study 2008. A more detailed comparison of the InfraDem age and size distributions of population resp. households with the distributions used by EWI/Prognos (2005) shows only minor deviations. The reason is that both studies used the official population statistics of the German Federal Statistical Office (Statistisches Bundesamt) – albeit from different years. The modification of the Lead Scenario in the residential sector can therefore focus on the number of population and households and disregard the small differences in distributions.

Figure 7.3 also shows that GDP forecasts in the Lead Study are lower before 2020 and higher until 2030. Although the Lead Study uses a higher base year value for the working population (due to a different statistical method), a lower rise during the next few years and a significant lower decrease up to 2030 lead to a more optimistic assumption of 3.5 million additional employees in 2030. The different statistical definitions of working population have been taken into account by considering the relative change in the working population number for the modification.

The energy scenario was modified for each scenario year by multiplying the InfraDem projections for demographic and economic demand drivers with sector specific energy intensities derived from the Lead Scenario and the elasticity between driver and corresponding heat, fuel or electricity demand (see Eq. 1). Each sector was assigned to a driving parameter. Table 7.3 shows values for elasticity and energy intensity derived from the Lead Scenario 2008 and used for the modification. Table 7.4 shows the difference between parameter values used in InfraDem and those used in the Lead Scenario. InfraDem projections are up to 12% lower for the working population and up to 5% higher for the number of households than the corresponding values in the Lead Study. Figure 7.4 shows a comparison of the resulting total final energy demand for different energy categories.

$$ED_{InfraDem} = ED_{Lead} \times \frac{PV_{InfraDem}}{PV_{Lead}} \times \frac{\Delta ED_{Lead}}{\Delta PV_{Lead}} \qquad (1)$$

with: ED = energy demand
PV = parameter value (population, employees, GDP, households etc.)

By applying this approach, the energy demand of single demand categories changes by up to 12% such as the industrial electricity demand. Figure 7.3 and Table 7.4 show that projections of drivers relevant for the residential demand are lower in the Lead Scenario, whereas GDP and employees used as drivers for commercial and industrial energy consumption are higher. Due to this compensating effect, the overall change in energy demand is smaller. The InfraDem high variant results in an overall final energy demand that is only 1–2% lower than in the Lead Scenario (see Fig. 7.4). Primary energy demand and CO_2 emissions are approximately 2% lower. The low variant results in a final energy demand that is 4–5% lower. Policy targets are still achieved after the modification as even lower energy demands are generated.

Table 7.3 Elasticities between demographic and economic parameters and energy demand (Δ energy demand/Δ parameter value) derived from the Lead Scenario 2008

	2010	2015	2020	2025	2030
Δ Electricity HH/Δ population	1.04	1.03	0.99	0.99	0.99
Δ Hot water HH/Δ population	1.06	0.91	0.91	0.92	0.87
Δ Process heat HH/Δ population	1.12	0.91	0.91	0.90	0.89
Δ Space heat HH/Δ living space	0.86	0.92	0.92	0.94	0.92
Δ Process heat IND/Δ GDP	0.97	0.90	0.87	0.87	0.88
Δ Electricity IND/Δ working population	1.06	1.00	0.98	0.99	1.00
Δ Space heat IND/Δ working population	0.90	0.95	0.96	0.96	0.98
Δ Hot water IND/Δ working population	0.66	0.89	0.95	0.95	0.95
Δ Process heat GHD/Δ GDP	0.89	0.82	0.82	0.84	0.90
Δ Electricity GHD/Δ working population	1.02	1.01	1.01	0.98	0.99
Δ Space heat GHD/Δ working population	0.89	0.88	0.89	0.92	0.94
Δ Hot water GHD/Δ working population	0.97	0.92	0.92	0.92	0.92
Δ Passenger transport pkm/Δ population	1.05	1.02	1.00	1.00	1.00
Δ Fuel demand/Δ passenger transport pkm	0.87	0.92	0.92	0.92	0.94
Δ Freight transport tkm/Δ GDP	1.11	1.05	1.01	1.00	0.97
Δ Fuel demand/Δ freight transport tkm	0.85	1.00	0.95	0.95	0.94
Δ Electricity HH/Δ population	1.04	1.03	0.99	0.99	0.99
Δ Hot Water HH/Δ population	1.06	0.91	0.91	0.91	0.87
Δ Process heat HH/Δ population	1.12	0.91	0.91	0.90	0.89

HH, households; IND, industry; GHD, commerce/manufacturing/services; pkm, passenger kilometres; tkm, tonne-kilometres

Table 7.4 Difference between parameter values in InfraDem projections and the Lead Scenario 2008 in % deviation from the original values used in the Lead Scenario

	2010(%)	2015(%)	2020(%)	2025(%)	2030(%)
InfraDem high variant					
Population	–0.4	–0.1	0.6	1.3	2.4
Working population[a]	0.0	0.3	–1.8	–5.2	–7.8
Private households	1.1	2.3	3.3	4.5	4.6
GDP (billion EUR_{2005})	2.9	3.2	1.2	–1.4	–3.1
InfraDem low variant					
Population	–0.6	–0.9	–1.0	–1.1	–0.9
Working population[a]	0.0	–0.6	–3.6	–8.0	–11.6
Private households	0.9	1.4	1.8	2.2	1.5
GDP (billion EUR_{2005})	2.7	2.3	–0.5	–3.9	–6.5

[a]Values for 2010 were adapted to the Lead Study in order to take account of different statistical methods underlying the data time series

7.3.2 Estimation of NO_x Emissions

The Lead Study 2008 focuses on energy demand, energy supply and CO_2 emissions determined by the amount of fossil fuels burned. Emissions of air pollutants have

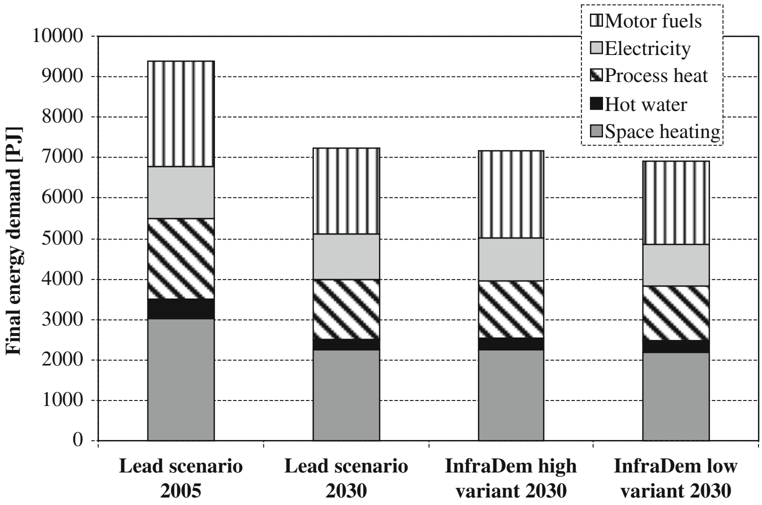

Fig. 7.4 Total final energy demand in the Lead Scenario for 2005 and 2030 and modified values for the InfraDem variants

Table 7.5 Aggregated NO_x emission factors in (kg/TJ) derived from (UBA, 2007) and used for InfraDem scenario analysis

	2005	2010	2015	2020	2025	2030
Road transport – buses	834	650	476	371	310	270
Road transport – passenger cars	142	117	119	127	120	115
Road transport – heavy duty vehicles	665	439	300	266	240	230
Air transport	326	310	295	279	269	262
Inland navigation	1,397	1,313	1,229	1,145	1,080	1,040
Rail transport	1,135	917	785	732	700	680
Power generation – hard coal	64	64	64	64	64	64
Power generation – lignite	73	73	73	73	73	73
Power generation – gases	61	58	57	58	58	58
Power generation – fuel oil	96	96	97	102	102	102
Power generation – total	68	67	67	67	67	67
Heat generation – hard coal	83	87	88	88	88	88
Heat generation – lignite	85	78	78	78	78	78
Heat generation – gases	33	31	30	28	28	28
Heat generation – fuel oil	50	46	44	43	43	43
Heat generation – total	42	39	38	36	36	36

not been calculated within the Lead Study. The calculation of NO_x emissions is usually more complicated and must be conducted on a detailed process level because emission factors are not only a matter of fuel input but also of technologies applied. However, scenario results for energy supply and energy demand can be used to estimate emissions of other substances by using emission factors from other studies. NO_x emission has been selected as a sustainability criterion because it is one of the most important pollutants in urban areas emitted by transport, residential and industrial activities. A national scenario for NO_x emissions and future emission factors can be derived from a study commissioned by the German Federal Environment Agency (UBA, 2007). Detailed information on a process level was used to determine the aggregated emission factors shown in Table 7.5, which can be linked to fuel consumption calculated in the energy scenarios. The most recent national emission scenario (UBA, 2008) was used to update the total NO_x emissions. Emission factors for 2025 and 2030 are extrapolated based on development up to 2020.

7.4 Results

The resulting values for selected sustainability indicators are shown for both InfraDem projection variants as input for the sustainability assessment in Chapter 11. The possible impacts of socio-economic framework data on energy demand are discussed here for the residential sector.

7.4.1 Scenario Results for Selected Sustainability Indicators

The final and primary energy demand, the share of renewable energies, the share of imported fossil energy, and direct CO_2 and NO_x emissions are selected sustainability indicators in the energy sector. Figure 7.5 shows the results of the energy scenario for the high and low variants. Primary energy demand decreases to around 75% between 2005 and 2030 and final energy demand to about 68%. CO_2 emissions drop to below 55%. NO_x emissions will drop even lower to around 48% as a result of technical abatement measures (mainly before 2020) and the substitution of fossil combustion (mainly after 2020). The share of renewable energies in the supply of primary energy reaches 25% in 2030. Total CO_2 emissions in 2030 are 445 million tonnes in the low variant and 460 million tonnes in the high variant of which 318 resp. 329 million tonnes are emissions from the power and heat supply. Calculated NO_x emissions in 2030 are 595,000 t resp. 615,000 t with 32% resulting from power and heat supply and 68% emitted from transport processes. The share of imported energy is 74.5% in 2005, 72.7% in 2020 and 57% in 2050.

The difference between the InfraDem high and low variant is between 3 and 4% for all of the four indicators shown in Fig. 7.5. This shows the rather small impact of the projections for number of population and households, GDP and working population on the indicators. However, the results fail to provide an answer to the relevance of ageing and the trend towards more and smaller households, which leads to an increasing floor space per capita. The two InfraDem variants are each based on the same population and household structure. Neither the Lead Study nor the underlying

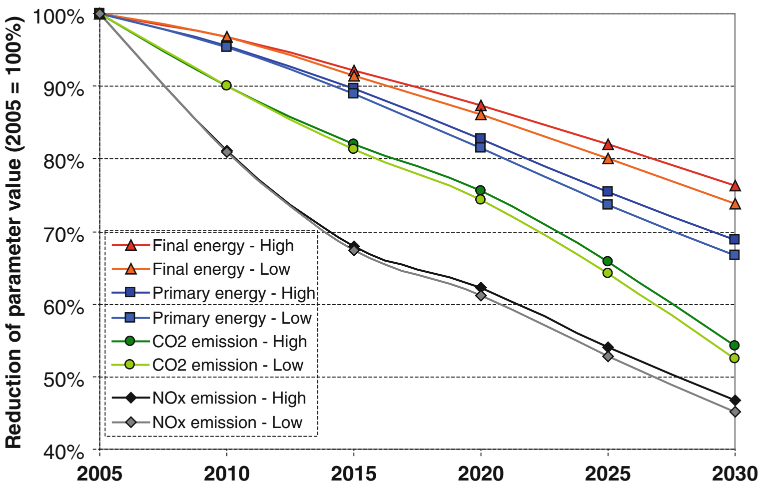

Fig. 7.5 Results of the modified energy scenario based on InfraDem projections: reduction in values for the sustainability indicators for the high and the low variant

reference studies, (EWI/Prognos, 2005 and EWI/Prognos, 2007), provide sufficient information regarding the influence of these demographic parameters on the energy demand. Therefore in Section 6.4.2, a separate estimation of these effects is performed by applying literature data and specific consumption data per household type.

7.4.2 Impact of Demographic Change on Energy Demand

The focus of this section is on the implications of ageing and changes in household structure on residential electricity and heat demand. Detailed information on how socio-economic drivers such as number and age of population, GDP etc. are linked to the energy demand is not usually published in detail in scenario studies and background information is often unavailable. Therefore, the impact of demographic change on energy demand cannot be fully understood from the scenario analysis. However, EWI/Prognos (2005) provides a detailed characterisation of the energy demand in households, describing some of the main demographic assumptions applied regarding population, age distribution and number, and the sizes of households based on official statistical data and their own assumptions. Unfortunately, the report does not provide the specific energy intensities that were applied on a detailed level to estimate energy demand in the future. Nevertheless, some important information on specific consumption can be derived, namely

- the usage of major electric home appliances per household size, and
- the residential living space per person and household size.

Table 7.6 Specific factors per household type derived from EWI/Prognos (2005) and StBA (2008)

	Factor for the use of major electric home appliances for each household type (%)	Assumed living space per person (m^2) and household type
1 person households	100	68
2 persons households	140	47
3 persons households	180	36
4 persons households	220	31
5 persons households	250	24

This information can be linked to the development of households in order to roughly estimate the influence of the changing population and household structure on heat and electricity demand in households. Table 7.6 shows the specific values per household type used for this estimation. By applying the household projection described in Chapter 2, effects can be described in relation to both the structure and number of households.

The results show that residential heat demand only rises by about 3% due to the change in household structure between 2006 and 2030, when we assume the living space as the sole indicator of demand with a constant specific heat demand per m^2. If we also take into account the development of the number of households as shown in Fig. 7.3, we can estimate a demand increase of 8.4% for the high variant and 5.4% for the low variant in 2030 with a peak of 8.7% resp. 6.3% in 2025. Electricity demand increases by 3% due to the change in household structure between 2006 and 2030 when estimated with usage factors for electric appliances in different households. If we also consider the number of households and population, the result is a demand increase of 1.4% in the high variant and a demand decrease of 1.8% in the low variant.

A second approach is to analyse expenditures of different age groups and households. The major statistical data source for this information in Germany is STBA (2006), which provides detailed information for the year 2003. These household consumption survey data were used by Kronenberg (2007) to derive values by household age and consumption purpose. We can allocate expenditures for electricity and heating fuels to the number of households per householder age group. Assuming that this expenditure distribution will remain constant in the future, we can estimate the effect of increasing household numbers and the ageing of the household members.

Figure 7.6 shows the results of this analysis as a time series of total expenditures in Germany for electric power and heating fuels. Under the assumption of constant expenditures per household age group, fuel demand for heating will rise by 2.8% between 2006 and 2030 in the InfraDem low variant. For the high variant, residential fuel demand will increase by 5.8%. Electricity demand will also increase due to the population ageing by 1.1% in the low variant and 4.2% in the high variant. The effects on energy demand have the same tendencies but are a bit lower for fuels

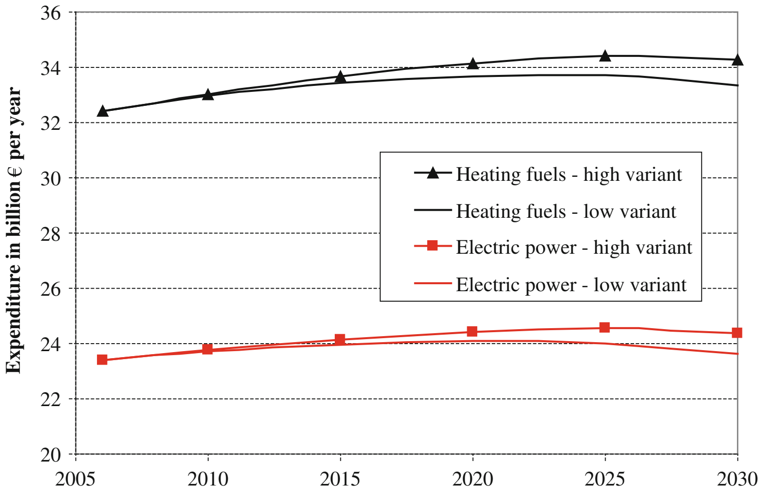

Fig. 7.6 Forecast of residential expenditures for energy in Germany. Approach: specific expenditure per household and age of household based on Kronenberg (2007) multiplied by number of households by age of household

and slightly higher for electricity than the estimations based on Table 7.6. Both estimations confirm the trend towards higher residential energy demand as a result of the demographic change at least until 2030 with a demand peak around 2025.

7.5 Conclusions

The future change in energy demand and the overall energy system is mainly driven by policy targets and the implementation of efficiency measures and new technologies. The scenario analysis shows a significant reduction in energy demand and emissions if the official policy targets are realised. The results for these sustainability indicators differ by about 3–4% between the InfraDem high and low variant. The impact of the two different population, GDP and household projections on the scenario is therefore rather small. However, the impact of demographic change may be an important factor as it is contrary to the policy targets of improving energy efficiency. Demand-side effects are expected, especially in the private households sector, due to increasing floor space per capita and correlated energy consumption on the one hand, and due to an ageing population with the higher specific heat demand of older people on the other (see also Chapter 10). These two factors alone are estimated to increase the residential energy demand by up to 10% or more in the period until 2030. Therefore, energy scenarios should deal with the effects of demographic change more explicitly and evidently as they may jeopardise efficiency targets. Effects on the national energy infrastructure can only be quantified for the generation capacities as a result of demand changes. Effects on the transmission and distribution grids mostly depend on local conditions and are also determined to a greater extent by other effects such as the development of decentralised power generation and electro-mobility as well as the changing spatial distribution of generation capacities due to the increasing use of renewable energies.

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Chapter 8
The Potential for District Heating Based on Renewable Energy: A Spatial Analysis

Christoph Schillings and Sonja Simon

Abstract The German government intends to cover the demand for primary energy by 16% of renewable energy in Germany in the year 2020, and to reduce CO_2- emissions by 40% as opposed to the year 1990. One relevant CO_2 emitter is energy sector which has a big potential to achieve this target. On the other hand, the demographic change will strongly influence the heat supply system, a part of the heat sector. The following chapter analyses the challenges that arise by the decreasing heat demand due to demographic change and the need for a modified heat supply system based on renewable energies to attain the given target. This is done by a spatial analysis using Geographical Information System taking into account the actual and future heat demand, the existing infrastructure stock and the potential of renewable energy (mainly solar, biomass and geothermal). The analysis shows that the decreasing heat demand in general is a critical precondition for network-bound heat supply infrastructure and that renewable energies can help in selected regions to provide CO_2-neutral heat using existing or new district heat systems.

8.1 Introduction

The energy sector is strongly influenced by demographic change. The latter will have less influence on the power supply infrastructure than on the heat supply infrastructure. This is due to the fact that despite the decrease/increase in population, the available power supply infrastructure does not have to be significantly adjusted. Furthermore, the changing age - structure is not that relevant for future power demand (Nitsch et al., 2004). However, the current heat supply infrastructure is very heterogeneous. On the one hand, heat supply networks exist in agglomerations, whereby the gas supply network, for example, is highly developed, while on the other hand more rural districts feature a highly decentralised heat supply system

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(individual oil-, coal-, or wood-fired ovens). Oil-fired heating systems are also quite common. Demographic change strongly influences the heat supply sector since its infrastructure has to be adjusted accordingly. Furthermore, the heat demand alters due to the changing age - structure, for example, there is a higher heat demand (higher room temperature) for older persons. The German government intends to cover 16% of the demand for primary energy with renewable energy by the year 2020, and to reduce CO_2- emissions by 40% compared to 1990 (Nitsch et al., 2004). Major emphasis is on the heat sector in order to achieve this target. The intention of this analysis is to discuss the extent to which the regions highly affected by demographic change can contribute to achieving the target using renewable energy based heat supply systems. The future heat demand and the potential development of the heat supply infrastructure are analysed and compared for the target regions Hamburg and Mecklenburg-Western Pomerania, which have been chosen for the InfraDem - project. The analysis of heat supply based on renewable energy – mainly biomass, solar heat and geothermics – is emphasised here. Figure 8.1 shows the performed steps of this analysis.

In addition to the inventory of available network-based heat infrastructure systems (heat networks and gas networks), the current and future heat demand of both regions will be analysed. The temporal change in the heat demand is modelled for two variants of demographic development, which are given in the frame scenarios by project partners at the Rostock centre (low variant and high variant).

The analysis is performed by means of a geographic information system (GIS) on a district level. Comparison of the results for the two scenarios leads to an initial forecast of eventual deficiencies or a potential overhang of infrastructure as opposed in temporal change in heat demand. The outcome is matched with an analysis on the availability potential of renewable energy.

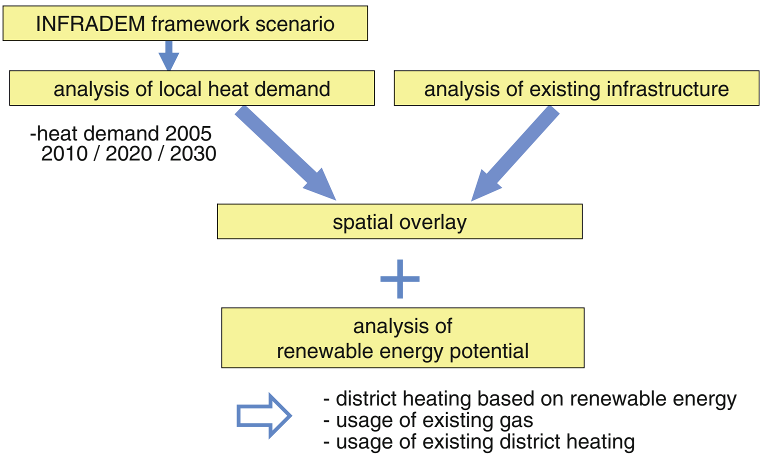

Fig. 8.1 Analysis steps

Based on this comparison possible strategies can be derived in order to appropriately react to the changes. Furthermore, the analysis shall reveals the regions (communities/districts) suitable for developing local heat supply networks based on renewable energy under the aspect of demographic change.

The work already performed within the framework of the German Agency for Environment (UBA) local heat supply project[1] (Fischedick et al., 2006), where local heat supply potential based on renewable energy has been analysed, serves as basis for this analysis. Unlike Fischedick et al. (2006) the present analysis

- focuses geographically on Hamburg and Mecklenburg-Western Pomerania,
- takes into account the temporal development of heat demand (2010, 2020, 2030) dependent on
  - demographic change
  - technological progress with regard to heat demand of buildings
- considers network-based infrastructure (gas supply network, district heating grid)

In the following, the individual steps taken are described in detail. In general, the entire analysis is performed for each of the two variants of the demographic projection in order to emphasise the influence of demographic change.

8.2 Development of Heat Demand

8.2.1 Current Heat Demand – Residential Buildings (2005)

The assumptions derived from the UBA local heat supply project (Fischedick et al., 2006) serve as a basis for the determination of the current heat demand in the housing sector in Germany. A certain heat demand [kWh/(m^{2}a)] is allocated to single- and two-family homes, as well as to small and big apartment houses taking into account the year of construction. Thus, a countrywide average value of the specific heat demand is derived for each construction age group.

The GIS - analysis in the InfraDem - project solely considers the federal states Hamburg and Mecklenburg-Western Pomerania. Thus, in contrast to the countrywide average values, a regional correction factor, taking into account construction features, is required for the heat demand of buildings. For Mecklenburg-Western Pomerania, we choose the correction factor that was applied to the new federal

[1] UFOPLAN-Vorhaben 205 41 104 im Auftrag des Umweltbundesamtes (UBA): Anforderungen an Nah- und Fernwärmenetze sowie Strategien für Marktakteure in Hinblick auf die Erreichung der Klimaschutzziele der Bundesregierung bis zum Jahr 2020. Forschungspartner: Wuppertal Institut für Klima, Umwelt, Energie GmbH; DLR-Institut für Technische Thermodynamik, Stuttgart; Institut für Energetik und Umwelt, Leipzig.

states in the UBA - project. This amounts to a 1.15-fold increase in the average countrywide heat demand [kWh/(m^2a)] (Fischedick et al., 2006).

For Hamburg, there is no correction factor available from the UBA local heat supply project. The heat demand for Hamburg was therefore calculated on a regional basis by means of the Heat Report for Hamburg (Heizspiegel, 2005b). Heat reports have already been issued in various communities for several years in order to allow the citizens compare heat cost and heat demand. In the heat report for Hamburg, a ranking of four classes is allocated to the heat demand per square metre of living space: optimal, average, above average, and extremely high. Thus, the heat report for Hamburg gives an overview of the conditions of residential buildings in the city in terms of their heating systems. Hamburg was found to have a higher heat demand in residential buildings than Germany as a whole (Heizspiegel, 2005a). Based on this, a correction factor of 1.14 to 1.17 was calculated for single- and two-family homes as well as for small and big apartment houses.

8.2.2 Extrapolation of Heat Demand Until 2030 – Building Stock

For the scenario applied here, the specific heat demand of existing residential buildings was extrapolated according to the age of groups of building from 2005 to 2030. The extrapolation is based on the assumption of the energetic restoration of residential buildings according to EWI/Prognos (2005). The frequency of the energetic restoration as well as the effectiveness of the restoration depend on the age of the building, and are differentiated by one-family/two-family homes and apartment houses. The values assumed for a respective building were aggregated and transferred to the relevant construction age class.

From the energetic restoration effectiveness, a respective new specific heat demand was derived for the energetically renovated living space within a construction age class for the year 2030 (and the interim points 2010 and 2020). The heat demand was weighted by means of the frequency of restoration, and a new average heat demand per square metre of living space was calculated for each construction age class at every respective point in time. For both regions analysed, the regional correction factor (1.14 to 1.17) was kept constant during the entire period of analysis.

8.2.3 Specific Heat Demand of New Residential Buildings Until 2030

For future residential construction a similar procedure was applied. Initially, the building to be constructed was allocated to three new construction - age classes: 2010, 2020 and 2030. A distinction was drawn between one- and two-family homes and small as well as big apartment buildings as was done for the construction - age classes of building stock. For each construction age class, individual average heat demand values were assumed for the newly built living space based on the AGFW main study (AGFW, 2010). These values drop until 2030. As to the further development of the heat demand of the construction age classes until 2010 and 2020, the restoration effectiveness and frequency were assumed according to EWI/Prognos (EWI/Prognos, 2005).

Table 8.1 exemplarily shows the values derived for the heat demand of residential buildings such as one-to-two-family homes. Remarkable is the high heat demand (345 and 342 kWh/(m^2a), respectively) in the period 1946–1960 (post-war period), which is due to the construction material used (building rubble) and insufficient thermal insulation. The heat demand of new buildings is constantly decreasing. For all buildings constructed prior to the year 2006, a decrease in heat demand is assumed for the decades 2010, 2020 and 2030 due to restoration measures. These measures are not applied to new houses built after 2006, as they will not be renovated within the time frame monitored. Thus, their heat demand will remain constant until 2030.

8.2.4 Determination of Residential Building Construction Until 2030

In addition to information on the development of the specific heat demand of residential buildings, data on newly built living space were required for the regional GIS analysis. This reveals the total heat demand, which is relevant for the extension of the heat supply infrastructure. The main data source for the construction of residential buildings in both federal states analysed, namely Hamburg and Mecklenburg-Western Pomerania, is the current spatial planning prognosis of the Federal Office for Building and Regional Planning (BBR, 2006). This is a detailed prognosis of all housing units built annually on a district level taking into account a given demographic projection until 2020. Within InfraDem, these construction projections were cumulated for the period up to 2010 and 2020.

The decay of existing old homes was also considered. According to BBR (2006), it amounts to 0.2% per year in the old federal states and 0.4% in the new federal states. These homes have to be replaced by construction of new ones, if required.

Since the detailed projection of construction activity on a district level by BBR (2006) ends in 2020, the projection is continued on the basis of basic trends. Initially, the average construction rate of homes/housing units per person between 2010 and 2020 was also kept for the decade 2020–2030. Likewise, the portion of newly built apartments in apartment buildings continued on the level of the decade 2020–2030.

Although the population projections of BBR on a district level end in the year 2020, the projection is continued on a federal state level until 2050. Therefore, the demographic development from 2020 to 2030 is equally spread across all districts. In each district, the same yearly change is thus assumed as that for the whole country. This leads to a cumulated construction rate for housing units for 2020–2030 according to BBR.

For InfraDem, these construction projections still have to be adjusted to the respective demographic projections of the Rostock Centre. From the comparison

Table 8.1 Heat demand (room temperature and warm water) [kWh/(m^2a)] exemplified by a one-to-two-family home taking into account the age of the building, restoration measures taken and the federal state

Heat demand one-to-two-family homes [kWh/(m^2a)]											
	Existing								New		
	<1900	1900–1945	1946–1960	1961–1970	1971–1980	1981–1985	1986–1995	1996–2000	2001–2005	2006–2010	2011–2020	2011–2030
HH 2005	253	240	345	184	169	137	81	81	81	–	–	–
2010	249	236	339	181	166	136	80	80	81	65	–	–
2020	240	228	327	174	160	131	79	80	80	65	55	–
2030	230	219	314	167	154	126	76	77	79	65	55	45
MV 2005	251	238	342	182	168	136	80	80	80	–	–	–
2010	247	234	336	179	165	135	80	80	80	65	–	–
2020	238	226	324	173	159	130	79	79	79	65	55	–
2030	228	217	311	166	152	125	76	76	79	65	55	45

Table 8.2 Calculation: space per housing unit

Space per housing unit (m^2/WE)				
State	Type of house	2006–2010	2011–2020	2021–2030
Hamburg	Newly built big apartment buildings	74	69	52
Hamburg	Newly built 1–2 family home	104	155	169
Mecklenburg-Western Pomerania	Newly built big apartment buildings	70	69	56
Mecklenburg-Western Pomerania	Newly built 1–2 family home	115	119	116

of the demographic projections according to BBR and the demographic scenarios in the InfraDem project for the federal states considering both demographic variants, a federal state specific correction factor was derived. This was multiplied by the construction rate of housing units as calculated previously. This leads to two construction - scenarios under consideration of the respective demographic development.

For the conversion of newly built housing units into additionally built living space, the average space of housing units according to BBR (2006) respectively the value to be continued until 2030 has been calculated and adopted (see Table 8.2).

These values show good agreement with the average space of a housing unit, given in the AGFW main study (AGFW, 2004) for one- and two-family homes (125 m^2/housing unit) and apartment houses (70 m^2/housing unit).

For the conversion of newly built housing units into newly built houses, the assumptions of the UBA local heat supply systems project (Fischedick et al., 2006) were applied. These are 1.3 housing units per one-to-two-family homes and 4.3 housing units in small apartment houses. The construction of big apartment buildings was not considered and neither was their reduction. The construction activity rate in each district is spread proportionally across the total number of existing buildings in each district.

8.2.5 Heat Demand of Industrial Buildings

The development of industrial building stock and its heat demand was not analysed. The respective values for the year 2005 applied in this analysis were taken from Fischedick et al. (2006) and were kept constant.

8.2.6 Determination of Heat Demand per Community

Analogue to the work of Fischedick et al. (2006) the heat demand was determined per community. Information on the residential structure based on land use data base LaND25 (Infoterra, 2002) and number of buildings in each commune based on data

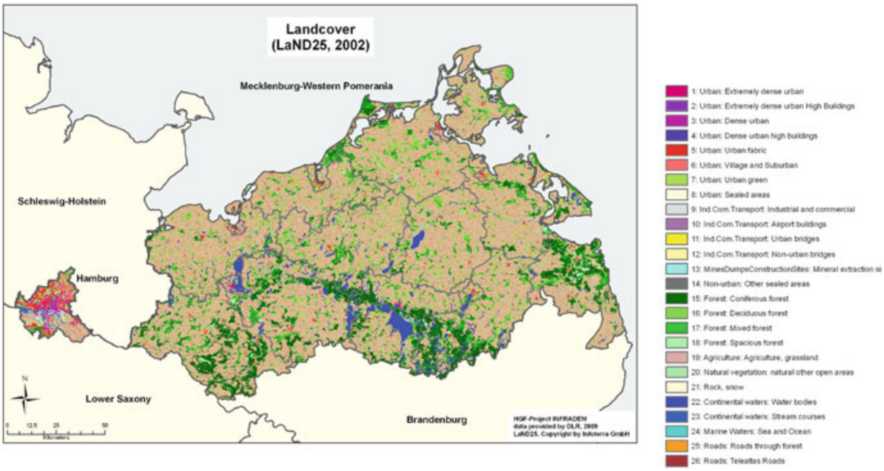

Fig. 8.2 Land use data set LaND25 (© Copyright Infoterra GmbH)

provided by the company infas-Geodaten for the base year 2005 as well as the new buildings derived from the demographic projections for the years 2010, 2020 and 2030, serves as analysis basis.

Figure 8.2 shows the land use dataset LaND25 for the federal states Hamburg and Mecklenburg-Western Pomerania in a spatial resolution of 25×25 m^2. By means of this dataset, the space of various residential densities can be calculated for each commune (e.g. very high building density of cities, medium building density or rural/suburban areas). Combined with the 2005 building stock, the heat demand and density of heat can be determined.

In order to be able to locally allocate the spreading of new buildings for the years 2010, 2020 and 2030, the demographic projection for the districts was broken down to the individual communities. The community-oriented assignment of the population was based on the proportional population per community as of 31 December, 2005 (destatis, 2009). Figure 8.3 shows the population decrease/increase

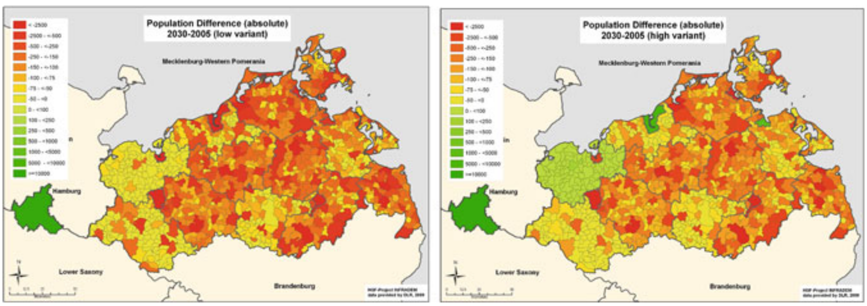

Fig. 8.3 Gap between the absolute number of population for 2030 and 2005 (on the *left* side low variant, on the *right* side high variant, *red* = decrease, *green* = increase of population)

according to the demographic projection applied. Basically, Hamburg shows a positive demographic development – for the low as well as the high variant. The district Nordwestmecklenburg and the cities Rostock and Greifswald show a positive demographic development only for the high variant. For the other districts, a decrease in relation to the districts of Mecklenburg-Western Pomerania can be seen.

Combined with information on the number of buildings per residential unit and that on the specific heat demand per house, the total heat demand for each district can be calculated. Based on the demographic projection and the construction activity, combined with the potential specific heat demand per house, the potential total heat demand can also be calculated.

Table 8.3 gives an overview of the total heat demand of Mecklenburg-Western Pomerania and Hamburg in the decades selected for the two variants of the demographic projection.

In the high variant, the heat demand of Hamburg (HH) increases by 3.3% by 2030 (basis year 2005). In the low variant, the heat demand decreases by 2.9% after a prior increase. In Mecklenburg-Western Pomerania (MV), the heat demand decreases by 7.6% or 9.0% for the low and high variant, respectively.

Since this study focuses on the change in heat demand in relation to time, we analysed the change in the total heat demand for the year 2030 as opposed to the demand in 2005. Figure 8.4 displays this relation for the high variant of the demographic projection. Districts marked green show an increasing total heat demand, while those marked red exhibit a decreasing heat demand. Districts marked blue show an almost constant total heat demand. Only Hamburg shows an increase in heat demand in the time span 2005–2030. The heat demand of all districts in Mecklenburg-Western Pomerania stagnates or decreases.

Figure 8.5 displays the same situation for the low variant of the demographic projection. For Hamburg, the change in colour (from light green to light red) is obvious. Here, for the low variant, the heat demand decreases until 2030. For the communes in Mecklenburg-Western Pomerania, a decrease in the blue-coloured districts can

Table 8.3 Change in the total heat demand (absolute and percentage, basis year 2005) per federal state per decade

Change in heat demand (GWh/a)					
State	Year	High variant	Gap to 2005(%)	Low variant	Gap to 2005(%)
HH	2005	15, 810	–	15, 810	–
	2010	16, 247	2.8	16, 173	2.3
	2020	16, 458	4.1	16, 028	1.4
	2030	16, 325	3.3	15, 349	–2.9
MV	2005	12, 955	–	12, 955	–
	2010	13, 149	1.5	13, 138	1.4
	2020	12, 550	–3.1	12, 470	–3.7
	2030	11, 964	–7.6	11, 794	–9.0

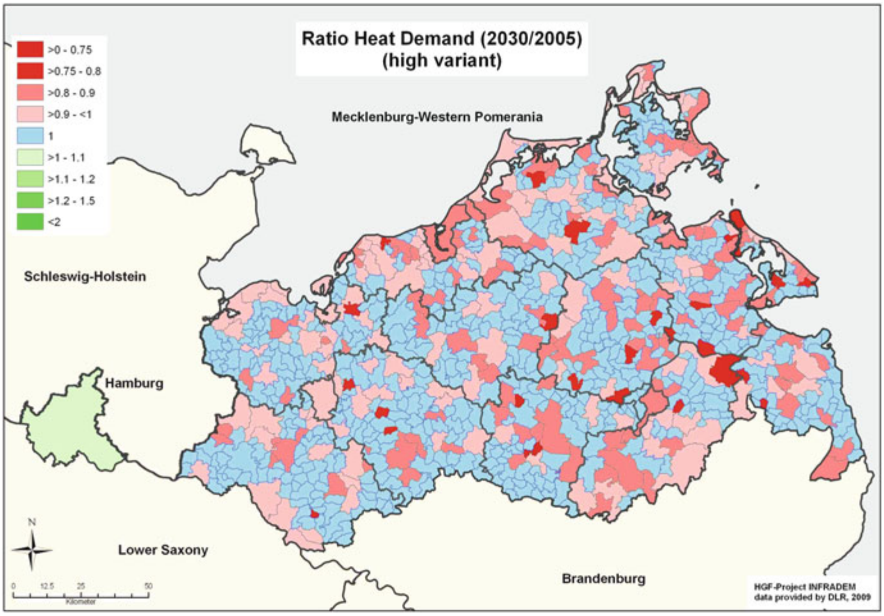

Fig. 8.4 Ratio of the total heat demand 2030/2005 (high variant of the demographic calculation)

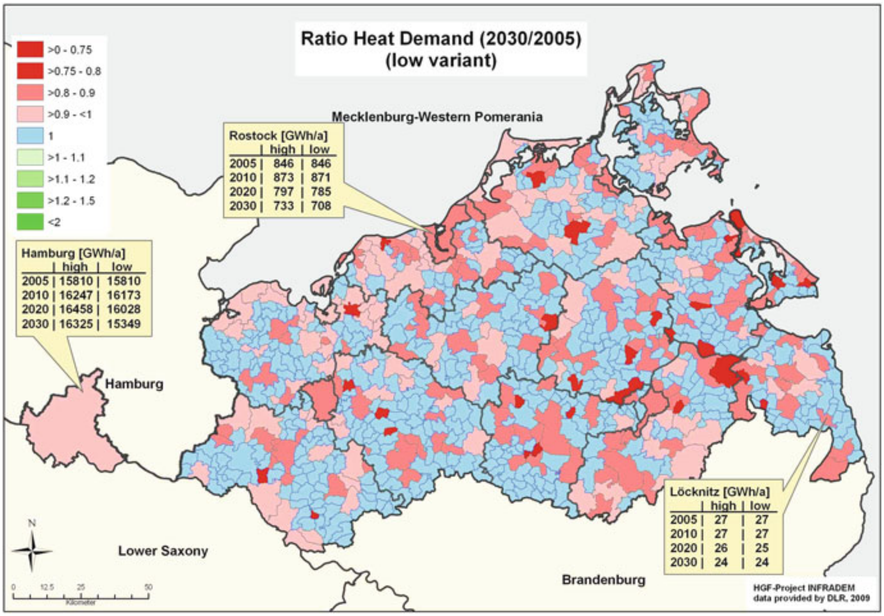

Fig. 8.5 Ratio of the total heat demand 2030/2005 (low variant of the demographic calculation)

Table 8.4 Ratio of the heat demand of the individual communes 2030/2005 (for the high and low variants)

Heat demand ratio 2030/2005		Number of communes	
Range		High variant	Low variant
>0 – 0.75	(red)	18	19
>0.75 – 0.8	(red)	11	13
>0.8 – 0.9	(light red)	122	151
>0.9 – <1	(pink)	135	132
= 1	(blue)	587	559
>1 – 1.1	(pale green)	1	0
>1.1 – 1.2	(light green)	0	0
>1.2 – 1.5	(green)	0	0
<2	(green)	0	0
	Sum	**874**	**874**

be seen. The communities previously showing a stagnating heat demand until 2030 now show a decreasing heat demand. Thus, an increase in the red-coloured districts becomes obvious.

This change in the heat demand due to different assumptions with respect to the population is displayed in Table 8.4 by the absolute number of districts. The decrease in the number of districts from 587 to 559 (high to low) is highlighted by the value 1 (blue) and the increase is represented by the values <0.9 (red). Hamburg is the only state that shows commune showing the value >1 for the high variant and, the value < 1 for the low variant.

8.3 Infrastructure Stock

The analysis of the network-bound infrastructure stock focuses on the available heat supply networks and the gas supply network stock. The outcome with regard to the heat supply networks is based on the evaluations of Fischedick et al. (2006). In Fischedick et al. (2006) the problem of the data source used (AGFW, 2005) is discussed, namely the exact location of the available district heating network is not safeguarded.

The data basis for the gas supply network analysis is a map of the German gas supply network (VGE, 2006), which has been updated for the purpose of the GIS-analysis. This map shows the main gas pipelines, however it does not give any information on the gas distributor network (gas pipes connected to houses). Thus,

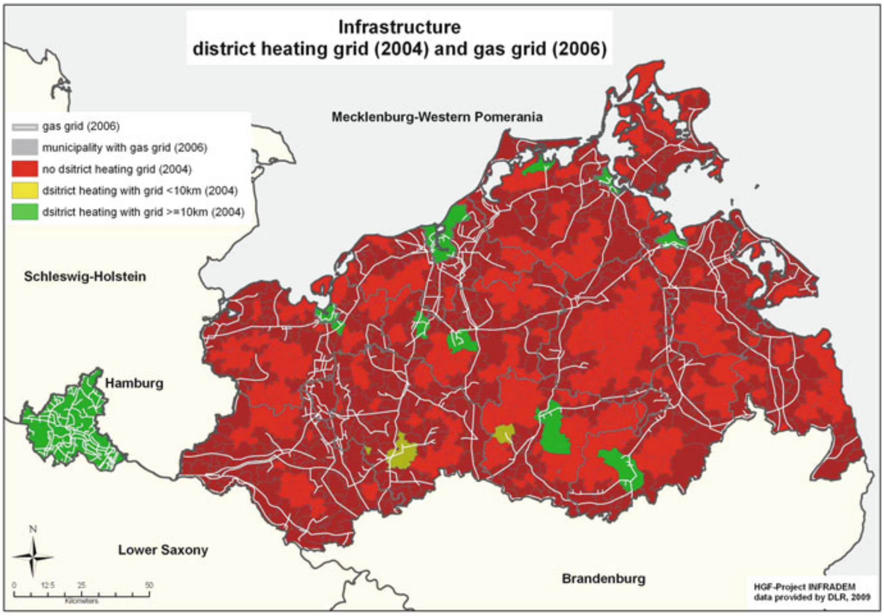

Fig. 8.6 Network-bound Infrastructure (Sources: gas supply network: VGE (2006); heat supply network: Fischedick et al. (2006))

based on these maps, no assured statement can be made on the absence of a gas supply network in a district.

Both data sets (heat supply networks and gas supply networks) are spatially inferred and lead to an outcome map, which is shown in Fig. 8.6. Hamburg's infrastructure is excellent due to the available heat supply network and a dense gas supply network. The rural districts in Mecklenburg-Western Pomerania have a heat supply network according to AGFW (marked in green or yellow). All of these districts also have a gas supply network (marked in grey with white lines).

The districts marked in red lacking a heat and gas supply network are districts in which the population is decreasing and are thus certainly not in line for future connection to a gas supply network.

8.4 Supply Potential (Renewable Energy Potential)

8.4.1 Geothermics

The Geothermics Report 98-1 of GFZ Potsdam (Kayser & Kaltschmitt, 1988) serves as basis for the information here on geothermics. A map illustrates regions that might have a hydrothermal energy potential. In order to use the map for our GIS

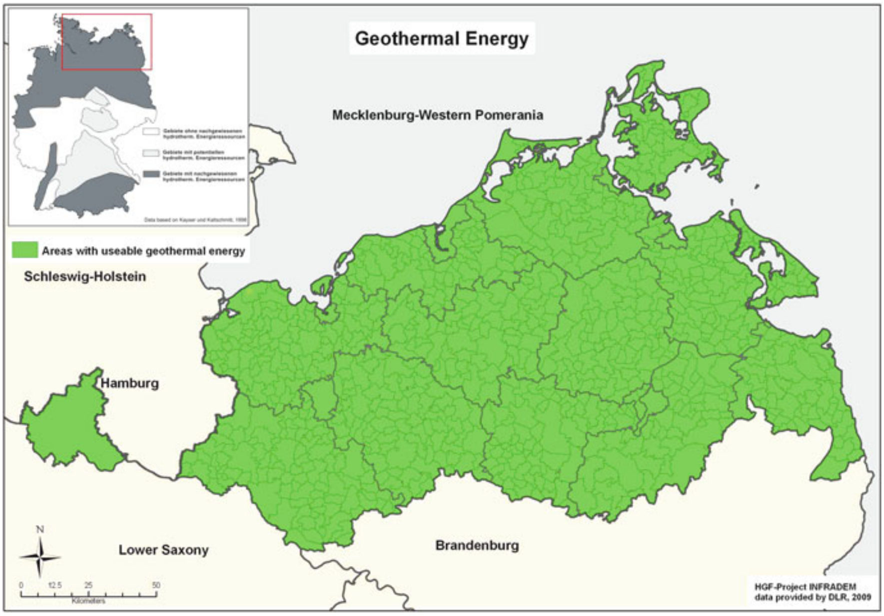

Fig. 8.7 Regions with confirmed hydrothermal energy sources (Source: Kayser & Kaltschmitt, 1998)

analysis, it was digitised and geo-referenced. Every commune was then assigned according to the specified hydrothermal potential. The target regions Hamburg and Mecklenburg-Western Pomerania cover an entire area with confirmed hydrothermal energy sources. Figure 8.7 shows the original map (small map of Germany) and the respective information on the target regions.

8.4.2 Solar Heat

Satellite-based calculations of radiation performed by DLR provide the data basis for our analysis of the solar heat potential. The annual sum of the global horizontal irradiation (GHI) in the year 2004 is used as an evaluation parameter. According to the analysis of hydrothermal energy sources, the annual total global radiation is determined for each district. Figure 8.8 displays the solar radiation for the target regions.

Basically, Germany as opposed to southern countries like Spain is less qualified for the use of solar heat. However, the available potential is easily usable everywhere within the region analysed because global radiation changes only slightly.

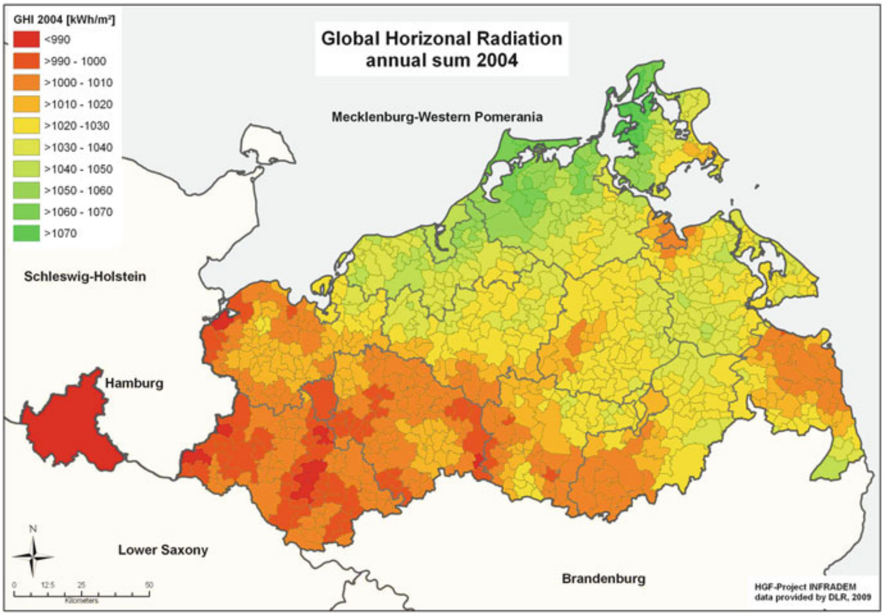

Fig. 8.8 Irradiation conditions for the year 2004 (total annual global radiation [kWh/m^2]) (Source: DLR)

8.4.3 Biomass

The energetic potential of wood, straw and biogas (liquid manure) indicated in the study "Ecologically optimised extension of renewable energy use" (Nitsch et al., 2004), as well as the correlating official data (StJB, 2009) on forest, agricultural and permanent green space, provide the basis for this study.

In order to calculate the spatial spread, the information on the space per commune contained in the data set LaND25 was applied. Since this data set only contains the classes "forest" and "agricultural space", the agricultural space was grouped into fields and permanent green space in order to adjust the spread to the statistical yearbook. The proportion of fields and green space in the individual federal states indicated in the statistical yearbook was applied and transferred to the individual communes indicated in the LaND25 data set.

In order to achieve a higher validity with regard to the regional usability of biomass, the determined potential was compared to the heat demand. This reveals which community holds a sufficient theoretical biomass potential to cover its own demand. Figure 8.9 shows the outcome of this analysis. The communities marked in dark red have less biomass than they require for their heat supply. These communities are mainly bigger towns.

The communities marked in green theoretically hold enough biomass to cover their own (mostly low) future heat demand many times over.

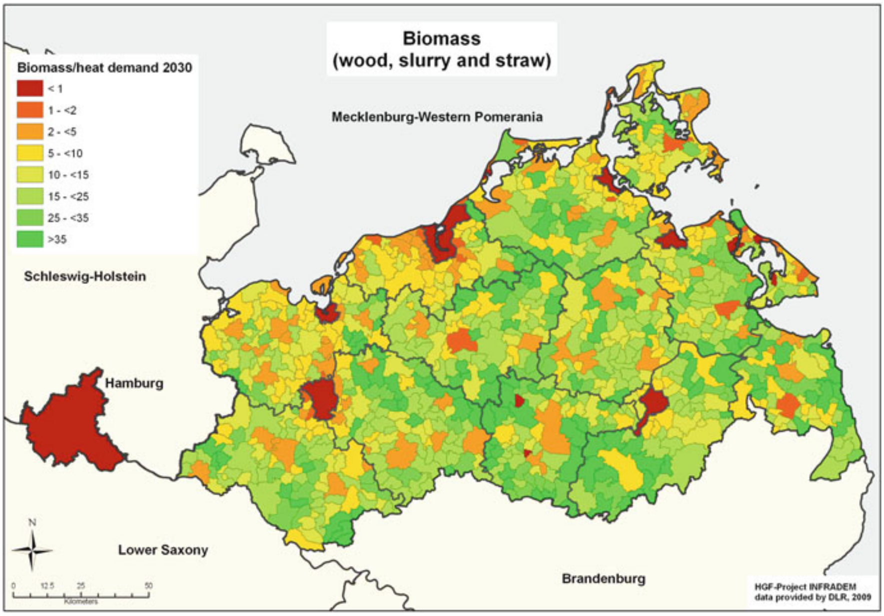

Fig. 8.9 Ratio of biomass potential to the heat demand per commune (biomass/heat demand)

8.5 Spatial Analysis and Conclusion

By means of a spatial interference of the basis data, initial statements on the local heat potential based on renewable energy can be made. Here, spatial interference means an overlay of the spatial information on heat demand, infrastructure and the renewable energy potential. Since this information is available for each district, spatially differentiated analyses can be performed by means of a geo-information system.

Analyses were performed by means of the diverse selection of criteria, which indicate the appropriate districts in terms of potential for a new or extension of an existing local heat supply network based on renewable energy.

The following criteria were applied:

The development of the heat demand is given by the ratio [heat demand 2030/heat demand 2005]. The availability of renewable energies (REG) with respect to the heat demand is given by the ratio [REG potential/heat demand 2030]. The availability of a gas supply network and existing heat supply networks are taken into account.

As to the renewable energy potential, biomass is decisive, since the geothermic potential is theoretically equally available in all districts, and global radiation for the use of solar heat only varies slightly between regions.

Analyses 1+2: potentially qualified municipalities for a new local heat supply network based on renewable energy

Criteria analysis 1: REG/heat demand 2030 >= 5
Gas supply network = 0 (not available)
Heat 2030/Heat 2005 >= 1

This analysis identifies 261 municipalities out of 874.

Criteria analysis 2: REG/heat demand 2030 >= 5
Heat 2030/heat 2005 >= 1

This analysis identifies 569 municipalities out of 874.

The only difference between analysis 1 and analysis 2 is the consideration of an existing gas supply network. Analysis 1 considers only those districts without a gas supply network. In analysis 2, the availability of a gas supply network is irrelevant for the installation of a new local heat supply network. Figures 8.10 and 8.11 show the municipalities selected for both analyses.

Analysis 3: Potentially qualified municipalities for the extension of an existing district heat supply network based on renewable energy

Criteria analysis 3: REG/heat demand 2030 >= 2
Heat supply network is available

This analysis identifies 7 municipalities out of 874.

Figure 8.12 shows the municipalities selected according to analysis 3.

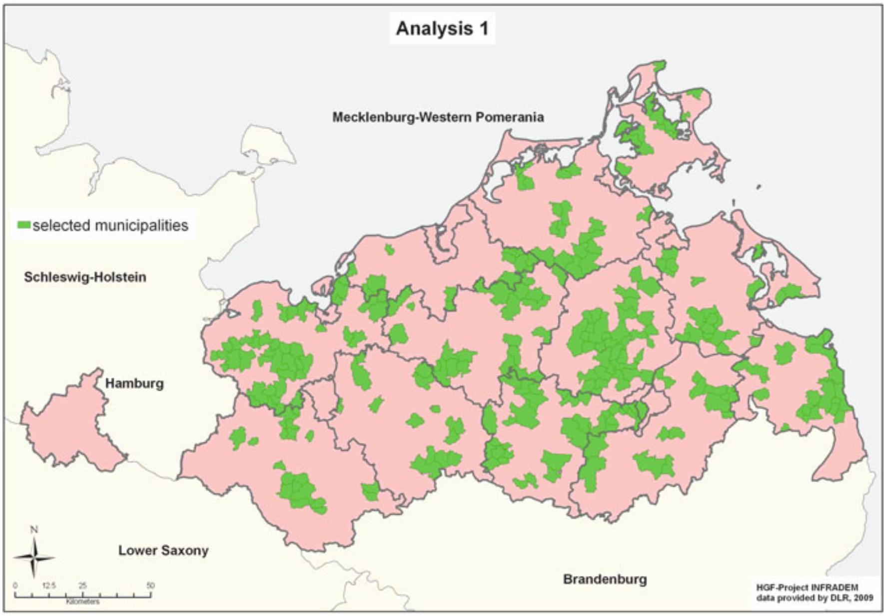

Fig. 8.10 Analysis 1: municipalities potentially qualified for the installation of a local heat supply network based on renewable energy

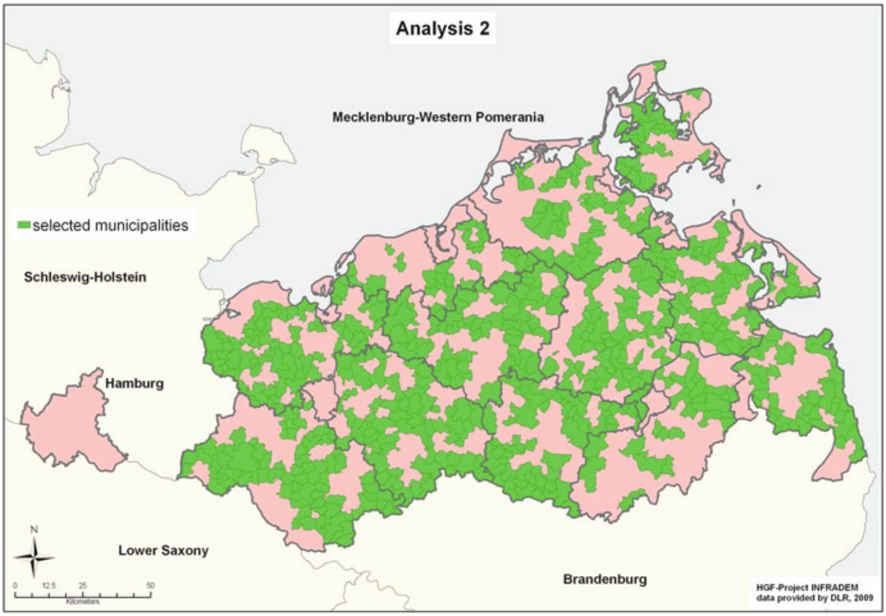

Fig. 8.11 Analysis 2: municipalities potentially qualified for the installation of a local heat supply network based on renewable energy, not taking into account the gas supply infrastructure

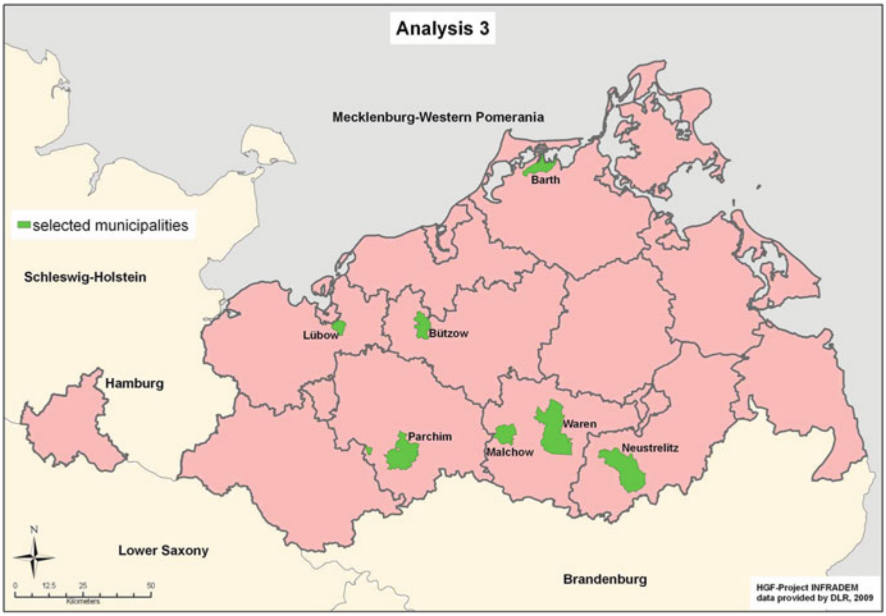

Fig. 8.12 Analysis 3: municipalities potentially qualified for the extension of an already existing local heat network based on renewable energy

The following conclusions are derived from several analyses based on data on the development of the heat demand, the heat supply infrastructure and the potential of renewable energy:

- In all communities, a general decrease in heat demand was observed, apart from Hamburg for the high variant of demographic development.
- Decreasing heat demand is generally a critical precondition for a network–bound heat supply infrastructure.
- The extension of the gas-based infrastructure as well as the potential installation of EE-based local heat supply networks must be thoroughly assessed on site.
- Communities with a high heat density (heat demand/ha) are more qualified for district heating systems than communities with a low heat density. This data on heat density should be analysed by means of an appropriate procedure.
- In general, rural communes have a high potential for the use of renewable energy.
- The extension of the existing heat supply network based on renewable energy only makes sense where a high potential of renewable energy is available.

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Part III
Households and Lifestyles

Chapter 9
Mobility of the Elderly – Facts and Projections

Anne Klein-Hitpaß and Barbara Lenz

Abstract Over the last few decades, the number of elderly people in western European and other industrialised countries has been increasing. These demographic processes will continue. The growing share of elderly people in the population will lead to new challenges for ageing societies, particularly when the baby-boom generation retire. As a result, elderly people have become a focal point of interest in politics and science, and consequently in transport research. The purpose of this paper is to provide a comprehensive overview of empirical findings on the mobility behaviour of seniors – today, in the past and in the future – followed by a simulation of the future transport demand of seniors, taking into account their changing motorisation rates and travel behaviour. The article is divided in two main parts. The first part provides a systematic overview of existing empirical findings and outlines expected effects in the near future derived from these findings. In the second part, we estimate the future travel demand using the TAPAS simulation model (travel activity pattern simulation). This microscopic model allows us to see how the overall travel demand will change, particularly due to demographic change – in response to altered population structures on the one hand and altered levels of motorisation or modified behaviour in the group of elderly people on the other. The results allow us to separate the demographic effects from the effects caused by increasing motorisation and changing behaviour.

Keywords Demographic change · Mobility · Travel demand · Cohort effect · Traffic safety

9.1 Introduction

The German population is an ageing and at the same time a shrinking population which also changes in terms of spatial distribution across the national territory.

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In 2005, 19.3% of the German population was 65 years of age or older. In the two projections of the Rostock Demographic Centre, this share will rise to 27.4% (high version) or 28.2%, respectively (low version) until 2030 with wide regional disparities (see Chapter 2). The absolute and relative growing number of elderly people and the imminent retirement of the so-called baby-boom generation – people born in the late 1950s and 1960s – will lead to challenges not only in the economy, health care and the social systems, but also in the demand for transportation and infrastructure. Seniors are the only growing age group in the future. The traffic situation will therefore be determined more and more by the elderly. They will lead more active and mobile life styles with an increasing number of driving licences and car ownership in combination with more kilometres travelled than senior generations before them. However, even if the mobility/travel demand of the elderly increases, this age group still has different (travel) behaviour than other age groups (Beckmann, Holz-Rau, Rindsfüser, & Scheiner, 2005; Rosenbloom, 2001).

Policy makers and spatial/transport planners should take into account that these active and mobile seniors are likely to have significant challenging impacts on transport demand. For appropriate transportation policies and policies for regional development, it is necessary to be familiar with the current developments as well as developments in the past. This also allows us to better assess potential paths of future development.

This article aims to enhance our understanding of the changing behaviour of seniors and to discuss possible future developments. It is divided into two main parts. In the first section, we will briefly describe demographic trends with regard to the ageing processes in Germany and in both model regions (Mecklenburg-Western Pomerania and Hamburg) and we will define "elderly". We will explain the consequences of ageing on transportation demand and describe the seniors' travel behaviour in terms of trip purpose or mode choice and – compared to other groups – in terms of their different needs. In addition, we will describe how this behaviour has changed over the last years and what assumptions can be made for the future.

After the systematic review of empirical research findings, we will derive relevant assumptions on the future mobility of elderly people in the second section and use them as input variables for our microscopic demand model TAPAS (for a comprehensive explanation of the model, see Chapter 5). We will discuss our simulation results on the future travel demand of the elderly. In order to be able to conduct a differentiated analysis of the effects leading to a change in travel demand we will separate the "quantitative" demographic effect, which is an increased proportion of the elderly in the total population, from the "qualitative" effects of increasing motorisation and behavioural change.

9.2 Demographic Change and Mobility Behaviour of Elderly People

As is the case in most European countries, Germany is experiencing a rapidly growing elderly population. The demographic development and its impact on transport demand have been the focus of many investigations and comprehensive studies (e.g. Wissenschaftlicher Beirat des BMVBW, 2004; Holz-Rau and Scheiner, 2004; Scheiner 2006), some of which can also be found in this book (e.g. Chapter 2, Chapter 4, Chapter 5, Chapter 6). Demographic impacts on passenger transport demand are not only the result of a numerical alteration in population and new patterns of internal migration but also the result of changing lifestyles and the demographic aspect of ageing, including the different needs and behaviour of seniors. The latter two aspects are the focus of the following section.

Looking at the travel behaviour of seniors revealed the following: In Germany, the share of elderly people will increase to nearly one third of the population by 2030. At the same time, the regional distribution of the proportion of elderly people with respect to the overall population will become quite irregular. The expected developments in Hamburg and Mecklenburg-Western Pomerania will highlight this.

Today, the share of elderly people (aged 65 and older) in Hamburg is about 18%. As Hamburg is a growing city with a prosperous economy that benefits from immigration, it will most probably be less affected by the ageing of its population than other regions in Germany and especially Mecklenburg-Western Pomerania. The predicted share of elderly people in 2030 is only 20% in the low scenario and even less (only 18%) in the high scenario (for more details, see Chapter 2). A closer look at the different age groups shows varying developments within the group of elderly people. While the share of people aged 65–74 will increase by 6.6% (high scenario) or 4.4% (low scenario) until 2030, the percentage of seniors aged 75 or older will rise by 45.5% (high scenario) or 42.8% (low scenario) with wide gender differences – the increase in the number of elderly men is approximately three times higher than the increase in elderly women.

The share of older age groups in the labour force in Hamburg will significantly increase, rising by about 30% from 2005 to 2030, i.e. from 30.9 to 43.5%. This development may also be expressed by the so-called old-age dependency ratio which indicates the number of people aged 65 and older per 100 people aged between 20 and 64. In the year 2030, this rate will be 32.7% in the high scenario or 36.7% in the low scenario for Hamburg. Today, it is 29%.

With respect to the overall development in the city, this means that – according to the "high" scenario – the population in Hamburg will grow in almost all parts of the city. It will only decrease in some areas of the inner city, but this will be overcompensated by increases in all other districts in the city (Fig. 9.1).

In the low scenario, or put in other words, in the less optimistic scenario, Hamburg will shrink in most areas except for some districts situated in the peripheral parts of the city. The population decrease in the inner city will be dramatic in some areas (Fig. 9.2).

The projections for Mecklenburg-Western Pomerania are very different. Both projections – the high and low scenarios – predict an increasing share of the elderly, reaching more than one third of the regional population (approx. 34% in both projections) with wide regional disparities.

This means that the elderly population in Mecklenburg-Western Pomerania will almost double, with important differences regarding the age groups. The share of

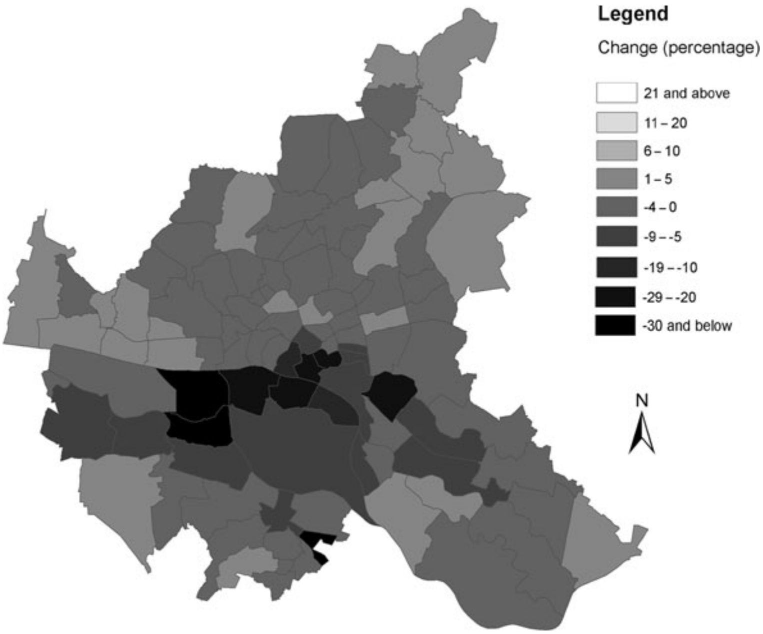

Fig. 9.1 "High scenario" for population development in Hamburg 2005–2030 (source: Rostock center for the study of demographic change)

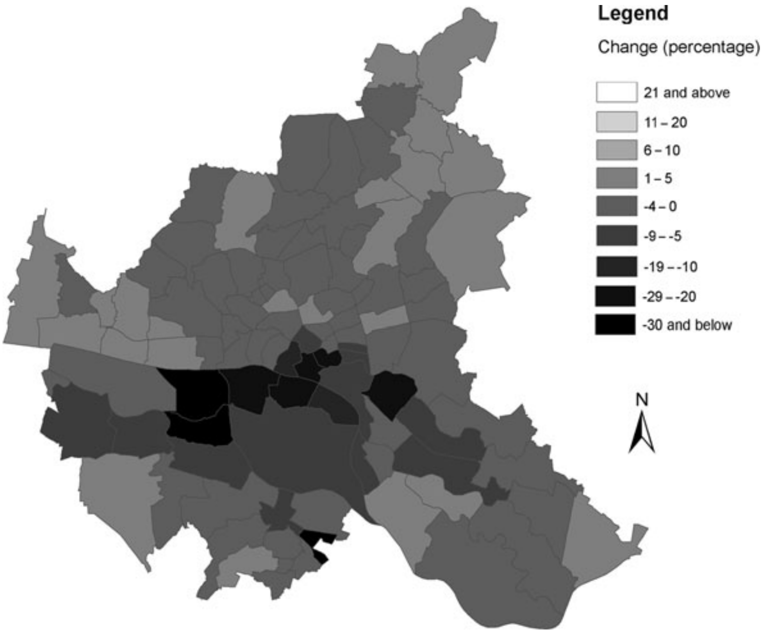

Fig. 9.2 "Low scenario" for population development in Hamburg 2005–2030 (source: Rostock center for the study of demographic change)

seniors aged 65–74 will rise by about 18% (high scenario) or 16% (low scenario), but for the older aged 75+, the share will rise by over 100% in both scnarios.

The old-age dependency ratio will develop correspondingly. In 2030, 66.5% (high scenario) or 68.8% (low scenario) of people aged 65+ are predicted per 100 people aged between 20 and 64 (data from the Rostock Demographic Centre, Kühntopf & Tivig, 2007).

Overall, this means that even given the optimistic setting, extensive areas of Mecklenburg-Western Pomerania will shrink considerably. An increase in population will dominate the regional development in the western areas (Fig. 9.3).

The picture that results from the low scenario does not completely differ from the high one, but areas of increasing population development become very small and infrequent, and are to be found almost solely around the city of Rostock (Fig. 9.4).

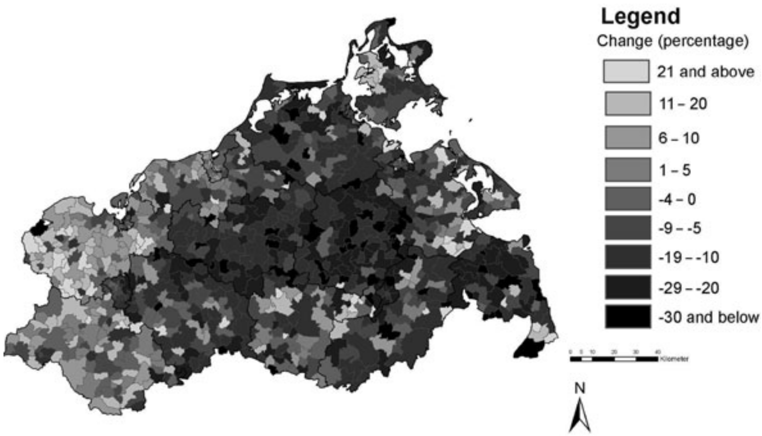

Fig. 9.3 "High scenario" for population development in Mecklenburg-Western Pomerania 2005 to 2030 (source: Rostock center for the study of demographic change)

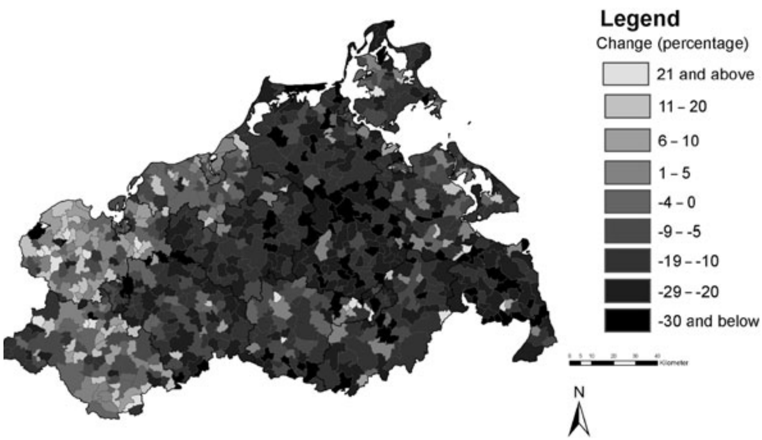

Fig. 9.4 "Low scenario" for population development in Mecklenburg-Western Pomerania 2005 to 2030 (source: Rostock center for the study of demographic change)

Hence, it becomes clear that elderly people will play a particularly important role in the future transport demand of Mecklenburg-Western Pomerania. As a thinly populated federal state with this predicted high share of elderly people and the perspective of ongoing shrinkage, Mecklenburg-Western Pomerania will face other and more severe problems than the metropolitan region of Hamburg, which has a dense population and infrastructure, and – in the worst case – will experience stagnating development with respect to the size of its population.

9.2.1 Definition of Elderly

As “old” or “elderly” are interdisciplinary terms, they have no clear definitions. Moreover, the concept of “old” is not based on a fixed point in time but is rather socially constructed. From this viewpoint, a person is usually “old” when they are retired, contrary to the self-perception of seniors who only start feeling old at the age of 75. According to studies carried out in Germany, elderly people feel on average 9.3 years younger than they actually are (GfK Panel Services, 2008; Otten, 2008).

In addition, being old is nothing stable; it is an individual process where the physical and psychological constitution of a person changes, and its course depends on a person’s specific conditions and individual characteristics and abilities. This is why research often breaks down late life into three sub-stages: early old age (65–75), middle old age (75–85) and old age (85+) (Hieber, Mollenkopf, Kloe, & Wahl, 2006; Huber & Baum, 2005; Mollenkopf, Marcellini, Ruopilla, & Tacken, 2004; Staudinger & Schindler, 2002). However, the delimitation of this classification is not exactly defined.

In its “Third Report on Ageing”, the German Federal Ministry for Family distinguishes a third and fourth stage of life (BMFSFJ, 2001). The third stage of life is defined as the early years of retirement, while the fourth stage is defined by life at 80 or 85 years of age and older depending on health and cognitive abilities when physical and mental abilities decrease significantly (BMFSFJ, 2001; Huber & Baum, 2005). The transition from one stage to another is particularly important, as it is the time when individual habits and abilities change and older people start adjusting their behaviour to the changing circumstances (Huber & Baum, 2005; Staudinger & Schindler, 2002). An alternative approach to define “old age” is to assess further life expectancy instead of years already lived, taking into account the remaining life span, which is relevant for participation in society and the decisions made in the older age (Sanderson & Scherbov, 2006).

In Germany, retirement is the “official” beginning of old age. The elderly are considered people aged 65 and older who have already retired. This definition is subject to restrictions: there is a temporal variability of retirement due to early retirement and old-age part-time work. Furthermore, based on normative employment biographies, this definition comprises a gender inequality disregarding women’s situation, which is often characterised by family responsibilities and reproduction work and less characterised by full time employment (Föbker, 2002).

However, for a pragmatic approach, the definition of the elderly as retirees aged 65 and above will be used here.

In the following, we will focus on the mobility of elderly people today and as we have seen it developing in recent years. Our central questions will be: What are the specific mobility patterns of elderly people? What factors have the most relevant influence on their mobility? How do elderly people travel and what means of transport do they use?

9.2.2 Facts About Seniors' Travel Behaviour

The ageing of societies leads to different needs and to a different transport demand in terms of quantity and quality. Both aspects are important for estimating the future demand: the quantitative aspect in terms of increasing absolute numbers of elderly people and increasing shares in the overall population, and the qualitative aspect in terms of changing lifestyles and behaviours, and also changing household structures.

According to the "Third Report on Ageing", mobility is essential for the quality of life in later years, for maintaining the extent of activity spaces and for living an enjoyable life during old age. With growing age, health restrictions increase and affect an individual's mobility, so that mobility is no longer self evident as it is in younger years (BMFSFJ, 2001). Thus, studies show that the attributed importance of mobility increases in the personal perception of elderly people. Thus, the older the seniors are, the more important mobility is (Blume, Follmer, Kalinowska, & Kloas, 2005).

Mobility is a prerequisite for the maintenance of everyday life – for shopping, leisure and social participation, and thus societal participation and integration. "Being mobile" has a positive connotation and is important for a positive self-perception, an independent lifestyle and for the quality of life (Banister & Bowling, 2004; Zohner, 2000).

Today, elderly people live more active and mobile lives than in the past. The activity spaces of seniors grow due to the increased car availability and use of the car as well as the expressed desire for holiday destinations ever farther away. Individualisation, broader value orientations and a broader spectrum of activities have led to differentiated lifestyles in older age. Seniors have become a very heterogeneous group, not comparable to the former image of the "old and frail".

The section that follows aims to identify seniors' basic mobility patterns and trends, including the increase in driving licences and car ownership, especially among elderly women. Particular attention will be paid to women, as their development with regard to car availability and holding a driving licence deviates from the group of men for both the recent years and in future.

9.2.2.1 Seniors' Mobility Patterns

The most recent data on mobility behaviour across the entire population can be found in the German national travel survey entitled *Mobility in Germany* which was

Table 9.1 Mobility indicators for selected age groups (source: MiD 2008, authors' calculations)

	45–64	65 and older	Total average
Mobility rate (%)	91	81	90
Trips per day	3.6	2.8	3.4
Kilometres travelled per day	44	23	39

Table 9.2 Mobility indicators for older age groups compared to the "younger old"

	50–59 years	60–64 years	65–74 years	75 years and older
Mobility rate (%)	91	89	86	74
Trips per day	3.6	3.5	3.2	2.3
Kilometres travelled per day	44	35	28	16

carried out in 2008 *(MiD* 2008*)*. This survey reveals that the mobility behaviour of elderly people is significantly different to that of younger groups. The most important differences are indicated by the mobility rate (percentage of people moving outside their homes on an "average day"), the number of trips made, and the number of kilometres travelled per person (see Table 9.1).

A more specific differentiation of the overall group of elderly people shows that "younger elderly people" (65–74 years of age) are quite an active and mobile group that is similar to the younger age groups of 60–64 and 50–59 in terms of the number of trips they make every day (Table 9.2). This picture changes when we compare the daily kilometres travelled by these age groups. In this case, there is a considerable difference between younger and older age groups. Whereas the mobility rate of the "younger old" is comparable to people under the age of 65, there is a clear decrease in older age. This is also true for the number of daily trips. Seniors aged between 65 and 74 make 3.2 trips per day in comparison to 3.1 trips made by the 50–59 year olds, and 3.5 trips by people aged 60–64. Regarding the distances, the decline in mobility as people grow older becomes even clearer. Whereas people aged 50–59 travel 44 km on average per day, seniors aged 65–74 travel an average of 28 km, while the "older old" cover an average distance of 16 km.

Shopping and leisure trips are the most prominent trip purposes for elderly people in Germany, followed by trips for private errands. Altogether, these purposes are the motivation for more than 90% of trips made by elderly people. This is true for all individuals over 65 years of age. In 2008, leisure and shopping trips almost completely compensated for the loss of trips to work. Differences in trip purposes between men and women disappear once they have retired.

The mode choice for people 65 and older continues to be characterised by quite heavy car use, even in the age group 75+. The car is used for 51% of trips made by people in the age group 65–74 (39% driver, 12% car passenger). For people aged 75+, this figure is 43% (31% driver, 12% car passenger). The average for these two age groups is 48% car use (36% driver, 12% car passenger). The second most important means of transport for elderly people are their feet: the 65–74 year olds make 32% of their trips on foot; in the age group 75+, this share is 38% (infas & DLR, 2009).

Comparing the recent data to earlier years[1] reveals massive changes in mobility behaviour, in particular for older age groups. During the last few decades, the mobility level (number of trips, kilometres travelled, modal split) of elderly people has constantly risen – as it did for all population groups – but in recent years, the increase was considerably higher for older people than it was for younger ones.

The share of elderly people who did not make a single trip during an average day declined from about 36% in the early 1980s to roughly 21% twenty years later (Dalaker & Luley, 2006) and to 19% in 2008 (see table 9.1). A similar trend concerns the number of trips. For the group aged 65–74, the number of trips increased from 2.8 trips a day in 2002 to 3.2 trips a day in 2008. For the older old, the number of trips a day climbed from 2.0 to 2.3 (infas & DLR, 2009).

At the same time, the length of trips increased significantly, albeit with decreasing growth rates in the most recent years. In 2008 seniors aged 60–64 travel an average of 35 km (2002: 33 km) per day, and those aged 65 to 74 travel an average about 28 km per day, also in 2008 (2002: 26 km). For the older old, aged 75 and over, a slight increase was observed: from 15 km per day (2002) to 16 km (2008) (ibid.).

So far the decline in the total number of trips made every day by elderly people was closely linked to the lack of work-related trips as the main type of mandatory trip. These work-related trips are nowadays compensated by leisure and shopping trips (ibid.). As a consequence, if only non-work trips are considered, then elderly people travel daily distances that are as long as the distances travelled by younger groups. It has also been shown that elderly people aged 65+ make much longer leisure trips because of increased motorisation. This is especially true for today's elderly men; elderly women are still less mobile. Several researchers argue that this gender difference is the result of lower incomes and of cohort socialisation rather than a reduced wish for mobility (Beckmann et al., 2005; Rosenbloom, 2001).

Looking at the transport means used for the trips shows an increasing reliance on the car, in accordance with general information of this age group (infas & DIW, 2003).

A comparison of the mode choice of people older than 60 years of age in 1982 with that of 2002 shows a significant shift to the car (Table 9.3). While in 1982, seniors aged 60 and older made half of their trips on foot and roughly one third by car, this share was reversed by 2002, when only one third still made their trips by foot while over 50% travelled by car. This shift applies to all older age groups. Respondents aged 80 years and more doubled their share of car trips from about 16% in 1982 to roughly 36% in 2002 (Dalaker & Luley, 2006). This development has continued since; figures already cited above have shown that roughly 48% of all

[1] To go further back, a comparison with the *KONTIV survey* 1982 („Kontinuierliche Erhebung zum Verkehrsverhalten") is useful but due to different methodologies it is also limited (Holz-Rau & Scheiner, 2006). To some extent, however, comparisons can be drawn (Beckmann et al., 2005; Dalaker & Luley, 2006).

Table 9.3 Changes in the mode choice of people aged 60 and older (source: Dalaker & Luley, 2006)

	1998				2002			
	Walk	Cycle	PT	Car	Walk	Cycle	PT	Car
60+	48.0	7.5	10.7	32.7	28.3	9.7	6.2	54.8
60–69	42.2	8.8	9.4	38.8	27.1	10.1	5.1	56.7
70–79	54.1	6.6	12.4	25.8	29.9	8.6	7.6	52.3
80+	67.0	1.5	14.3	15.8	38.3	8.7	15.1	35.9

trips made by elderly people were by car in 2008, going hand in hand with a slight decline in the use of public transport (from 9 to 8% for the group aged 65+).

A study commissioned by the German Federal Ministry of Economics showed similar results. Among other things, the study revealed that most retired people believe their car will allow them longer lasting mobility (InnoZ, 2009). Car availability is thus important for "realized mobility", i.e. making trips, but also for the possibility of being mobile, keeping up "mental" mobility or *motility* (Franz, 1984). This also proves that self-determination in older age is an important value (Banister & Bowling, 2004; Hieber et al., 2006).

In the age group 75+, a decline in non-motorised transport was also observed between 2002 and 2008. Older people walk and cycle less and they are less likely to travel as passengers in a car, but are more likely to drive a car. This finding corresponds to other research showing that motorised mobility can compensate for an individual's physical disabilities (Engeln & Schlag, 2003; Hieber et al., 2006). To maintain unassisted lives, the car plays and will continue to play an important role, both for realised mobility and for the possibility of being mobile.

The changes in the observed behaviour of elderly people must be considered against the background of changing framework conditions on the one hand and diversified lifestyles on the other. The following sections will discuss these aspects.

9.2.2.2 Increased Driver Licensing and Car Ownership

The increased mobility of seniors is closely connected with an increase in driver licensing and car ownership.

The share of elderly people who hold a driving licence increased from 42% in the 1980s to 65% in 2002 (Bühler & Nobis, 2007), and continued to rise from 2002 to 2008. Within the total population aged 18+, the share of driving licence holders went up from 83 to 88%. It is remarkable that the share of driving licence holders decreased among the younger age groups (18–39), while it increased among the elderly: in 2002, 73% of all seniors aged 65–74 held a licence compared to 83% in 2008. Rising driving licence availability was also observed for the "older old" aged 75+. People aged 40 to 49 have a driving licence share of 96%. We can therefore conclude that for the next 25 years at least, high shares of licence ownership among the elderly will be normal (infas & DLR, 2009). This development is mainly driven

Table 9.4 Driving licence ownership of different age groups in Hamburg and Mecklenburg-Western Pomerania 2005 and 2030 (figures calculated by extrapolating the share of driving license ownership in 2005 to the year 2030 for the particular cohort)

Age in 2005	Age in 2030	Driving license holdership (%)
35–44	60–69	94
45–59	70–84	89
60–64	85–89	82.3
65–74	90–99	70.8

by the increasing share of female road users who, so far, had lower shares of licence ownership in the older age groups.

The development in the two model regions Hamburg and Mecklenburg-Western Pomerania is very similar to what can be found on the national level (Table 9.4).

The increased number of driving licence holders correlates to growing car availability. This is especially true for seniors' households: the older the seniors are, the higher the increase of car ownership between 2002 and 2008. For the elderly aged 60–64, the share of car owners increased from 88 to 91%, while for the elderly aged 75 years and older, it rose from 51 to 64%. At the same time, it must be kept in mind that there is a strong link between the economic situation of households and the probability of car ownership, particularly in households of elderly people (infas & DIW, 2003; infas & DLR, 2009).

The significant increase in both driving licence and car ownership is caused by the increasing number of women with a driving licence and a car. While the number of men with driving licences and cars has remained more or less stable on a high level for the last few decades, the corresponding number of driving licence and car ownership for women is higher than ever before (Kaiser & Kraus, 2008).

Overall, MiD 2008 showed that the total travel volume of women (in terms of number of trips and average trip length) increased notably with higher rates compared to men. Particularly striking is the growth for women aged 75+; in contrast to this, men of older age reduced mobility in 2008 compared to 2002 (infas & DLR, 2009). However, elderly women still make fewer trips and their trips are shorter on average than those of men of the same age groups (Table 9.5).

Table 9.5 Gender-specific mobility behaviour 2008 of elderly people (source: MiD 2008, authors' calculations)

	Number of trips		Time spent for trips (min)		Total daily trip length (km)	
	Men	Women	Men	Women	Men	Women
65–74	3.5	3	87	75	33	23
>75	2.7	2	69	50	20	12
Average of total population	3.5	3.3	81	76	46	33

It may be assumed that this gender gap in terms of trips and average trip length will be closed or at least diminished progressively by 2030 as more and more women will own a driving licence. However, as we can see in recent studies, the behaviour of men and women is increasingly assimilating – except for the family phase when traditional patterns are still quite strong.

Assimilation also occurs with respect to car ownership. While in 1995, 100 cars out of 1,000 were registered to women, in 2005 the number tripled, and the prediction for 2030 says that 545 cars out of 1,000 will be registered to women (Kaiser & Kraus, 2008; Shell Deutschland, 2004).

However, not only a private car and a driving licence are crucial for the realisation of mobility needs, individual possibilities and constraints such as income, time budgets and individual abilities are also very important.

Today, the economic situation of elderly people in Germany is better than ever, even though there are big differences. About 20% of the population is aged 65 and older, but only 18% of the consumption expenditure is attributed to seniors (BMFSFJ, 2001; Motel-Klingebiel, Tesch-Römer, & Kondratowitz, 2004). The mobility of the elderly therefore very much depends on their income situation. In this context, it has also to be considered that shares within the household budgets of elderly people will most probably be modified in the future as a shift to more expenditure for health care is expected (see below).

Interim conclusion: The paragraphs above have shown the increase in the mobility of older age groups and set this increase in relation to a broader availability of private transport options. At the same time, it was pointed out that although this is an important reason for the increase in mobility, it is not the only one. Other aspects have to be included and considered, such as changes in individual practices, individual framework conditions and constraints, which are mostly embedded in general social changes, such as the increased self-reliance and independence of women, holding a driving licence and owning a car.

Concerning behavioural change, it can be expected that “the next big wave of baby boomers” (Goulias, Blain, Kilgren, Michalowki, & Murakami, 2007) will keep up their usual travel behaviour such as the regular use of the car, but also quite generally lead more active and mobile lifestyles. Today, the overlapping of effects like increasing mobility desires and needs, increased physical health and behavioural cohort effects can already be observed among the elderly population.

In order to determine future expectations, it is therefore also important to assess the behaviour of younger age groups, because it is likely that their mobility patterns as they grow older will be shaped significantly by their current habits and routines. To understand how these patterns are shaped at an early stage, mobility biographies can be helpful, although this approach must be developed further. Data is also required to understand the transfer of behavioural patterns from active to retirement life phases (Beckmann et al., 2005; Lanzendorf, 2002; 2003; Newbold, Bruce, Darren, Spinney, Kanaroglou, & Paez, 2005; Scheiner, 2007).

A particularly important question is whether the mobility of the elderly will still increase and compensate for the expected overall mobility decrease due to the shrinking population. With respect to future demand, there are different trends, which are partially contradictory as the following section will show.

9.2.3 Future Expectations

Accordingly, in 2030 the great majority of seniors will hold a driving licence and many of them will own a car. During their working life, they used their cars as a matter of course in their everyday lives. It can be taken for granted that the depicted trend of growing car availability and licence ownership will continue and that the future elderly will rely ever more on car use. Cars are considered particularly important for the maintenance of independent and unassisted lives.

Compared to this cohort effect, age effects such as driving cessation due to health restrictions are only of minor significance. High car availability is the central determinant of seniors' mobility behaviour and it significantly influences the mode choice. The proportion of elderly people without a car and the typical "captives" of public transport will diminish considerably.

Household income and the economic status of a person are important for mobility. The higher the income, the more mobile seniors are. As mentioned above, the financial situation of seniors in Germany can be considered as good. The average income of retired people is higher than ever. However, a growing share of retired people will draw less income in the future. This will be caused by different aspects such as fragmented careers due to periods of unemployment or longer periods of education. The age cohorts reaching retirement age will be affected by both the adjustment measures of pension payment and dropping state pensions. Growing pensions can be expected only for a minor group of retired people. An increasing gap between higher and lower incomes is expected that will most probably influence the future transport demand. Furthermore, it should be assumed that senior households in 2030 will spend more money on health care, nursing and energy – which may influence the mobility budget (see Chapter 4). Even if the seniors' consumption gains in weight due to the growing share of this age group in the population, this does not necessarily mean that the individual has more purchasing power (BMFSFJ, 2001; Kohli, 2006).

It is not clear so far how the growing share of older single-person households will affect the modal split by increasing car ownership. Car ownership is particularly expensive for small households, and the smaller the household, the higher the share of the household budget for expenditure on the private car.

9.3 Future Trends in Mecklenburg-Western Pomerania and Hamburg

The objective of this section is to describe and interpret the results that were achieved by estimating the future transport demand in the two model regions

Hamburg and Mecklenburg-Western Pomerania using the micro-simulation TAPAS model. We will start by giving a short overview of the general concept of the model. Then, we will outline the data sources which were used to feed the model, and finally we will present the results of the model calculations.

9.3.1 Approach Used to Estimate Future Transport Demand

The calculations were carried out with the TAPAS model developed at the DLR Institute of Transport Research. The objective of this model is to represent in a detailed way the quantity and characteristics of the everyday travel demand of people in a specific region. For this purpose, TAPAS uses an approach that is based on individual activity plans. Activity plans indicate what activities people perform and provide information about the type of locations. This leads to travel demand by assigning specific activity plans to specific types of individuals – students, for instance, have different activity plans compared to housewives. The outcome of the model is the number and length of trips, mode choice and choice of locations in the sense of places where activities are performed.

The selected approach for the estimation of future transport demand allows for separating quantitative effects given by the increasing share of elderly people in the total population from qualitative effects stemming from behavioural change. Both effects are represented in the TAPAS model, as it includes as input information the expected population structure in both model regions (quantitative part) and it takes into account behavioural change based on the findings reported in the previous section. The conceptual steps to produce the link between demographic change and transport infrastructure are comprehensively illustrated in Chapter 5.

TAPAS uses a microscopic approach focusing on individuals. Therefore detailed data on mobility behaviour as well as demographic and socioeconomic data are mandatory.

The basic information about mobility behaviour was generated from the national study “Mobility in Germany” containing information on the everyday travel behaviour of 60,700 people in private households. The second data source was a large national study on time budgets (“Zeitverwendung in Deutschland”) from 2002 with detailed information on the time use and realised activities of about 12,000 people in Germany. In addition to this, data and future projections on the population and households in the model regions Hamburg and Mecklenburg-Western Pomerania were provided by the Rostock Center, and extended by further national statistical data. These data sources delivered differentiated information about households (size, work force, car availability, annual season ticket ownership, etc.), individual activity patterns, time budgets and general characteristics of mobility behaviour. To design the likely behavioural characteristics of elderly people in 2030, they were “rejuvenated” by ten years. This means that the mobility behaviour characteristics assigned to them were those that are typical today for the groups who are ten years younger – in other words, people aged 75 in 2030 behave as if they were 65 today. The rejuvenation takes into account the fact that seniors in 2030 can be expected to be more active and have very mobile lifestyles due to better health and fitness and to a changed self-estimation of feeling younger.

To take all aspects – demographic, household (motorisation) and behavioural aspects – into account, several steps were necessary:

- The demographic developments were predefined by the data submitted by the Rostock Center for the Study of Demographic Change.
- The growing share of driving licences among the elderly was considered by extrapolating today's driving licence ownership of the "middle aged" groups into the future.
- Behavioural aspects such as "feeling younger" and "being more mobile" were taken into account by rejuvenation.

In the following section, the results of the model calculations will be presented. These results are based on the two population forecasts (see above) and will be referred to as the high scenario and low scenario, respectively.

9.3.2 Future Transport Demand of the Elderly in the Model Regions – Projections of Seniors' Travel Behaviour

This section will start by providing details about the framework conditions of elderly people's mobility which have an important impact on their travel demand. In the second part, we will provide deeper insight into the quantitative consequences that demographic change will have on the travel demand of elderly people in the year 2030. As the situation differs considerably for Hamburg and for Mecklenburg-Western Pomerania, the results will be presented by region.

9.3.2.1 Hamburg

In both scenarios - either high or low - the number of elderly people living in Hamburg will rise until 2030, but the figures will differ only slightly between high and low scenario. To estimate the future transport demand, it was assumed that the share of elderly people who have a car at their disposal will remain about the same as in 2005, i.e. two thirds of people aged 65 or more. However, because of the growing share of elderly people within the population, there will also be a growing share of elderly among the car owners. This figure will go up from 20% in 2005 to 22% in the high and 24% in the low scenario.

Divided more precisely into different age groups, we can see that car ownership is increasing, especially in the group of the older old (75+ years of age). While in 2005 about 92,000 people aged 75+ had a car, the number rises to about 136,000 in 2030 in the high scenario and 133,400 in the low scenario.

The number of trips made by the elderly increases only slightly if the average increase is considered. This increase occurs in particular for seniors who own a car.

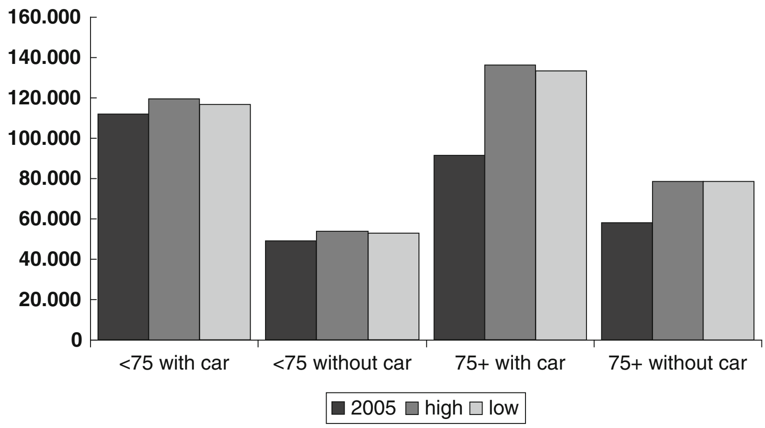

Fig. 9.5 Trips made by "young old" and "old old" in 2030 compared to 2005 for the high and low scenarios for Hamburg

Here again, it is above all the group of older seniors who contribute the most to the increase in future travel demand as their number will considerably grow. While in 2005, this group made about 420,000 trips, this number is predicted to grow by about 50% to roughly 624,000 trips (high scenario) or 612,000 trips (low scenario) in 2030 (Fig. 9.5). Although there are differences between the scenarios, it is interesting to see that the differences in quantitative effects due to the travel demand of elderly people are marginal.

At the same time, it is noteworthy to see that the number of trips made by the older old without a car also increase by about 17% for the low and 21% for the high scenario, although their average number of trips does not grow. This shows again that a larger part of the observed effects have to be attributed to the growing absolute numbers of elderly old, which means it is a quantitative effect. Overall we see that while the number of trips will increase for both the older age group and the group of younger old, this is not true for the younger age groups. Up to the age of 45, there is only a small growth in the number of trips in the high scenario and a decline in trips made in the low scenario.

Regarding the modes of transport used by seniors for their trips, there is almost no change between 2005 and 2030 in the modal split of elderly people living in Hamburg. The car will remain the most important mode being used for 46% of all trips in both 2030 scenarios (45% in 2005) in the group of younger olds, and 42%, again in both 2030 scenarios (41% in 2005), for the older olds. The second most important modes are feet and public transport, both very slightly growing from 2005 to 2030.

9.3.2.2 Mecklenburg-Western Pomerania

The Federal State of Mecklenburg-Western Pomerania is characterised by sparse population and mostly rural areas. Rostock is the biggest city with approximately 200,000 inhabitants. There are only few cities of a certain size in the state, but many small towns with less than 1,000 inhabitants. Consequently, less than 5% of the population live in cities with more than 10,000 residents. In comparison with Hamburg, the future travel demand in Mecklenburg-Western Pomerania is regionally strongly differentiated.

The increasing number of seniors over the coming decades in Mecklenburg-Western Pomerania is important. The share of the group of the younger old (aged 65–74) will increase from 13.0% to 17.6% (high scenario) or 17.8 (low scenario) of the total population. The share of older olds (75 years and more) will grow from 7.5% to 17.5% (high scenario) or 17.8% (low scenario). In absolute figures this means that in 2030 the number of elderly people in Mecklenburg-Western Pomerania will rise up to 504,000 for the high and 490,000 for the low scenario compared to 328,000 in 2005. The quantitative development of population groups is shown by Fig. 9.6 . This reveals that all population groups will decrease in absolute numbers except for elderly and students.

According to the increase in total numbers, the number of trips made by seniors will considerably grow by 60% in the high and 52% in the low scenario. In contrast to this, a significant decrease in absolute number trips will be found for the younger working people up to the age of 45. Among the elderly, those owning a car (especially the older old with a car) are mainly responsible for the quantitative increase in trips. While the younger old made about 937,000 trips a day in 2005, this number goes up in 2030 by about 30% to 1.2 million trips in both scenarios. As was the case in Hamburg, the increase here is in particular due to the rising number of motorised seniors aged 75 and older: in 2005, they made about 196,000 trips a day, while

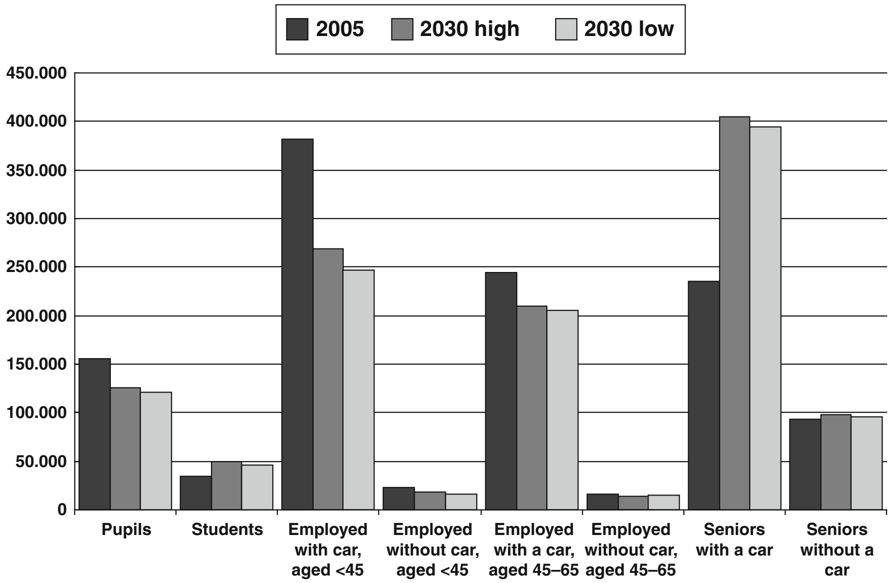

Fig. 9.6 Number of people per age group in Mecklenburg-Western Pomerania in 2005 and for both scenarios

this number almost triples in 2030 in both scenarios – again due to quantitative and qualitative effects.

In contrast, the number of trips made by younger employed people decreases: While they make about 1.79 million trips in 2005, this number goes back to 1.28 million in the high scenario and to 1.17 million in the low scenario.

To illustrate the particular regional differences in Mecklenburg-Western Pomerania, two examples will be outlined more explicitly. The first is Rostock: an independent city with about 200,000 inhabitants and the biggest city in the federal state. Rostock has a comparatively young population as a result of its university. In addition to the seniors, students are the only population group for which growth is expected. This is the reason why population forecasts expect a more or less stable population structure with a mild shrinking tendency in the city of Rostock. According to the high scenario, a population growth of 2.6% is expected for 2030 compared to 2005 while the low scenario predicts shrinkage of –2.9%. The number of households remains more or less stable in the low scenario (–0.3%) and increases by +8% in the high scenario.

To contrast the development of Rostock with other parts of Mecklenburg-Western Pomerania, the rural district of Uecker-Randow was chosen. Uecker-Randow is situated in the south-east close to the Polish border. With about 77,000 inhabitants in 2005 distributed across 54 municipalities and a population density of 46 inhabitants per km^2, it is one of the most sparsely populated counties in Germany and a structurally weak area. In Uecker-Randow, about 55% of the population live in municipalities with less than 500 inhabitants. After the reunification in 1989, Uecker-Randow lost more than 20% of its inhabitants. The younger and mobile age groups in particular migrated to more prosperous parts of Germany, leaving behind an over-proportionate number of older people, and this tendency is still continuing. According to both the high and low scenarios, the population shrinkage in Uecker-Randow will aggravate in future, and the region's population decreases by 29% in the low scenario and 26% in the high scenario. The shrinkage also affects the number of households, which declines by 20% in the low scenario and by 15% in the high scenario, respectively.

The future transport demand in these regions will differ significantly, as can be shown through the analysis of trips between traffic analysis zones (TAZ)[2]. In Rostock, trips made by students increase from 16% (low scenario) to 23% (high scenario). Conversely, the situation for the same group in Uecker-Randow is characterised by a decline of 40% (low scenario) or 36% (high scenario). In Uecker-Randow, this decrease of trips also applies to the elderly. The number of trips they make falls off by 28% (low scenario) or 24% respectively (high scenario). In Rostock, the number of trips is more or less stable for both students and elderly people. A slight decrease can be observed for both

[2]A traffic analysis zone (TAZ) is a special area delineated by state and/or local transportation officials for tabulating traffic-related data. A TAZ usually consists of one or more housing blocks and represents the spatial background for the analysis of transport behaviour with transport models (http://www.census.gov/geo/www/cob/tz_metadata.html).

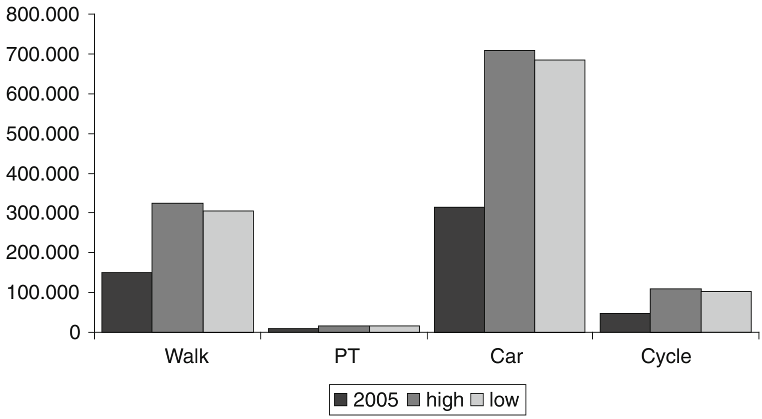

Fig. 9.7 Trips of elderly people (65+) by mode in Mecklenburg-Western Pomerania – 2030 compared to 2005

groups in the low scenario and a slight increase is expected in the high scenario.

An increase in trips occurs particularly for seniors with a car. In Rostock, the overall number of trips made by the elderly is expected to rise by about 40% (44% high scenario; 38% low scenario), and the trips made by students grow by over 80% in both scenarios. The younger population structure leads to a higher transport demand in Rostock. The results for Uecker-Randow are completely different: the number of trips decreases for all age groups except seniors owning a car.

In Mecklenburg-Western Pomerania in total, the mode choice will be clearly dominated by the use of the private car. Public transport will only be used to a small percentage (Fig. 9.7).

To separate the different effects – quantitative due to demographic changes and qualitative due to behavioural changes – an independent model calculation was made for the low scenario for Mecklenburg-Western Pomerania. The result of this special evaluation clearly separates the different effects.

If we assumed that the population in 2030 was identical to the population in the basis scenario in 2005, the future transport demand would be only half (47%) of what is predicted. Taking the demographic changes into account, we see that roughly one third of the total increase is due to demographic changes (32%). 21% of the increase in trips is due to behavioural change and growing motorisation. Although one fifth is quite a significant share, demographic changes has a much higher impact on the future transport demand than behavioural change. However, the latter must not be neglected either.

9.4 Summary and Conclusions

Demographic change will considerably alter travel demand. The simulations for the model regions Hamburg and Mecklenburg-Western Pomerania have shown that these alterations occur because of an increasing number of elderly people and behavioural change. At the same time, it has become evident that this process is closely related to car availability among the older population. More specifically, it could be demonstrated that the demographic impacts are stronger than behavioural changes. While elderly people will lead more active and mobile lives, the expected changes in the transport demand are predominantly a demographic effect. In this context, it should be remembered that ageing is a spatially selective process, which implies that the future transport demand will be differentiated by the proportion and characteristics of groups of the elderly.

Elderly people will maintain their mobility more and more with their own car, which in turn will lead to different requirements for both the environment and infrastructures.

First of all, the aspect of safety must be addressed. The need for security increases with growing seniority. This is especially true when an individual's personal skills and competencies decrease gradually. Even though seniors will become healthier, more active and more mobile, they will still be older people with different needs, and receding competencies and abilities.

Traffic safety with safe roads in general and visible signs and markings in particular is as important as the perception of safety for elderly people. Additionally, ensuring safety in public space is as essential as the subjective perception of safety. This applies in particular to the public transport sector. Operators and those responsible for public transport should react appropriately to ageing: a small-scale development of the public transport network is indispensable if the elderly are to be kept as customers in the future.

Besides these changing requirements for infrastructure, the usage of the road network will change in future to a varying extent depending on the region. In sparsely populated rural areas like in Mecklenburg-Western Pomerania, the transport demand and thus road usage is predicted to decrease, whereas in Hamburg, the situation will remain more or less the same in the future as it is today.

In the case of a sharp decrease in transport demand, thinning the road network is a conceivable solution that should be taken into consideration. Apart from this, the dimensioning of roads has to be examined.

Traffic planning and transport policy must address these issues. A slogan like "Getting there safely is better than getting there quickly" (Scheiner, 2004) should represent reality to a greater extent as demographic processes and particularly ageing are taken into account.

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Chapter 10
On the Energy Demand of Households

Kerstin Engel, Patrick Hansen, and Tobias Kronenberg

Abstract Demographic change affects the energy use in the household sector, which accounts for a major share of overall energy use. To understand this chain of effects better, we will devote this chapter to a more detailed analysis of households' energy consumption. EVS data are used to identify differences in energy use between age groups, and the special roles of transport and space heating are discussed. We show that the effect of demographic change is not uniform across Germany: it depends on the technological and socio-economic conditions, which differ between regions.

Keywords Energy demand · Households · Demographic change · Space heating living space

10.1 Introduction

Demographic change manifests itself primarily in the household sector through changes in the number and composition of households. Overall energy demand is then indirectly affected via the changing structure of final demand. This transmission channel was analysed in Chapter 4 using an input–output approach. However, because of the central role played by households, it is important to examine the relationship between the demographic structure of households and their consumption patterns more closely. The present chapter is closely related to Chapter 4, drawing on the same set of data and providing more detail on the demography-dependent consumption changes which drive the results of the input–output model.

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The chapter proceeds as follows. Section 10.2 places the energy demand of households in the greater context of overall energy use in Germany, thereby motivating our focus on the household sector. Section 10.3 forms, in a way, the core of the chapter, examining the demographic structure of the household sector in Germany, Hamburg and Mecklenburg-Western Pomerania and the corresponding consumption patterns in great detail, using data from the EVS household survey (cf. Chapter 4). Section 10.4 discusses the special role of space heating, which is closely related to the amount of living space occupied by households. Section 10.5 concludes this chapter.

10.2 The Importance of Household Energy Demand

The special importance of the household sector can be clearly seen in Fig. 10.1, which shows an energy flow chart for the Federal Republic of Germany in the year 2008. An energy flow chart provides an easily comprehensible (though somewhat

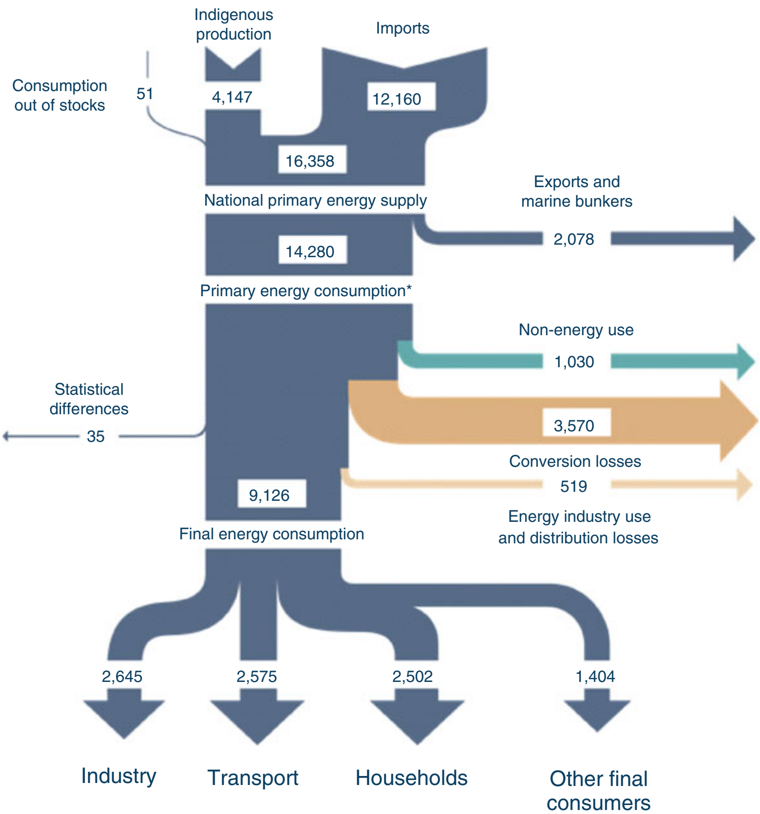

Fig. 10.1 Energy flow diagram for Germany in PJ, 2008. Source: Arbeitsgemeinschaft Energiebilanzen (2009), authors' translation

simplistic) representation of the production, distribution, and consumption of energy in an economy. As indicated by the arrows, the energy flow generally moves from the top of the figure to the bottom. Going through different stages, energy is first produced or imported in the form of primary energy, then converted and distributed and finally consumed as final energy.

At the top of the chart, Germany's import dependence is visualised by a thick arrow representing 12,160 PJ of imported primary energy and a thin arrow representing 4,147 PJ of indigenously produced primary energy. Together with 51 PJ of energy taken out of stocks, a total of 16,358 PJ of primary energy were made available. About one tenth of this, 2,078 PJ, was exported or stored in bunkers. Thus, 14,280 PJ of primary energy were available for consumption in Germany. Non-energy use of primary energy resources (petroleum used to produce plastics, for example) amounted to 1,030 PJ. Another 3,570 PJ were subject to conversion losses, 519 PJ were used or lost within the energy sector, and a "loss" of 35 PJ appears as a statistical artefact. Thus, only 9,126 PJ were consumed in the form of final energy.

Our interest here lies primarily in explaining final energy consumption. 2,502 PJ were used by households, representing a share of 27%. However, the transport sector consumed another 2,575 PJ, about 50% of which was actually used by households. In total, households therefore accounted for roughly 42% of total final energy use. Clearly, developments in the household sector affect a significant share of overall energy use. Therefore, knowledge of the future development of private households and their demand for energy is relevant for infrastructure planning and energy policy.

Figure 10.2 shows the energy use of private households (excluding transport) by use category in the year 2007. All households together consumed 2,201 PJ. Most of this, almost 70%, was used for space heating. Another 13% was used for water heating. Mechanical energy (for the use of electrical appliances) accounted for another 10%, other process heat (mainly for cooking) for 6%, and lighting for 2%.

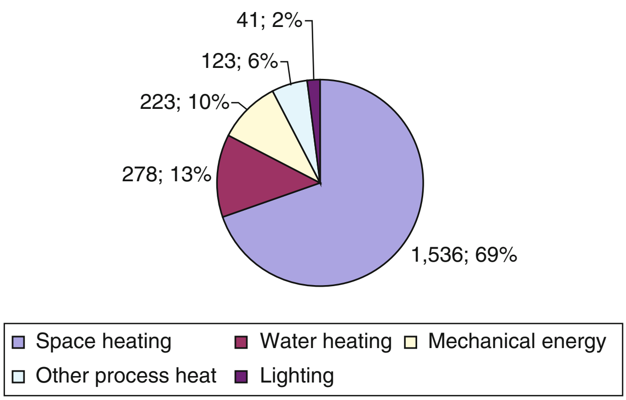

Fig. 10.2 Energy consumption of households (excl. transport) by use category in PJ, 2007. Data source: Bundesverband der Energie- und Wasserwirtschaft (2008)

To sum up, the household sector accounts for more than a quarter of total final energy use. If the participation of private households in the transport sector is also taken into account, their share in final energy use adds up to more than 40%. Hence, the evolution of the private household sector is highly relevant for future energy demand. In order to assess the potential impact of demographic change, we will examine the relationship between the demographic structure and the consumption patterns of households in the following section.

10.3 Demographic Structure and Consumption Patterns

In this section, we use data from the EVS 2003 household survey, which was already introduced in Chapter 4. The data allow us, on the one hand, to identify certain relationships between a household's demographic characteristics (here: age of main income earner and number of household members) and the structure of its consumption expenditure. On the other hand, they allow us to examine the differences between households in Germany as a whole, Hamburg, and Mecklenburg-Western Pomerania, which are relevant to understanding the different developments in those regions.

10.3.1 Regional Demographic Characteristics

Hamburg and Mecklenburg-Western Pomerania are federal states in the North of the Federal Republic of Germany (cf. Fig. 10.3). In order to identify different consumption patterns between older and younger households, all households have been sorted into age groups.[1]

In the following, we first describe the demographic characteristics of Hamburg and Mecklenburg-Western Pomerania. Then, we examine households' disposable income and households' consumer expenditure. Finally, since our focus is on energy and transportation services, we take a closer look at households' expenditure on these consumption categories.[2]

Although both Hamburg and Mecklenburg-Western Pomerania have populations of a similar size (about 1.7 million in 2003), their demographic characteristics differ considerably from each other and from Germany as a whole. Table 10.1 shows that the average German household consisted of 2.12 persons in 2003, whereas the average household size was 1.79 persons in Hamburg and 2.09 persons in Mecklenburg-Western Pomerania, respectively. Thus, the average household

[1] "Age group of a household" or "age group" stands for "age group of the households' main income earner", "households younger/older than xx years" stands for "households with a main income earner who is younger/older than xx years".

[2] The classification of consumption expenditure is based on SEA, the German version of the international COICOP standard (Classification of Individual Consumption by Purpose). Here we focus on SEA code 07 (transportation), 045 (energy) and 096 (package holidays).

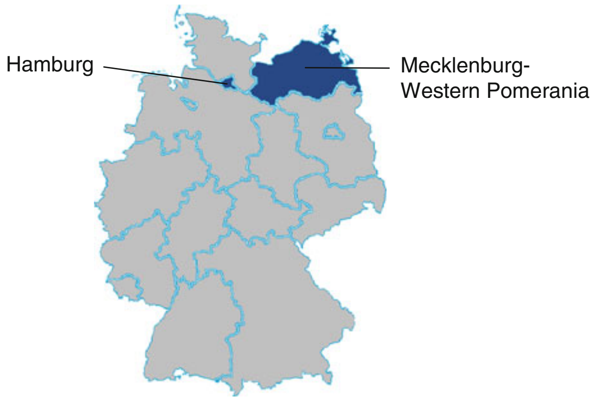

Fig. 10.3 Federal republic of Germany with 16 federal states. Source: Wikipedia, authors' adaptation

Table 10.1 Average number of household members by age group

Age group	Hamburg	Germany	Mecklenburg-Western Pomerania
U25	1.25	1.53	1.44
U30	1.41	1.75	1.72
U35	1.85	2.27	2.59
U40	1.95	2.70	2.74
U45	2.31	2.83	2.81
U50	2.16	2.68	2.54
U55	1.80	2.36	1.94
U60	1.75	2.04	1.78
U65	1.73	1.80	1.69
U70	1.49	1.72	1.55
U75	1.48	1.52	1.67
U80	1.43	1.40	1.50
85+	1.26	1.36	1.58
Ø	1.79	2.12	2.09

Source: authors' calculations based on EVS 2003 data

in Hamburg is significantly smaller than in Germany and Mecklenburg-Western Pomerania. This applies to nearly all age groups.

A reason for this can be found in Fig. 10.4, which shows that the share of single-person households is significantly higher in Hamburg than in Mecklenburg-Western Pomerania or Germany. This is typical for large cities compared to rural areas. Moreover, the share of households with three or more members is much smaller in Hamburg (19.1%) than in Mecklenburg-Western Pomerania (28.2%) and in Germany (28.9 %).

Splitting the population into age groups (cf. Fig. 10.5) is of particular interest in this study because older and younger households display different consumption patterns. Hamburg's share of households aged between 25 and 45 years is much

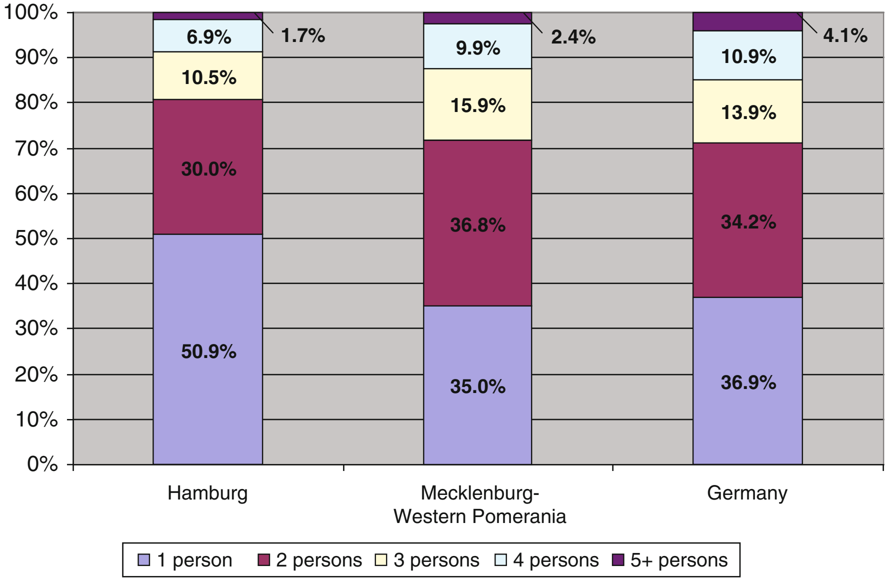

Fig. 10.4 Fraction of households with x members in Hamburg, Mecklenburg-Western Pomerania and Germany. Source: authors' calculations based on EVS 2003 data

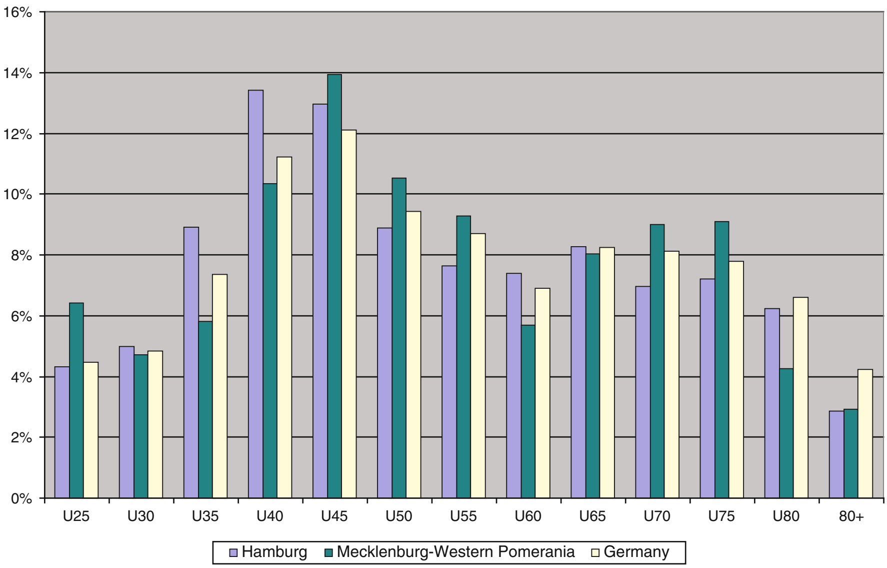

Fig. 10.5 Population split by age group of households. Source: authors' calculations based on EVS 2003 data

higher than Germany's, whereas the share of households aged between 25 and 40 in Mecklenburg-Western Pomerania is considerably below the national average. An essential reason for this difference is internal migration in Germany. According to Tivig and Hetze (2007), mainly young people are leaving Eastern Germany in order to settle in regions with a prosperous economy such as Hamburg, for instance. As a result, the share of older households is higher in Mecklenburg-Western Pomerania than in Hamburg.

10.3.2 Disposable Income and Private Consumption Expenditure

Having discussed the demographic characteristics of the two regions, we now turn to the economic situation of households. Table 10.2 shows that there are remarkable differences between the two federal states: the disposable income of the average

Table 10.2 Disposable income, private consumption expenditure per household

	Hamburg		Germany		Mecklenburg-Western Pomerania	
Disposable income	€2,682	77.8%	€2,885	75.5%	€2,232	79.2%
Private consumption expenditure	€2,086	100.0%	€2,178	100.0%	€1,767	100.0%
Food, non-alcoholic beverages	€250	12.0%	€263	12.1%	€243	13.8%
Alcoholic beverages, tobacco, narcotics	€44	2.1%	€40	1.9%	€41	2.3%
Clothing, footwear	€113	5.4%	€112	5.1%	€98	5.6%
Rental (incl. utilities)	€337	16.2%	€201	9.2%	€239	13.5%
Imputed rental (incl. utilities)	€188	9.0%	€314	14.4%	€173	9.8%
Maintenance, repair of the dwelling	€51	2.4%	€61	2.8%	€26	1.5%
Energy	€107	5.1%	€120	5.5%	€107	6.1%
Furnishings, household equipment	€109	5.2%	€127	5.8%	€111	6.3%
Health	€80	3.8%	€84	3.9%	€44	2.5%
Transport	€229	11.0%	€306	14.1%	€247	14.0%
Communication	€68	3.3%	€68	3.1%	€64	3.6%
Recreation, culture	€267	12.8%	€261	12.0%	€215	12.2%
Education	€26	1.2%	€20	0.9%	€16	0.9%
Restaurants, hotels	€113	5.4%	€100	4.6%	€58	3.3%
Miscellaneous goods, services	€103	4.9%	€100	4.6%	€82	4.7%
Rest	€595		€707		€465	

Source: authors' calculations based on EVS 2003 data

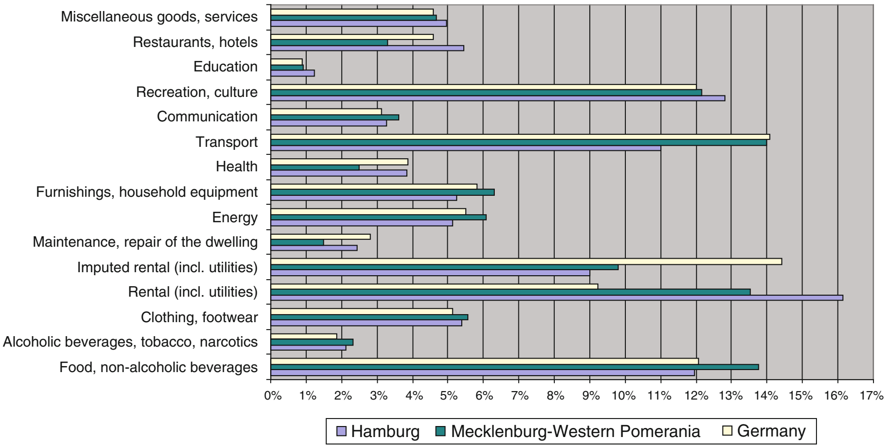

Fig. 10.6 Composition of private consumption expenditure. Source: authors' calculations based on EVS 2003 data

household in Mecklenburg-Western Pomerania is €450 lower than in Hamburg. A reason for this is – among other things – a low wage level in East Germany. The difference also appears in private consumer expenditures for which the bigger part of disposable income (over 75%) is used. Mecklenburg-Western Pomerania's share of essentials expenditure – in the form of energy, furnishings, clothing or food – in private consumption expenditure is much higher than Hamburg's, where the share of luxuries expenditure – for restaurants, education, health, maintenance – is higher in return (cf. Fig. 10.6). It is worth mentioning that in both regions rental expenditure is higher than in Germany (and imputed rental expenditure lower accordingly). In other words, there are fewer proprietors of a house or flat in Hamburg and Mecklenburg-Western Pomerania than in the whole of Germany.

Splitting-up disposable income by age group (cf. Fig. 10.7) shows very plainly that such segmentation is useful: income ranges between €1,481 (U25) and €3,575 (U55) in Germany, for instance. These differences can be attributed, among other factors, to increasing income during working life. At the age of 60, as the share of pensioner households begins to grow, income falls on average. In Hamburg, the age-income relationship is not as exemplary as in Germany but it still shows parallels. In Mecklenburg-Western Pomerania, by contrast, a sharp difference can be observed between U65 and U70 households in terms of disposable income. This results from a lower wage level and a high unemployment rate in the U65 age group in East Germany. Reaching retirement age often leads to an increase in disposable income because pensions are higher than unemployment benefit.

Table 10.2 shows that the disposable income per household is lower in Hamburg than in Germany. However, this does not indicate that Hamburg is relatively poor because the average household in Hamburg consists of fewer persons (cf. Table 10.1). On the contrary, average income per capita amounts to €1,500 in Hamburg, which is higher than the German average of €1,360 and most certainly higher than in Mecklenburg-Western Pomerania, where it amounts to only €1,070.

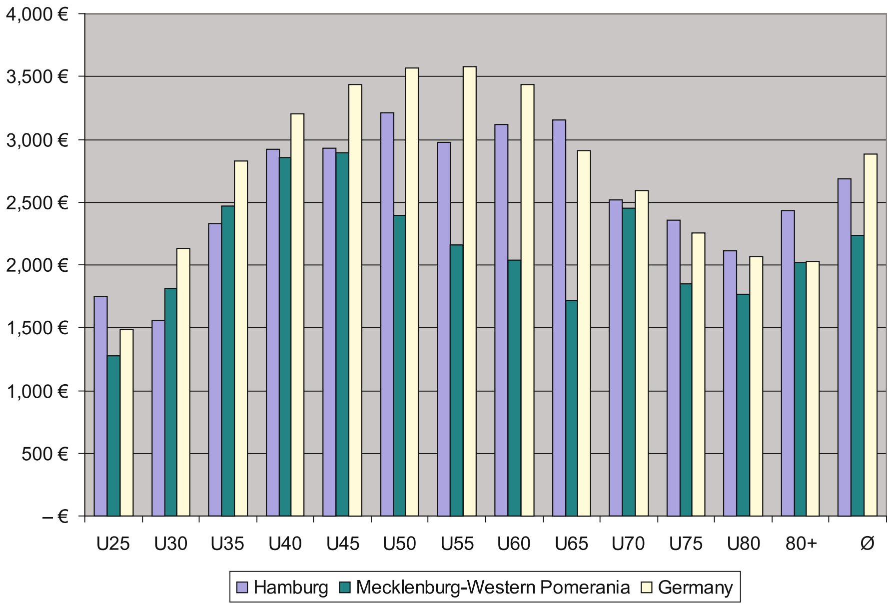

Fig. 10.7 Disposable income by age group, per household. Source: authors' calculations based on EVS 2003 data

Private consumption expenditure per capita amounted to €1,167 (Hamburg), €1,027 (Germany) and €847 (Mecklenburg-Western Pomerania), respectively. Private consumption expenditure also differed between age groups (Table 10.3).

Table 10.3 Private consumption expenditure per household

Age group	Hamburg	Germany	Mecklenburg-Western Pomerania
U25	€1,277	€1,310	€1,131
U30	€1,410	€1,683	€1,525
U35	€1,841	€2,080	€1,838
U40	€2,045	€2,280	€1,974
U45	€2,275	€2,442	€2,146
U50	€2,465	€2,574	€2,189
U55	€2,122	€2,567	€1,732
U60	€2,400	€2,558	€1,847
U65	€2,593	€2,326	€1,687
U70	€1,927	€2,196	€1,572
U75	€2,102	€1,894	€1,523
U80	€1,823	€1,630	€1,423
80+	€1,961	€1,562	€1,381
Ø	€2,086	€2,178	€1,767

Source: authors' calculations based on EVS 2003 data

10.3.3 Energy Expenditure

Table 10.4 shows energy expenditure by age groups, per household and per capita. In Germany energy expenditures per household range from €71 to €141 depending on age, and on average they amount to €120. Expenditures per capita also differ considerably, ranging from €44 to €79.

Hamburg and Mecklenburg-Western Pomerania spend €107 per household on energy. Households under the age of 50 in Hamburg spend less; those over the age of 50 spend more money on energy than households in Mecklenburg-Western Pomerania. Informative are expenditures per capita, because in Hamburg the average household size in every age group is smaller than in Mecklenburg-Western Pomerania (cf. Table 10.1). As a result, energy expenditures per capita in every age group in Hamburg are significantly higher than in Mecklenburg-Western Pomerania (on average: €8). They are also higher than in Germany (€60 vs. 57).

In all considered regions, one can see that the older the household, the higher the energy expenditures per capita. A reason for this could be that older people spend more time inside their flats and houses than younger people, which would require a higher heating demand.

A detailed analysis of energy expenditure is thus advisable. Energy expenditure was split within the EVS, namely into expenditures for “electricity”, “gas”, “liquid fuels”, “solid fuels”, “heat energy”, and “ice used for cooling and refrigeration purposes” (cf. Table 10.5). (The latter is of negligible importance and therefore receives no further attention in the following.)

Table 10.4 Energy expenditure by age group, per household and per capita

Age group	Hamburg		Germany		Mecklenburg-Western Pomerania	
	Per household	Per capita	Per household	Per capita	Per household	Per capita
U25	€66	€53	€71	€47	€75	€52
U30	€70	€50	€81	€47	€72	€42
U35	€90	€49	€101	€45	€104	€40
U40	€104	€54	€118	€44	€130	€47
U45	€112	€49	€131	€46	€132	€47
U50	€110	€51	€135	€51	€124	€49
U55	€118	€65	€140	€59	€104	€53
U60	€113	€64	€141	€69	€109	€61
U65	€126	€73	€129	€72	€106	€63
U70	€115	€77	€124	€72	€90	€58
U75	€111	€75	€116	€76	€99	€59
U80	€111	€77	€110	€79	€95	€63
80+	€124	€99	€108	€79	€103	€65
Ø	€107	€60	€120	€57	€107	€52

Source: authors’ calculations based on EVS 2003 data

Table 10.5 Composition of energy expenditure by age group

Age group	Electricity (%)			Gas (%)			Liquid fuels (%)			Solid fuels (%)			Heat energy (%)		
	H	G	M	H	G	M	H	G	M	H	G	M	H	G	M
U25	39	46	36	40	14	11	0	7	7	0	1	1	20	32	47
U30	43	46	40	18	16	14	2	7	1	0	1	1	37	30	43
U35	48	44	33	13	19	21	4	9	9	0	1	0	35	26	37
U40	41	43	37	21	22	19	4	11	13	0	2	3	34	23	28
U45	42	42	40	19	24	19	2	13	15	1	1	2	36	19	24
U50	45	43	36	17	24	21	2	12	10	1	2	2	35	19	31
U55	40	42	40	18	24	19	3	13	7	1	2	2	38	18	32
U60	43	42	40	18	24	19	7	15	7	1	2	0	31	18	34
U65	40	40	37	20	22	23	9	16	3	0	1	2	30	20	35
U70	34	40	34	27	22	15	6	15	7	0	1	2	34	21	43
U75	35	39	35	14	21	20	9	16	8	3	2	4	38	22	32
U80	43	39	37	18	21	14	5	16	7	0	1	0	35	23	42
8+	41	38	36	11	21	20	17	20	4	0	1	1	30	18	39

Source: authors' calculations based on EVS 2003 data[3]

Table 10.5 shows that electricity accounts for the largest share of total energy expenditures of German households. Its share lies between 38 and 46% and tends to decrease with age. One reason for this could be the higher prevalence of electrical appliances and so-called "power eaters" such as home cinemas, flat screen TVs, etc. in younger households. Another reason is probably a more intensive use of personal computers in younger households. The second highest expenditures are for heat energy, proportionately 18–32% with younger households having larger shares in this category. An explanation for this could be that more younger households tend to live in rented flats with central heating than older households. Other substantial expenditures are for gas and liquid fuels. The latter increases with the age of household, thereby supporting the thesis that older households have a higher heating demand. Older households often live in suburban houses with oil-fired heating.

In Hamburg as well as in Germany, households of all age groups devote most of their energy expenditure to electricity (about 40%), and younger households tend to spend proportionately more on electricity than older households. About one third of energy expenditures in Hamburg is on heat energy, followed by gas and solid fuels. Households older than 55 years of age spend much more on oil than households under the age of 55 years.

In Mecklenburg-Western Pomerania the situation is different. Electricity and heat energy expenditures account for the largest part of the energy budgets. The share of gas is about 20% in most age groups, whereas the share of liquid fuels displays a high degree of variation, reaching values of between 1 and 15%. The clear-cut

[3] "H" stands for "Hamburg", "G" for "Germany", "M" for "Mecklenburg-Western Pomerania".

age-specific trends which we observed in Hamburg and Germany did not seem to exist in Mecklenburg-Western Pomerania.

10.3.4 Transport Expenditure

In the previous section, domestic energy use was discussed. Since households also consume energy for transportation purposes (see Section 10.2), we will now turn to consumption expenditures on transportation. First of all, we will examine aggregated energy expenditures by age group (cf. Table 10.6).

In Germany households spend €306 per month on transport, which corresponds to a share of 14.1% in private consumption expenditure. Transport expenditures therefore account for the second highest share of total expenditures (cf. Table 10.2). Transport expenditures increase until a household's age reaches 55 years, and then they decrease gradually, from €400 in households of middle age to €108 in the age group 80+. In Hamburg, transport expenditures are generally lower than in Germany, but the age profile is similar. In Mecklenburg-Western Pomerania, however, transport expenditures increase until U50 when they decrease rapidly before increasing again – an observation which calls for a more detailed analysis.

In order to better understand the variation in transportation expenditures, we split them into expenditures on "vehicles", "spare parts and accessories", "fuels and lubricants", "maintenance and repair", "other services", "passenger transport (air)" and "passenger transport (other)". Figure 10.8 shows the distribution of transport

Table 10.6 Transport expenditure by age group, per household and per capita

Age group	Hamburg		Germany		Mecklenburg-Western Pomerania	
	Per household	Per capita	Per household	Per capita	Per household	Per capita
U25	€106	€84	€194	€127	€151	€105
U30	€129	€91	€292	€167	€297	€173
U35	€184	€100	€326	€143	€294	€114
U40	€245	€126	€341	€126	€316	€116
U45	€252	€109	€353	€125	€291	€104
U50	€350	€162	€404	€151	€389	€153
U55	€190	€106	€405	€172	€217	€112
U60	€323	€184	€384	€188	€223	€125
U65	€295	€170	€322	€179	€226	€134
U70	€228	€153	€287	€167	€244	€157
U75	€240	€162	€204	€134	€100	€59
U80	€126	€88	€127	€91	€186	€124
80+	€58	€46	€108	€79	€72	€45
Ø	€229	€128	€306	€144	€247	€118

Source: authors' calculations based on EVS 2003 data

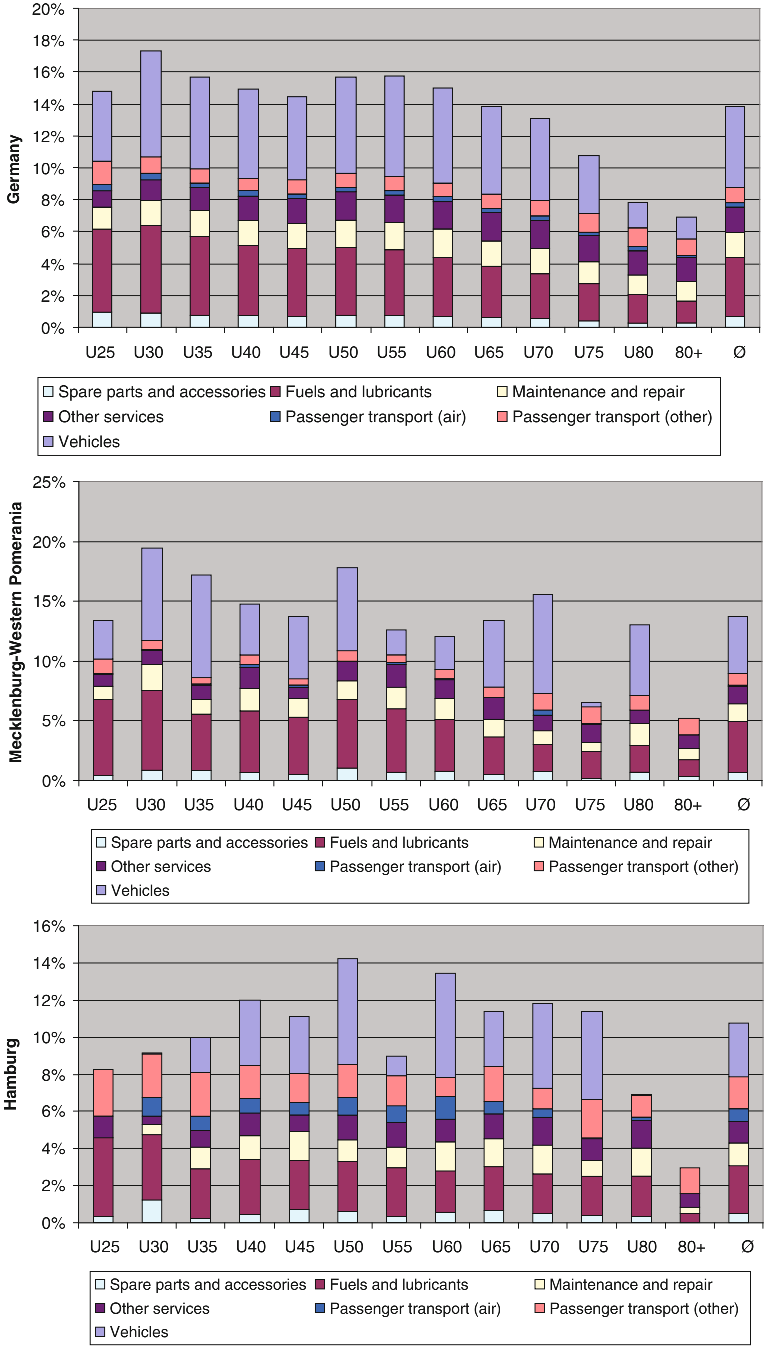

Fig. 10.8 Share of transport expenditure in relation to private consumption expenditure in Germany, Mecklenburg-Western Pomerania and Hamburg. Source: authors' calculations based on EVS 2003 data

expenditure in private consumption expenditure over these categories in Germany, Mecklenburg-Western Pomerania and Hamburg.

In many German households, the majority of transport expenditures is spent on buying new or used vehicles, accounting for an average 5.1% of private consumption expenditures. "Vehicles" means new or used motor vehicles, motorcycles, bicycles and carriages. With 3.7% of consumption expenditures, fuels and lubricants are the next most important category. Maintenance and repair and other services (for instance imputed or actual rentals of garages and parking spaces) require 1.6% each. Further expenditures in the field of transport comprise passenger transport (other) – which includes train, bus and taxi rides – spare parts and accessories and passenger transport (air). Most of these expenditure shares are relatively similar across all age groups – only vehicle expenditures fluctuate, which can be explained by the fact that such expenditures occur at rare intervals and the huge price differences between a used bike and a new limousine, for example.

These observations provide an explanation for the differences between Germany and the federal states (Table 10.6): transport expenditures in Hamburg account for a smaller part of total consumption expenditure because the two major components, vehicles and fuels, are less important in Hamburg. The ups and downs in Mecklenburg-Western Pomerania result from erratic vehicle expenditures; in other respects, the expenditure shares are similar to Germany.

We will now discuss fuel and lubricant expenditures separately. Both represent a household's active participation in transport. In all regions, a declining share was observed for both categories in private consumption expenditures as households got older (cf. Fig. 10.9). There are a number of explanations for this: for example,

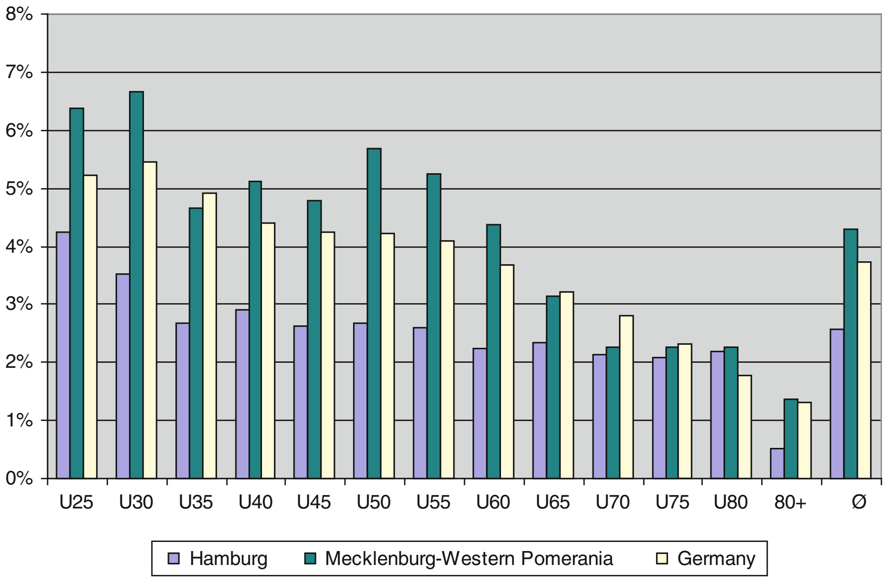

Fig. 10.9 Share of fuel and lubricant expenditure in relation to private consumption expenditure. Source: authors' calculations based on EVS 2003 data

pensioners' households have no work-related expenditures, older women do not have driving licences or do not drive themselves, to name but a few.

Households in Mecklenburg-Western Pomerania and Germany spend a larger share of their expenditures on refuelling their vehicles than Hamburg's households, 4.3 and 3.7%, respectively, versus 2.6%. This large gap results mainly from divergences in households under 60 years of age, that is, in households with no or only few pensioners. A reason for this is probably the exceptional position of Hamburg within Germany for using cars. In rural areas, many people of working age use their car to commute, whereas in a big city like Hamburg, households of all age groups tend to use public transport, walk or cycle more often, and so the difference between pensioners' households and households of working age is not as large as elsewhere.

10.3.5 Package Holiday Expenditure

There are two further categories that round off our understanding of transport expenditures even if they are not part of the SEA category "transport": package holidays in Germany and abroad. They are relevant to this study because buying a package holiday means buying transport services indirectly (Kronenberg, 2008). As might be expected, the share of expenditures on package holidays abroad is much higher than on package holidays in Germany, for the most part because travel costs are higher (cf. Table 10.7). Exceptions occur in Hamburg's age groups U80 and 80+.

The share of package holidays abroad rises strongly in Germany and more so in Mecklenburg-Western Pomerania up to the age of 75. In the two oldest age groups, however, it falls again, probably because the oldest households are no longer willing to accept longer journeys and possible difficulties (for example, in the case of

Table 10.7 Share of package holiday expenditure in private consumption expenditures

	Hamburg (%)		Germany (%)		Mecklenburg-Western Pomerania (%)	
Age group	Germany	Abroad	Germany	Abroad	Germany	Abroad
U25	0.0	0.0	0.2	1.3	0.5	1.2
U30	0.1	1.9	0.3	1.7	0.2	0.3
U35	0.2	2.2	0.4	1.6	0.6	0.9
U40	0.4	2.0	0.4	1.6	0.4	0.9
U45	0.4	1.7	0.5	1.7	0.6	1.6
U50	1.2	2.4	0.5	1.9	0.2	1.6
U55	0.6	4.0	0.5	2.1	0.5	1.8
U60	1.5	2.3	0.5	2.4	0.6	2.9
U65	0.7	2.4	0.8	2.9	1.0	2.6
U70	1.1	2.2	1.1	3.2	0.7	5.3
U75	1.4	1.5	1.4	3.0	0.7	6.2
U80	1.7	0.9	1.5	2.2	0.8	2.0
80+	2.5	2.3	1.6	1.8	0.6	3.3
Ø	0.8	2.1	0.7	2.1	0.6	2.3

Source: authors' calculations based on EVS 2003 data

illness). It is noticeable that the age groups U70 and U75 in Mecklenburg-Western Pomerania spend more than twice as much (in terms of percentage of consumption expenditures) on package holidays abroad than average households. We did not identify such a trend for Hamburg.

The share of package holidays in Germany is higher for pensioners' age groups in all three regions (with exceptions in Hamburg). A sharp decline in old age was not determined here.

10.3.6 Summary

In this section, we identified regional differences in consumption expenditures between Hamburg and Mecklenburg-Western Pomerania – two federal states in Northern Germany with an approximately equal number of inhabitants (in 2003) whose borders are 50 km away. It should be made clear that households' private consumption is closely connected with the age of households. This means that demographic change plays an important part in the structure of future household expenditure.

Our findings strongly underline the need for regional analyses. The age structures of households in Hamburg and Mecklenburg-Western Pomerania are completely different, and there are relatively more young households in Hamburg and relatively more old households in Mecklenburg-Western Pomerania, which is vitally important for consumption patterns. A prime example is energy expenditure per capita. An age-related effect is clearly visible in both regions, whereby expenditures increase with the increasing age of households. Within each age group, however, households in Mecklenburg-Western Pomerania spend less money on energy than in Hamburg (€52 vs. €60 on average). In our second focus "transport", demographic aspects were also apparent, for instance concerning fuel and lubricant expenditures, which fall sharply with increasing age. There is a large variation between households in the different regions: middle-aged households (U50, U55, and U60) in Mecklenburg-Western Pomerania spend more than twice as much of their private consumption expenditures on fuels and lubricants as households in Hamburg.

10.4 The Special Role of Space Heating

10.4.1 Demographic Determinants of Space Heating

Since a large share of households' energy consumption accrues with the purpose of space heating (cf. Fig. 10.2), we will give this area some more attention in the following. In addition to factors such as income or technological progress, there are further variables which are directly related to demographic change and are therefore the focus of the present analysis. Under demographic aspects, the following three factors play an important role with regard to the future development of space heating:

– heating duration
– temperature perception
– living space

The heating duration is relevant because time budget surveys have shown that the amount of time spent at home is higher during pension age (Statistisches Bundesamt, 2004). Physical change in old age leads to a change in temperature perception such that more heating is generally required. The following section focuses, however, on the third determinant, the living space occupied by households.

10.4.2 Living Space by Age Group

Figure 10.10 shows the relationship between household age and living space. The figure is based on data from the EVS conducted in 2003. Concerning living space per household, a hill-shaped relationship can be observed (left axis). This also holds for the average number of household members per household (right axis). A rough thesis concerning the relationship between household members and living space may therefore be formulated: the more members a household has, the larger the occupied living space is, and conversely, the smaller the number of household members, the smaller the living space.

In order to assess the consequences of population ageing on living space – and space heating – it is also useful to look at living space per household member. The reason for this is the so-called "remanence effect". Although the number of persons in a household falls – from age group U45 onwards – as the age of the household rises, living space is often not adjusted to the change in the number of

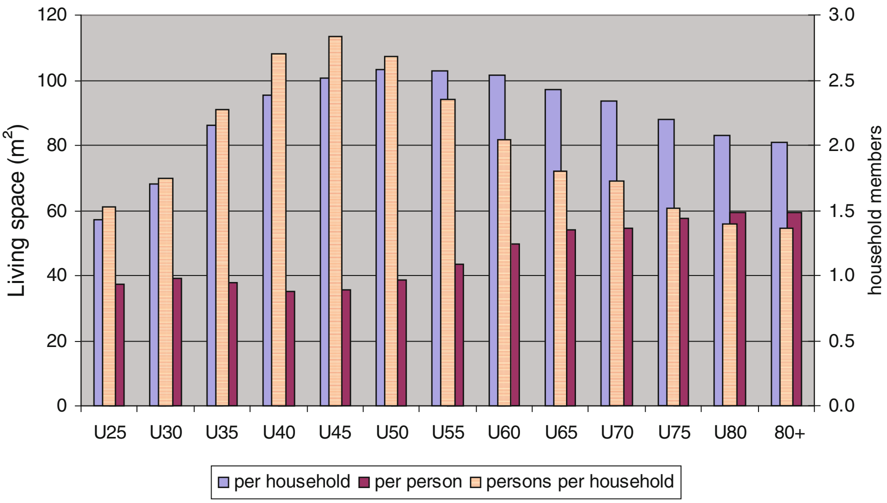

Fig. 10.10 Living space per household and household member in different age groups, 2003. Source: author's calculations based on EVS 2003 data

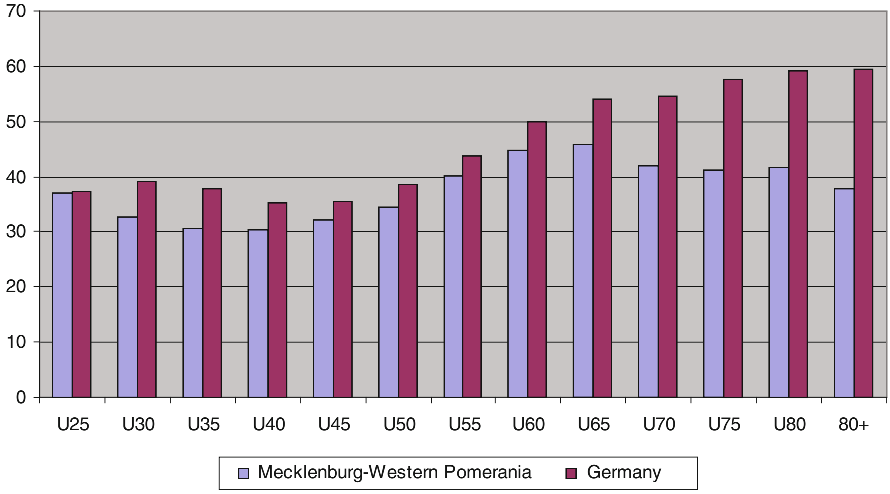

Fig. 10.11 Living space (m^2) per household member in Germany and Mecklenburg-Western Pomerania, 2003. Source: author's calculations based on EVS 2003 data

household members due to habits or high transaction costs (Braun & Pfeiffer, 2005). For this reason, older one- and two-person households often live in apartments that were originally intended for more members. Therefore, the apartment size does not shrink to the same extent as the number of household members. As a result, the ageing of the population will probably lead to more households living in apartments where living space has not been reduced with the falling number of household members. These apartments require relatively more heat energy than smaller apartments. Hence, the ageing of the population will tend to lead to higher energy consumption through the remanence effect. In reality, an interaction with other effects is to be expected here as well.

In Hamburg, the remanence effect can be observed in a similar way to Germany. In Mecklenburg-Western Pomerania, however, a different picture emerges, as shown in Fig. 10.11. It can be seen that from age group U70 upwards, the living space per capita is lower than that of the younger households. Braun and Pfeiffer (2005), comparing West and East Germany, found that the remanence effect is at work in East Germany, but that it is partly obscured by the fact that older households live in significantly smaller apartments, while young households (under 40 years of age) have converged towards the typical West German level of living space. This means that the ageing of the population will – *ceteris paribus* – lead to an increased demand for energy.

10.4.3 Living Space by Household Members

Figure 10.12 (left-hand panel) shows the living space of households consisting of one, two, and more persons and the corresponding average of all households.

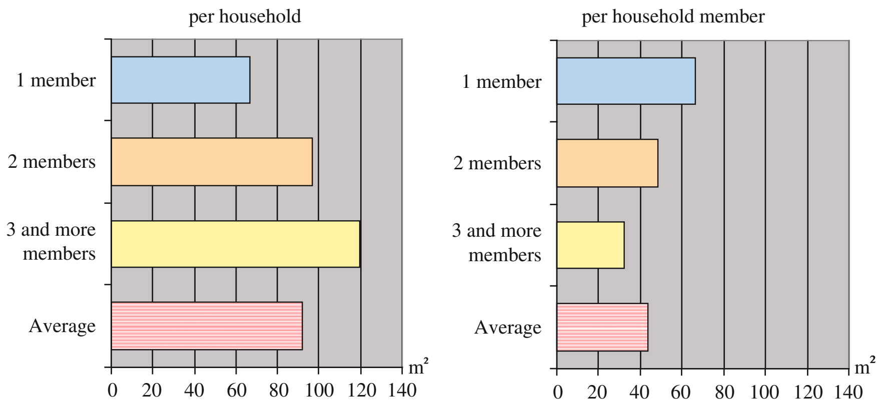

Fig. 10.12 Living space by number of household members, average over all households, 2003. Source: author's calculations based on EVS 2003 data

One-person households occupy an average living space of 66 m^2, while two-person households require 97 m^2. The average living space of a household amounts to 92 m^2. In the right-hand panel, living space per household member is displayed.

It can be clearly seen that the living space per household member becomes smaller as the number of household members rises. The single household member in a one-person household has an average of 66 m^2 at their disposal, whereas a member of a household with three or more persons has less than half of that – only 32 m^2. The reason for this is probably that the space devoted to places such as living rooms, kitchens and bathrooms is used by all household members (Behrends & Kott, 2009). On average, each household member in Germany had 43 m^2 of living space in 2003.

Figure 10.13 shows the (temperature-adjusted) direct energy use in 2006 for living per household (left-hand panel) and per household member (right-hand panel), differentiated by household size. In correspondence with living space, the energy use of multiple-person households is clearly higher than that of households with fewer members. However, the energy use per household member is higher the smaller the household is. This is caused by the aforementioned fact that the amount of living space per member increases when the number of members decreases. Furthermore, each room has to be heated only once, and not for each person using the room. The future development of household sizes – tending towards smaller households – may therefore affect the demand for energy. The tendency towards smaller households, as outlined above, will *ceteris paribus* lead to an increasing direct energy demand for space heating. The effect of shrinking household sizes, however, is not the only effect occurring in reality. Interaction with other effects caused by the reduction in population numbers is also to be expected.

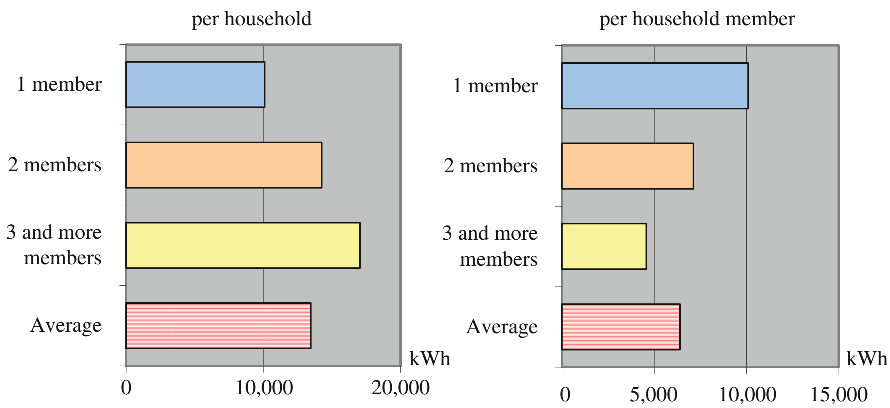

Fig. 10.13 Energy for space heating by number of household members, per household (*left*) and per household member (*right*), in kWh, 2006. Source: Statistisches Bundesamt (2008), author's calculations and visualisation

10.4.4 The Link Between Living Space and Energy Consumption

In analyses of energy consumption in the household sector, the development of building space constitutes a decisive parameter. The existing stock of building space is composed of the space in old and new buildings. The total living space is calculated by adding up the living space in old and new buildings. In the period from 1990 to 2006, the living space in Germany increased by 23% (see Fig. 10.14). In contrast, the energy intensity, which results from the energy consumption per square metre

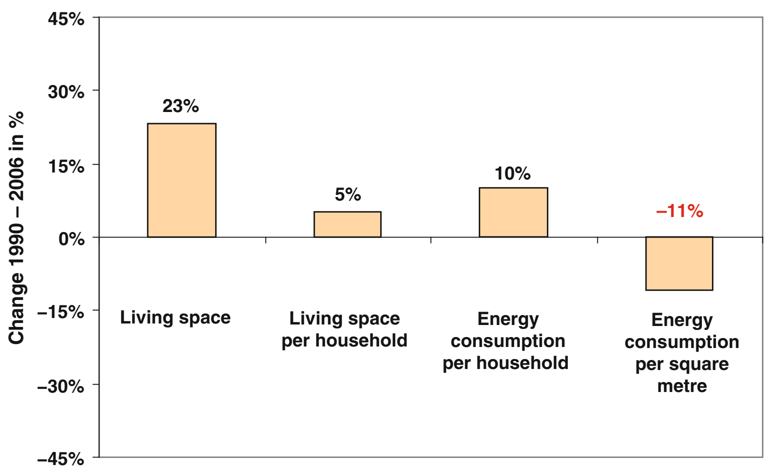

Fig. 10.14 Development of living space and energy consumption of households (1990–2006) in %. Source: BMWi (2009), author's calculations and visualisation

of living space, declined by 11% in the same period. Improvements in building and heating technology, as well as changes in the behaviour of households, all had an impact. The overall energy consumption of households would have increased less if the trend towards smaller households and the increases in both total living space and living space per home had not counteracted the savings effects. The trend towards smaller households thus caused a rise in the demand for living space and therefore a higher demand for heating. In addition to the demand for heating, the fact that households are equipped with more sophisticated technology also led to an increase in energy consumption.

The effects of these developments led to a total increase in the final energy consumption of households of just under 10% in the period from 1990 to 2006.

Analyses conducted by the Federal Statistical Office (Statistisches Bundesamt, 2008) substantiate the described effects on heating energy consumption. Table 10.8 shows that in the period from 1995 to 2006, the consumption of heating energy only decreased by a total of 17 PJ. Measures to increase energy efficiency were counteracted by the effects of increased living space and smaller households as well as the population growth in the period. These effects compensated for almost all savings in energy.

Finally, the level of consumption in general, which rose in the period between 1990 and 2006, also contributes to the increase in energy consumption. On the whole, this shows that consumption and energy demand have not yet been decoupled. The efficiency improvements realised so far are by no means sufficient to compensate for the negative effects of increased consumption, the rise in living space and the fact that private households are equipped with more and more electric appliances.

More than 60% of today's building stock was built before the first oil crisis, which means that there is still scope for substantial energy savings by improving energy efficiency. The programme to reduce CO_2 emissions from buildings ("CO_2-Gebäudesanierungsprogramm") is therefore a key component of German climate protection activities. The programme offers low-interest loans for the energy-related modernisation of existing buildings. According to the analysis by Kuckshinrichs et al. (2010), this results not only in fuel cost savings, but also in additional advantages for the investor and revenue for the national budget.

Table 10.8 Change in energy use for space heating in households, 1995–2006

	Change 1995–2006 (PJ)
Demographic development	Circa 24
Size of households	Circa 60
Living space per household	Circa 181
Energy efficiency	Circa –282
Change in space heating	Circa –17

Source: Statistisches Bundesamt (2008), authors' calculations and visualisation

10.5 Conclusion

As shown in this chapter, there is ample reason to expect that demographic change will affect the energy demand of households. As households account for 42% of total final energy use, this will clearly affect overall energy use. However, the different dimensions of demographic change will affect the level of energy use in different ways. The ageing of the population leads *ceteris paribus* to an increase in the overall heat demand in Germany. The examination of Mecklenburg-Western Pomerania shows by way of example that due to the adjustment processes between East and West Germany large regional differences may arise. The tendency towards smaller households as a consequence of demographic change also leads to an increasing heat demand, because it implies a larger amount of living space per person which must be heated. The population shrinking leads *ceteris paribus* to a reduction in energy consumption. Demographic change thus generates different counteracting effects on the energy consumption of households.

When considering the relationship between demographic change and overall energy demand, space heating plays a special role – not only because it accounts for a major share of households' total energy demand but also because there may be cohort effects due to the remanence effect. At the regional level, substantial differences can be observed between the "heating mix" of households. This is partly due to technological differences (district heat is more common in East Germany) but also due to socio-economic factors (East German households being on average poorer and more likely to live in rented apartments than West German households). Hence, infrastructure planners should take the technological and socio-economic conditions of the planning region into account.

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Part IV
Evaluation of Findings

Chapter 11
Evaluation of Findings on Sustainability Strategies

Hermann Keimel and Holger Schlör

Abstract The German national sustainability strategy and the federal spatial planning policy provide the basis for deriving a concept for sustainable development that corresponds to the object of study in the InfraDem project. Nine indicators of sustainability have been applied in the InfraDem project to evaluate the contribution made by demographic development to sustainable development. These indicators have been chosen according to the object of study. They are not applicable for the evaluation of overall sustainable development in Germany, Hamburg or Mecklenburg-Western Pomerania. This type of evaluation requires additional indicators, referring to factors such as research and development, habitation and the preservation of nature, which are not considered in this study. In order to achieve sustainable development, further measures – substitution and technological progress – as well as a change in behavioural patterns are required (for example, in the case of carbon dioxide emissions). A theoretical concept for the definition of sustainable spatial development, stipulating appropriate indicators and related target values, is required.

Keywords Demographic development · Regional sustainable indicators · Scenarios · Target values · Contribution of demographic development to sustainable development

11.1 Introduction

In April 2002, the German government published a paper on a national strategy for sustainable development entitled “Perspectives for Germany” (German Federal Government, 2002). Since then, the sustainability strategy has been a vital policy in Germany. In order to allow for the assessment of the strategy’s effectiveness,

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appropriate indicators have been chosen, composed mainly of quantitative objectives (Federal Statistical Office, 2008).

This national strategy forms the basis for the evaluation of the contribution made by demographic development to sustainable development in our analysis focusing on energy and transport, as well as in the regional analyses on Hamburg and Mecklenburg-Western Pomerania.

Section 11.2 describes the sustainability concept of the InfraDem project. This concept mainly deals with the issue of transferring the national strategy to the regional level.

In Section 11.3, the chosen sustainability indicators and target values are explained in ecological, economic and social terms, and they are used to measure the project outcome. The final Section 11.4 provides a résumé.

11.2 Sustainability Concept

The national sustainability strategy and the federal spatial planning policy provide the basis for deriving a sustainability concept that corresponds to the object of study in the InfraDem project.

In April 2002, the German Federal Government decided on a national strategy for sustainability: "Perspectives for Germany" (German Federal Government, 2002). This strategy defines sustainable development, as well as the fundamental targets and tasks of the government and society. It includes long-term orientation with regard to the ecological, economic and social development of the Federal Republic of Germany.

According to the federal spatial planning policy adopted in 1997 (German Federal Parliament, 1997), the principle of spatial planning is a sustainable spatial development, harmonizing with the social and economic requirements of the region and its ecological role, thus leading to a lasting, spaciously balanced order.

However, a clear definition of sustainable spatial development is not yet possible. To a large extent, scientifically founded target values and threshold values are missing for the definition of sustainable spatial development. A pragmatic solution is offered by the procedure applied by the Federal Office for Building and Regional Planning (BBR), namely concentrating on the indicators on the measurement of sustainability deficiencies (German Federal Parliament, 2005).

Focusing on national values is not an appropriate, target-aimed perspective when assessing sustainability deficiencies. A deviation from the average is not necessarily a problem or a deficiency. Different spatial starting positions and potential unavoidably cause regional differences. The issue of more or less sustainable spatial development is therefore addressed in the InfraDem project by adopting the BBR concept, which allows for ranges of acceptable or critical differences. The target values only provide minimum and/or maximum regional standards. Sustainability targets are endangered when these values are either lower or higher.

For 2030 – the final year of our model calculations – no defined target values are available. The available target values mainly refer to the years 2010 or 2020 or even in certain cases to 2050. The given target values referring to the year 2030 are therefore partly interpolations of those referring to 2020 and 2050. If no target values are available for 2050, then we have derived them for 2030 on the basis of scientific studies, forecasts, and other sources.

11.3 Indicators of Sustainability and Target Values

Figure 11.1 shows an overview of the indicators of sustainability, which have been applied in the InfraDem project. These indicators are used to evaluate the contribution of demographic development to sustainable development in our sector-based study (energy and transport) and our regional study (Hamburg and Mecklenburg-Western Pomerania). They are not applicable for the evaluation of the overall sustainable development in Germany, Hamburg or Mecklenburg-Western Pomerania. Such an evaluation requires additional indicators, referring to areas such as research and development, habitation and preservation of nature, which are not considered in this study.

11.3.1 Ecological Dimension

The ecological dimension of sustainable development is grouped into the areas of energy consumption, climate and air quality. For each area, one indicator has been chosen and a corresponding target value set (Table 11.1).

On the occasion of the third and final energy summit, held on 3 July 2007, representatives from research and industry, as well as policy makers were invited by

	Ecological Dimension	Economic Dimension	Social Dimension
Area	Energy consumption	Prosperity	Accessibility
Indicator	Proportion of renewable energy in the primary energy consumption (%)	Gross domestic product per head (€)	Accessibility of regional centres and airports (min)
Area	Climate	Labour market	Transport safety
Indicator	Carbon dioxide emissions (t)	Employment rate (%)	Number of fatal car accidents
Area	Air quality	Productivity	Energy security
Indicator	Nitrogen oxide emissions (t)	Energy productivity (€/J)	Energy import (J)

Fig. 11.1 Indicators of sustainability

Table 11.1 Indicators of sustainability: ecological dimension

Area	Energy consumption	Climate	Air quality
Indicator	Proportion of renewable energy in the primary energy consumption (%)	Carbon dioxide emissions (t)	Nitrogen oxide emissions (t)
Target 2020: Germany	20% (German Federal Government, 2007)	Reduction as opposed to the year 1990 by 40% (Federal Statistical Office, 2008)	Reduction of 60% compared to 2000 (Commission of the European Communities, 2005; German Advisory Council on the Environment, 2008)
Target 2030: Germany	30%, according to (Nitsch, 2008)	Reduction of 50% compared to 1990, according to (Nitsch, 2008)	Reduction as opposed to the year 2000 (German Advisory Council on the Environment, 2008)
Target 2030: regional	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)

Federal Chancellor Dr. Angela Merkel to lay the foundation for a German energy and climate policy programme (German Federal Government, 2007). This programme stipulates that the proportion of renewable energy is to be increased to 20% of the primary energy consumption by 2020. There is no stipulated target yet for the year 2030. In the current study, a target of 30% has been set based on the Lead Study 2008 performed on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Nitsch, 2008). This study describes one way of reducing greenhouse gas emissions to around 20% of the 1990 value in Germany by 2050. The strategy aiming to substantially expand renewable energy is a significant design element. The target values for the federal states Hamburg and Mecklenburg-Western Pomerania (75% of the value for Germany) follow – as described in Section 11.2 – the concept of sustainable spatial development applied by the Federal Office for Building and Regional Planning (German Federal Parliament, 2005).

Carbon dioxide emissions have been chosen as an indicator for climate stabilisation. According to the government's strategy for sustainability, carbon dioxide emissions are to be reduced by 40% from the level in 1990 by the year 2020 and by 80% by 2050 (Federal Statistical Office, 2008). The target reduction of 50% by 2030 corresponds to the (rounded) value for 2030, which is calculated as an interim result in the scenarios of the Lead Study in 2008 (Nitsch, 2008). The target value for the federal states Hamburg and Mecklenburg-Western Pomerania (75% of the value for Germany) again follow – as described in Section 11.2 – the concept of sustainable spatial development applied by the Federal Office for Building and Regional Planning (German Federal Parliament, 2005).

Nitrogen oxide emissions have been chosen as an indicator for the achievement of acceptable air quality. The EU Commission considers a reduction of 60% in nitrogen oxide emissions by 2020 compared to the values for 2000 as sufficient. In their Thematic Strategy on Air Pollution, they state that such a reduction is sufficient: "... to attain levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment" (Commission of the European Communities, 2005, p. 2). According to the German Advisory Council on the Environment (2008), more ambitious targets than a reduction of 60% are required for the protection of environment and health. They only accept this figure as an interim target. However, they do not suggest more concrete further targets. Therefore, we propose a reduction target of 80% for the year 2030.

Figure 11.2 shows a decomposition analysis of the development of carbon dioxide emissions in Germany. This analysis is based on the "high" population variant. Technology, behaviour patterns and preferences are assumed to remain constant (see Chapter 4).

The level effect indicates the influence of the increasing gross domestic product assuming other factors remain constant.

The demographic effect indicates – assuming other factors remain constant – the influence of the changing consumption and production patterns due to the aging population.

Assuming other factors remain constant, the income effect indicates the influence of the changing consumption and production patterns due to rising income.

The estimates show that demographic development only contributes to a small extent to the attainment of the corresponding target.

This also holds for the scenario that assumes low population growth. Furthermore, neither Hamburg nor Mecklenburg-Western Pomerania attains the reduction targets.

Figure 11.3 shows the development of carbon dioxide emissions in Germany (high scenario) by means of a decomposition analysis. It illustrates how the measures suggested by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety (Nitsch, 2008) affect the achievement of the corresponding reduction targets (see Chapter 7).

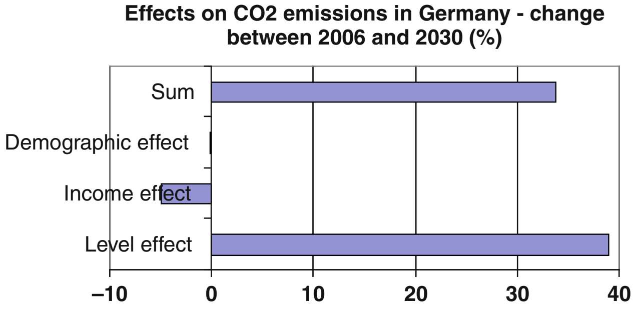

Fig. 11.2 Decomposition analysis (high scenario) using the example of climate (carbon dioxide emissions)

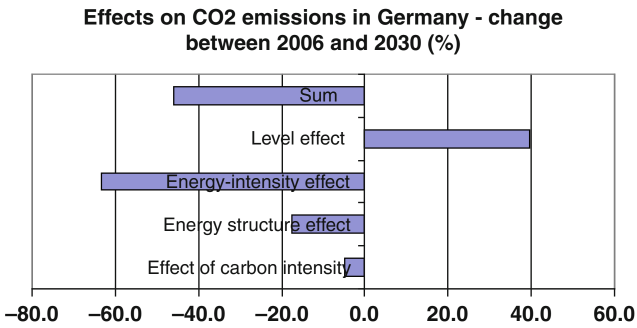

Fig. 11.3 Adding further tasks: decomposition analysis (high scenario)

The level effect indicates the influence of the rising gross domestic product assuming other factors remain constant.

The effect of carbon intensity indicates the influence of the change in the composition of fossil energy sources (bigger portion of lower carbon fossil energy sources) assuming other factors remain constant.

The energy structure effect indicates the influence of the growing share of renewable energy sources in the energy mix assuming other factors remain constant.

The energy intensity effect indicates the influence of the decreasing energy consumption per domestic gross product unit assuming other factors remain constant. It consists of the technology effect (increasing energy efficiency) and the structure effect (growing part of the domestic gross product of low-energy production areas – mainly in the service branch).

Similar results were observed for nitrogen oxide emissions. Demographic development does not directly influence the share of renewable energy resources in the primary energy consumption as the latter is affected by political and economic decisions.

11.3.2 Economic Dimension

The economic dimension of sustainable development is grouped into the areas of prosperity, labour market and productivity. A respective indicator with the corresponding target values was chosen for each area (Table 11.2).

The gross domestic product (GDP) is a measure of a country's overall economic performance. It is considered to be an important indicator for a national economy and its growth, but is not conceived as a general measure of wealth. There are diverse relations between the development of GDP and other topics in relation to sustainability. Thus, social factors like the structure of population, the availability of labour, the child care system as well as the social solidarity of the society play an important role for the international competitiveness of the economy. Growing economic performance is desirable under the aspects of common benefit. Sufficient economic

Table 11.2 Indicators of sustainability: economic dimension

Area	Prosperity	Labour market	Productivity
Indicator	Gross domestic product per capita (€)	Employment rate (%)	Energy productivity (€/J)
Target 2020: Germany	No target	75% (Federal Statistical Office, 2008)	Double the figure for 1990 (Federal Statistical Office, 2008)
Target 2030: Germany	No target	80%, according to "best practice" (Eurostat, 2007)	A 2.5-fold increase compared to 1990, according to (Nitsch, 2008)
Target 2030: regional	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)	At least 90% of the value for Germany (German Federal Parliament, 2005)	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)

growth guarantees existing jobs and allows for new jobs. It also stabilises the welfare state while coping with an aging population and the desired social equity of generations.

In the national strategy for sustainability (Federal Statistical Office, 2008), no quantitative target per head is given for the indicator GDP. However, growing economic performance is emphasised under the aspects of common benefit. Therefore, in our study, no concrete target value is stipulated for the indicator of wealth. The target value for the federal states Hamburg and Mecklenburg-Western Pomerania (75% of the value for Germany), as described in Section 11.2, follows the concept for sustainable spatial development of the Federal Office for Building and Regional Planning (German Federal Parliament, 2005), whereby the 75% threshold follows the EU development area classification.

The shift in the ratio of pensioners to employees leads to the threat of a growing financing shortfall in a society's social security system. Consequently, it will become more important to optimally exploit the available labour potential. The government is therefore aiming to increase the employment rate, i.e. increase the number of gainfully employed persons between the ages of 15 and 64–73% of the total population by 2010 and to 75% by 2020 (Federal Statistical Office, 2008).

The target employment rate of 80% by 2030 is realistic, as demonstrated by the employment rates achieved in other European countries in 2007 (Switzerland 78.6%, Norway almost 76.8%) (Eurostat, 2007).

The target values for the federal states Hamburg and Mecklenburg-Western Pomerania (90% of the value for Germany) again follow – as described in Section 11.2 – the concept for sustainable spatial development of the Federal Office for Building and Regional Planning (German Federal Parliament, 2005).

The use of energy is very important for the economic process, since almost every production activity is related to the consumption of energy. Private households consume energy predominantly for heating, warm water, electronic devices and the operation of vehicles. The level of energy consumption can lead to diverse environmental impacts, such as adverse effects on landscapes, eco-systems, soil, waters, and groundwater as a result of the exploitation of energetic resources, the emission of pollutants and greenhouse gases that affect the climate, the generation of waste, as well as the consumption of cooling water when converting und using energy sources. The importance of energy is strongly emphasised from an economic and environmental point of view in the government's strategy for sustainability. The energy productivity indicator is applied in this report (GDP in real terms, per unit of primary energy consumption). The government aims to double the energy effectiveness by the year 2020 compared to 1990 (Federal Statistical Office, 2008).

The target 2.5-fold increase in the energy effectiveness by 2030 was derived from the Lead Study 2008 (Nitsch, 2008).

The target value for the federal states Hamburg and Mecklenburg-Western Pomerania (75% of the value for Germany) again follows – as described in Section 11.2 – the concept for sustainable spatial development of the Federal Office for Building and Regional Planning (German Federal Parliament, 2005).

Figure 11.4 shows the trend of the employment rate in the regions considered (high scenario). The proportion of elderly people among employable persons with a lower employment rate is currently increasing, but it will level out in 2010 followed by a decrease.

The sustainability targets will not be attained in Germany or Mecklenburg-Western Pomerania. Hamburg will arrive at the corresponding sustainability, if the criterion of 90% of the federal value is applied. This indicates the difficulty of measuring sustainable spatial development in relation to the overall national target. If the national value does not comply with the requirements of sustainability, the regions will exhibit better results than the national value when an indicator is applied and it will not necessarily contribute to sustainability in a positive way. The sustainable use of the respective resources is compared to use in the other regions.

In Hamburg, the GDP per head will reach 184% of the national value in 2030 (high scenario) as opposed to 175% in the year 2005. In Mecklenburg-Western Pomerania, the GDP per head will be 72% of the national value in 2030 as opposed

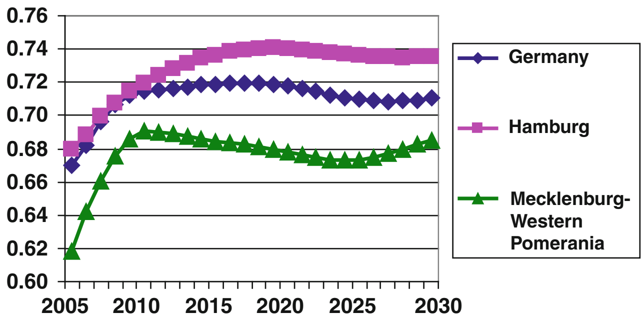

Fig. 11.4 Example labour market: employment rate (high scenario)

to 73% in 2005 (see Chapter 2). Whereas the relative wealth will continue to increase in Hamburg, it will remain constant in Mecklenburg-Western Pomerania, indicating sustainability deficiencies.

The energy productivity only slightly increases when the influence of economic growth, rising income and demographic change are considered and all other factors are assumed to remain constant in all regions and scenarios analysed (see Chapter 4). Consequently, if the measures outlined in the Lead Study 2008 (Nitsch, 2008) are neglected, the sustainability target will not be attained (see Chapter 7).

11.3.3 Social Dimension

The social dimension of sustainable development is divided into the areas of accessibility, assurance of transport and energy supply, to which an individual indicator has been allocated (Table 11.3).

Regional centres are sites of highly ranked, household-oriented infrastructural organisations in the areas of transport, education and research, culture and sports, as well as administration. Simultaneously, trade and industry concentrate here on supplying goods and services, which exceed the daily requirements. Spatial

Table 11.3 Indicators of sustainability: social dimension

Area	Accessibility	Transport safety	Energy security
Indicator	Accessibility of regional centres and airports with cars (min)	Number of fatal car accidents	Energy imports (J)
Target 2020: Germany	Regional centres: at most 45 min (German Federal Parliament, 2005) Airports: at most 2 h (State Parliament of Mecklenburg-Western Pomerania, 2005)	Reduction of 70% compared to 2001 (Green Parliamentary Group in the German Federal Parliament, 2007)	Reduction of 26% compared to 2005 (Commission of the European Communities, 2008)
Target 2030: Germany	Regional centres: at most 45 min (German Federal Parliament, 2005) Airports: at most 2 h (State Parliament of Mecklenburg-Western Pomerania, 2005)	Reduction of 80% compared to 2001 according to "Vision Zero" (Verkehrsclub Deutschland, 2004)	Reduction of 40% compared to 2005, according to (Nitsch, 2008)
Target 2030: regional	Regional centres: at most 45 min (German Federal Parliament, 2005) Airports: at most 2 h (State Parliament of Mecklenburg-Western Pomerania, 2005)	At least 75% of the value for Germany, according to (German Federal Parliament, 2005)	No target

and regional planning organisations worded guidelines back in the 70s, such as the threshold of 45 min for cars and 60 min for public transport for access to regional centres (German Federal Parliament, 2005). The guideline for the accessibility of airports corresponds to the air transport concept of the federal state of Mecklenburg-Western Pomerania.

Many European countries have quantitative targets aiming to reduce fatal car accidents. These targets more or less follow the targets stated in the White Paper on transport policy issued by the European Commission (Commission of the European Communities, 2001). The year 2010 is the target year and the aim is to halve the number of people killed by car accidents in 2001.

Moreover, “Vision Zero” aims at zero people dying in car accidents. This target is considered a qualitative target in order to intensify measures for traffic safety. In Sweden, Switzerland, Denmark and Norway, “Vision Zero” is an official target.

In Germany, the discussion on “Vision Zero” has been initiated by the German association of car drivers (Verkehrsclub Deutschland, 2004). The political party “Bündnis 90/die Grünen” has taken up “Vision Zero” and outlined a strategy for achieving this target in a position paper (Green Parliamentary Group in the German Federal Parliament, 2007). The party demands a reduction of at least 70% in fatal car accidents by 2020 compared to the rates in 2001. It also aims to avoid car accidents in the long term. Our target values are based on this aim.

The target values for the federal states Hamburg and Mecklenburg-Western Pomerania (75% of the value for Germany) again follow – as described in Section 11.2 – the concept of sustainable spatial planning applied by the Federal Office for Building and Regional Planning (German Federal Parliament, 2005).

The EU Commission aims to reduce energy imports by 26% compared to 2005 before 2020 (Commission of the European Communities, 2008). This value has been adopted for Germany in this study. The target value for 2030, namely a reduction of 40%, follows the Lead Study 2008 (Nitsch, 2008). With regard to the federal states, the stipulation of target values for the reduction of energy imports does not make sense.

Table 11.4 shows the accessibility of regional centres (within 45 min by car) and of airports (within 2 h by car) for the residents of Mecklenburg-Western Pomerania.

Regional centres comprise basic, sophisticated and high-level requirements. Therefore, the situation in Mecklenburg-Western Pomerania is critical because only half of the number of residents reaches them within a decent time span (max. 45 min). The minor increase in accessibility between 2005 and 2030 is due to

Table 11.4 Example: accessibility in Mecklenburg-Western Pomerania; proportion of residents who reach regional centres and airports within the mentioned time (%)

High version	2005	2030
Regional centres	48.8	50.7
Airports (Hamburg and Berlin)	31.4	32.3
Airports (Hamburg, Berlin and Rostock)	94.0	94.5

demographic reasons. The more rurally structured districts of Mecklenburg-Western Pomerania will shrink more than the districts around the regional centres (see Chapter 2).

Almost 100% of the residents in Mecklenburg-Western Pomerania reach an airport within 2 h. The targets defined in the air transport concept of the federal state of Mecklenburg-Western Pomerania are therefore attained. However, this indicator provides little information on the quality of air transport connections in Mecklenburg-Western Pomerania. To this end, the methods of transport to corresponding airports have to be considered. The scenario assuming a low population density shows accessibility indicators of the same dimension.

With regard to the number of people killed by car accidents, both Hamburg and Mecklenburg-Western Pomerania fail to attain the targets in both scenarios based solely on demographic development and unchanged traffic behaviour.

Energy imports are largely independent of demographic development. When strategies for an increased use of renewable energy are implemented, the sustainability targets should be reached (see Chapter 7).

11.4 Conclusions

Demographic development and the induced economic effects contribute only to a minor extent to the achievement of sustainable development. It is therefore doubtful that demographic change will lead to sustainability. In order to achieve this goal, further measures, such as substitution and technological progress, as well as a change in behavioural patterns are required (for example, in carbon dioxide emissions).

A theoretical concept for the definition of sustainable spatial development stipulating appropriate indicators and related target values is required. This concept could follow the targets of sustainability applied by the German government, but it should also take into account the different starting positions, the potential of and the problems in the individual regions. An agreement on what the individual regions should do could follow the idea of burden sharing, a concept which was applied by the EU in the context of the Kyoto Protocol. Science could contribute to this process by stipulating target values or procedural issues. However, sustainability as a normative concept must be defined by society as a whole.

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Chapter 12
Policy Implications: The Regional Perspective and Beyond

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Abstract The following chapter summarises the key findings of the preceding chapters, embedding them into a discussion of general infrastructure policy. The resulting central question is how the burden of infrastructure adaptation associated with demographic change can be allocated. Inevitably, normative principles associated with regional infrastructures become the focal points, mainly culminating in the discussion on the equality of opportunity of welfare and the practice of regional redistribution policy. In this context, the implications for infrastructure planning and for sustainable development are discussed. Finally, the results, which are analysed with a focus on Germany, are reconsidered in terms of their relevance for other countries.

Keywords Infrastructure policy · Infrastructure planning · Sustainable development · Equivalent living conditions · Statutory duties

12.1 Introduction

The previous chapters discussed various aspects of demographic change and its effects on the economy and society in general. These analyses focused on technological aspects of grid-bound infrastructures during demographic changes.

In this concluding chapter, we draw the main themes of the book together by summarising the key findings (Section 12.2). One of the most relevant findings is that demographic development will be spatially heterogeneous. Accordingly, the requirements for the adjustment of grid-bound infrastructures, which result from preserving the operating ability and upholding normative principles (duties to

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supply), vary spatially. The impact of the spatial heterogeneity on adjustment costs is analysed in detail for specific infrastructures in Section 12.3. In Section 12.4, relevant normative spatial principles for the provision of infrastructures are described and their impact on the adjustment of infrastructures to demographic changes in the context of political options outlined. The chapter proceeds with a discussion on the implications for infrastructure planning (Section 12.5) and sustainable development (Section 12.6). Furthermore, since the analysis focuses on Germany and two selected regions within it, we also discuss to what extent the results of the InfraDem project are relevant for other countries (Section 12.7).

12.2 Summary of Key Findings

The starting point of our analysis was the identification of two long-term trends that will shape demographic development in Germany over the first half of the twenty-first century: an increasing life expectancy and a birth rate below the reproduction level. These trends cause the German population to age and shrink. According to the demographic projections outlined in Chapter 2, the mean age will increase by roughly 4.5 years between 2005 and 2030, while the population size will decrease from 82.4 million to between 78.6 and 81.2 million, depending on the assumed net migration. The demographic projections for Hamburg and Mecklenburg-Western Pomerania clearly show that there are significant differences across regions. Therefore, studies on the effects of demographic change should not only be undertaken at the national level; they should be complemented by regionally differentiated studies to capture the regional diversity of demographic developments.

Another key element of Chapter 2 was a projection of GDP, taking into account the demographic developments in Hamburg, Mecklenburg-Western Pomerania and Germany as a whole. A simple Solow-Swan growth model was used to estimate the impact of demographic change, which affects the size of the labour force, on GDP. The model results suggest that despite the reduction in the labour force, and the increasing age dependency ratio, real GDP will still continue to grow for two reasons: First, the reduction in the labour force does not imply a proportional decrease in employment, because currently there is much slack (i.e. unemployment) in the German labour market. Second, technical change can be expected to raise productivity further, and output per worker will grow rapidly enough to overcome the increasing age dependency ratio, thus allowing output per capita to continue grow.

In Chapter 3, a more sophisticated growth model was used to study the effects of demographic change on the accumulation of various types of capital (real capital, human capital and two varieties of technical knowledge). This analysis showed that as demographic development makes human capital increasingly scarce, other forms of capital are accumulated more rapidly. Real capital and technical knowledge serve as substitutes for human capital and enable the economy to overcome the increasing scarcity of human capital.

Demographic developments affect not only the level of GDP and other macroeconomic variables; they also affect the structure of consumption and production. In Chapter 4, these structural effects were analysed with the help of input–output models for Germany and the two selected regions. The model results show that demographic change does indeed have significant effects on the composition of final demand, which in turn affect sectoral production and – since industries differ in energy and emission intensities – overall energy use as well as the associated emissions. These structural changes have important implications for infrastructure planning and sustainable development, especially at the regional level.

The regional aspects of demographic change were further analysed in Chapter 5, focussing on the development of transportation demand in Hamburg and Mecklenburg-Western Pomerania. This analysis confirmed the importance of regionally differentiated policies, pointing out that in Mecklenburg-Western Pomerania the use of roads may decrease to such an extent that – for the sake of efficiency – it might become sensible to disassemble certain roads. The authors of Chapter 5 emphasised, however, that such a decision should not only depend on the intensity of road use but also on accessibility questions. With respect to air transport, the situation is different because the number of flights per capita grows relatively quickly in the projections outlined in Chapter 6. As a result, the demand for air transport in Mecklenburg-Western Pomerania is expected to increase.

Whereas Chapters 5 and 6 focussed on transportation, Chapters 7 and 8 discussed the relevance of demographic development for the energy system. In Chapter 7, it was shown that demographic change tends to have a negative impact on energy efficiency in the sense that it increases energy demand per capita due to the higher specific heat demand of older people. However, since demographic change is subject to high regional variability, it may actually increase the prospect of supplying district heat by means of renewable energy in many municipalities, as evidenced by the spatial analysis conducted in Chapter 8.

Despite addressing different topics and using different approaches, the earlier chapters of this book used a common methodology based on identifying differences between age groups and deriving their implications for future energy use and transportation demand. Chapters 9 and 10 went a step further by considering not only differences between age groups but also behavioural changes within each age group over time. As argued in Chapter 9, this is highly relevant for questions involving mobility, where cohort effects may arise because individuals belonging to a given cohort retain their mobility patterns as they get older, at least to a certain extent. These effects arise, for example, with respect to driving licenses, which are usually obtained at the age of 18 or slightly older and remain valid, in principle, forever. Chapter 10 showed that cohort effects may also arise in the field of energy, pointing out the special role of heat demand and the remanence effect.

Chapter 11 discussed the findings of the previous chapters and their relevance for the political ideal of sustainable development. It points out that energy and transportation are highly relevant to sustainable development because they are closely related to greenhouse gas emissions and other environmental problems and also because the availability of energy and transportation services is directly related to the issue of social sustainability. The key finding of Chapter 11 is that demographic change and the associated economic impact contribute to the achievement of sustainable development, but only to a minor extent. If sustainable development is to be achieved, significant changes are necessary in technology and behaviour.

12.3 The Burden of Infrastructure Adjustments to Demographic Change

The analysis in Chapter 2 showed that demographic changes take place on a scale and with a speed that require consideration in long-term decision making. With respect to politics, they are important for the adjustment and organisation of social security systems (especially the pension scheme); on the supply side of the economy, investment decisions with a long-term planning horizon are affected. Among capital goods, long-living goods (characterised by a low depreciation rate) and capital-intensive goods are hit by demographic demand changes (Chapters 4, 9 and 10). The latter includes grid-bound infrastructures.

Demographic adjustments will at the same time result in a population increase and decrease (Chapter 2) and they will be overlaid by long-term trends of behavioural changes (e.g. rise in air traffic, Chapter 6). Thus, specific capacity adjustments to demand changes (Chapter 5, decreasing road use in Mecklenburg-West Pomerania) will be required.[1]

- If capacity limits of existing infrastructures are reached as demand rises and there is a statutory duty to supply or if it is profitable to satisfy this demand, investments that guarantee supply will generally be inevitable.
- Under-utilisation results (assuming decreasing population density (urban sprawl) and existing statutory duties to supply) in rising specific user costs (cost per connected resident) of technical infrastructures as a consequence of the constant operating and maintenance cost of non-adjusted grids and a decreasing number of users.

An estimate of the development of the per capita cost for the region Havelland-Fläming shows the following tendencies (Siedentop et al., 2006):
Specific user costs

- in less densely populated municipalities exceed the regional average by 10%.
- are especially high in less densely populated municipalities whose population declines. They exceed the regional average by 20–30%.
- of growing municipalities also exceed the average.

[1]The deviation of requirements from normative principles will be discussed in the following section.

Therefore, a population decrease of 10% and more results in an increase of 10–20% in the specific user cost in the considered regions. Analysed infrastructures included water supply, waste water, road transport and long-distance heating. These figures clarify that especially residents in shrinking regions experience a rise in specific user cost.[2]

Furthermore, the experience of East German regions that have already shrunk reveals that water supply, waste water and long-distance heating grids are functionally impeded by under-utilisation (Koziol, 2007). In these regions, decreasing population density has resulted in reduced flow velocities of the transported media which causes increased storage periods. As a consequence, water quality decreases and unpleasant odour and heat losses occur. To maintain functionality, flow velocity can be enhanced or the pipeline cross-section can be reduced (Koziol & Walther, 2006). Thus, costs for these infrastructures will grow by under-utilisation or by increased operating costs or negative growth-caused investments and lift specific user cost even more (Umweltbundesamt, 2007; Haug & Deilmann, 2008).

12.4 Normative Principles in the Context of Regional Infrastructure Provision

In addition to demand and technical feasibility aspects of infrastructure adjustments to demographic changes, the normative environment from which infrastructure provision strategies are deduced is of crucial importance. Whether the demand for infrastructures is to be satisfied and therefore whether infrastructures have to be planned depend among other things on an existing statutory duty to supply or a possible conflict with other principles, such as profitability requirements of municipal utilities. A further aspect that affects infrastructure supply is financing. For example, the possibility to communalise the local demographic burden might be deduced from the principle of equivalent living conditions that constitutes – as prescribed by law – the foundation of several distributional institutions in Germany. Such an option is decisive for investments.

In this section, normative principles will be presented which are related to the emergence and distribution of burden resulting from demographic adjustments. This facilitates the discussion on infrastructure policy and comprehensive planning in the context of demographic adjustments.

These principles are the integrative definition of distributive justice according to John Roemer (Section 12.4.1), the principle of equivalent living conditions prescribed by the German Constitution that serves as a guideline for regional distribution policy (Section 12.4.2), the services for the public (Daseinsvorsorge) defined as a municipal duty to supply technical and social infrastructures (Section 12.4.3), and the legal form of the infrastructure supplying institutions (Section 12.4.4).

[2] Similar results are presented in Koziol (2007). See also Kuckshinrichs and Schlör (2005, 2006) and Schlör, Hake, and Kuckshinrichs (2009).

12.4.1 Equality of Opportunity for Welfare – In Spatial Context

Equality of opportunity is a broadly accepted consensus in western democracies. This is stated, for example, by John Roemer (Roemer, 1995): "Citizens of western liberal democracies generally endorse equality of opportunity,. . .". Several normative principles in the Federal Republic of Germany that enter the constitution at different points and form the institutional base of the society can be justified by this convention.

Roemer specifies the convention and thereby proposes a theory of distributive justice (EOPW in Roemer (1996) and Roemer (1998)). The theory consists of an aggregation procedure of individual preferences to a social welfare function. The result of the aggregation depends on a parameter that quantifies personal responsibility. Rawls and the utilitarian welfare function can be interpreted as extreme parameterisation of the aggregation procedure that results from the extreme personal responsibility concepts of "completely personal responsible" and "completely not personal responsible", respectively.[3] The definition of social welfare is relevant for the deduction of an economic policy. The optimal policy derived from a utilitarian welfare function is less redistributive than a policy derived from Rawls' welfare function.

With his approach, Roemer transforms 1. the question of the appropriateness of a specific form of utility aggregation to the question of the appropriateness of a specific parameter value, and 2. the discussion about distributive justice to a discussion about personal responsibility. The debate about justice thereby becomes increasingly steady and objective.

EOPW can be applied to spatial aspects of distributional justice. A deviation can be motivated in the following way (parent-child special case): The starting point is the assumption that a child cannot be held responsible for economic conditions during his/her childhood. Therefore a child has to be compensated for deficits of well-being that it suffers as a result of adverse economic conditions for which its parents are responsible. Thus, for example, children should be compensated for disadvantages that are caused by spatial conditions of their parents' residence. Reasons for spatial income deficits are spatial productivity deficits, geographic conditions, lack of resources, high transport costs or historical conditions (e.g. the economic system in the former GDR). Compensation could be reached by direct transfers or the provision of education and health infrastructure.

If adults are completely personally responsible for their residence after reaching the legal age, it follows immediately that no further redistribution in favour of these

[3]The generalised welfare function is based on the conception of circumstances. Individuals decide on the basis of circumstances. For some circumstances, individuals are held responsible, for others they are not. Differences in individual well-being resulting from circumstances for which individuals are held responsible should not be compensated and vice versa. The classification of circumstances is the responsibility parameter. With increasing fineness of the classification (partition), the room for personal responsibility disappears.

adults can be justified on spatial deficits. Eventually, these adults could improve their individual well-being by migrating to a non-disadvantaged region.

However the dissociation from static social networks such as partner, family, and friends, which emerge in a phase of life up to the legal age and result from the residence of parents in a disadvantaged region, may also be interpreted as a mobility barrier that lies beyond personal responsibility and limits the personal options to choose residence freely. If adults are held only limited responsible for their residence, a claim of compensation for spatially caused individual welfare deficits results. This claim should fall quantitatively below the claim of a child that has not yet reached legal age. The compensation could be administrated by transfers or the reduction of mobility barriers.

12.4.2 Equivalent Living Conditions and the Practice of Spatial Distribution Policy in Germany

Based on these considerations, the principle of equivalent living conditions could be deduced. It is formulated as the basic principle in Article 72 Paragraph 2 Clause 3 of the Basic Law for the Federal Republic of Germany[4]:

> "(2) The Federation shall have the right to legislate on matters falling within... Article 74, if and to the extent that the establishment of *equivalent living conditions* throughout the federal territory or the maintenance of legal or economic unity renders federal regulation necessary in the national interest."

and put into effect in Article 107 (fiscal equalisation scheme, Finanzausgleich):

> "(2) Such law shall ensure a reasonable equalisation of the disparate *financial capacities* of the Länder, with due regard for the financial capacities and needs of municipalities (associations of municipalities). It shall specify the conditions governing the claims of Länder entitled to equalisation payments and the liabilities of Länder required to make them as well as the criteria for determining the amounts of such payments. It may also provide for grants to be made by the Federation to financially weak Länder from its own funds to assist them in meeting their general financial needs (supplementary grants)."

and in the "Maßstäbegesetz". At the level of German federal states, a similar mechanism equilibrates the financial power (tax revenues per resident) of municipalities. The interpretation of the principle of equivalent living conditions shows up in the comprehensive regional planning (Raumordnung) and the horizontal fiscal transfer of German federal states. In this context, the financial capacity (tax revenues of federal states per resident) is defined as operational equalisandum.

If the latter definition was justified by pragmatic or ideological considerations cannot be reconstructed directly. However, it can be argued that tax revenues of federal states have to be equalised to establish uniform preconditions for the construction of infrastructures (among others grid-bound infrastructures). As soon as

[4]Basic Law for the Federal Republic of Germany, https://www.btg-bestellservice.de/pdf/80201000.pdf, Published by: German Bundestag, Public Relations Division, Berlin April 2010.

grid-bound infrastructures form the basis for economic activity and thereby the possibility to generate income, the conception can be interpreted as "resource egalitarian" (Roemer).

In addition to the equalisandum, the degree of equilibration constitutes a politically interpreted determinant of equivalent living conditions. The degree can be quantified by comparing financial capacity before and after horizontal fiscal transfers. It shows that the financial power of MV rises with horizontal fiscal transfers from 47 to 98% of the average of German fiscal states.[5] This means a high degree of equalisation is reached and seen as appropriate. It can be deduced that the actual redistribution policy in Germany is based on the principle of equivalent living conditions and presumes, in the sense of Roemer's theory of distributional justice, a concept of a low degree of personal responsibility for residence with regard to the federal state.

12.4.3 Statutory Duties to Supply

Further principles of spatial infrastructure provision are statutory duties to supply. They are justified by the postulate of a welfare state (Sozialstaatspostulat, Article 20 Paragraph 1 GG) in the Basic Law. The service of general interest (Daseinsvorsorge) is deduced from this postulate. It confirms a public duty to provide goods and services that are required for a meaningful human existence. These goods and services are called *basic services* (Grundversorgung, Forsthoff, 1938; Jellinghaus, 2006). Basic services are technical and social infrastructures for the community. Statutory duties to supply can be found, for example, in the Landeswassergesetz Mecklenburg-Vorpommern (LWaG M-V):

Water supply § 43 duties of the public water provision:	*Wasserversorgung § 43, Aufgaben der öffentlichen Wasserversorgung:*
(1) Municipalities have to supply in the range of their autonomy in their territory population drinking and industrial water… (provider of public water supply)	*(1) Die Gemeinden haben im Rahmen der Selbstverwaltung in ihrem Gebiet die Bevölkerung und die gewerblichen und sonstigen Einrichtungen ausreichend mit Trink- und Brauchwasser zu versorgen… (Träger der öffentlichen Wasserversorgung).*
§ 40 Obligation to dispose waste water:	*§ 40 Abwasserbeseitigungspflicht:*
(1) Waste water disposal shall be administrated by municipalities in the range of their autonomy…	*(1) Die Abwasserbeseitigung obliegt den Gemeinden im Rahmen der Selbstverwaltung…*

[5]Ministry of Finance Mecklenburg-Vorpommern (May, 2010) http://www.regierung-mv.de/cms2/Regierungsportal_prod/Regierungsportal/de/fm/Themen/Finanzverfassung/Laenderfinanzausgleich/index.jsp

or in the Telekommunikationsgesetz (TKG, Kontrahierungszwang (Busche, 1999))

§78 Universal services	*§ 78 Universaldienstleistungen*
(1) Universal services are defined as the lowest level of services for the public,... for which end users must have independent of their residence and business location for an affordable price direct access and whose supply for the public as basic services has become indispensable.	*(1) Universaldienstleistungen sind ein Mindestangebot an Diensten für die Öffentlichkeit,... zu denen alle Endnutzer unabhängig von ihrem Wohn- oder Geschäftsort zu einem erschwinglichen Preis Zugang haben müssen und deren Erbringung für die Öffentlichkeit als Grundversorgung unabdingbar geworden ist.*
(2) As universal services are determined: 1. the connection to the public telephone network...	*(2) Als Universaldienstleistungen werden bestimmt: 1. der Anschluss an ein öffentliches Telefonnetz...*
§ 84 TKG Availability, unbundling and quality of universal services:	*§ 84 TKG Verfügbarkeit, Entbündelung und Qualität von Universaldienstleistungen:*
(1) If enterprises perform universal services, end users have a claim that these services are supplied.	*(1) Soweit Unternehmen Universaldienstleistungen erbringen, haben Endnutzer... einen Anspruch darauf, dass diese Leistungen erbracht werden.*

Infrastructures that are required to meet statutory duties to supply are predominantly provided by *municipal* companies. If this legal form includes normative implications will be analysed in the following section.

The general duty for the provision of infrastructures does not depend on its price with respect to its value. Therefore, the provision of infrastructures can be profitable or not. In the latter case, the duty to supply infrastructures or the financing of its provision has to be interpreted as direct regional goal-orientated subsidy. It complements other regional subsidies such as horizontal fiscal transfers. Finally, this duty must be – if necessary – financed from public funds.

If the provision is technical or in the sense of disproportionally high costs impossible to realise, duties to supply are frequently limited. For example, the water law (Wassergesetz) of Mecklenburg-Western Pomerania (LWaG) releases the municipal authorities from the duty to supply water

Water supply § 43	*Wasserversorgung § 43*
... The duty to provide does not exist if (1) the provision is technically or because of unjustifiable costs impossible...	*... Die Versorgungspflicht besteht nicht 1.wenn die Versorgung technisch oder wegen des unverhältnismäßig hohen Aufwands nicht möglich ist...*

and dispose of waste water:

Obligation to dispose of waste water (§ 40)	*Abwasserbeseitigungspflicht (§ 40)*
(3) The obligation to dispose waste water following paragraph 1 and to the relinquishment of waste water following paragraph 2 is not applicable... if a different disposal of the waste water is... because of unjustifiable cost appropriate... and the public welfare is not affected.	*(3) Die Pflicht zur Abwasserbeseitigung nach Absatz 1 und zur Überlassung des Abwassers nach Absatz 2 entfällt..., wenn eine anderweitige Beseitigung des Abwassers... wegen eines unvertretbar hohen Aufwandes zweckmäßig ist... und dadurch das Wohl der Allgemeinheit nicht beeinträchtigt wird.*

Another form of limiting the (costless) duties to supply can be found in electricity networks. Contributions towards the construction of a connection can be raised by owners[6]:

§ 11 contribution towards network construction costs	*§ 11 Baukostenzuschüsse*
(1) The network operator can charge a customer... with a contribution towards network costs for the partial coverage of the construction and reinforcement cost of local low voltage facilities under economically efficient management.... Contribution towards network costs are allowed to cover 50% of these cost at most.	*(1) Der Netzbetreiber kann von dem Anschlussnehmer einen... Baukostenzuschus zur teilweisen Deckung der bei wirtschaftlich effizienter Betriebsführung notwendigen Kosten für die Erstellung oder Verstärkung der örtlichen Verteileranlagen des Niederspannungsnetzes... Baukostenzuschüsse dürfen höchstens 50 vom Hundert dieser Kosten abdecken*

The burden analysis (Section 12.3) has shown that high infrastructure costs as a result of direct network connection will primarily affect shrinking regions with a low population density. It can be expected that exceptional rules will be preferred in these regions. The possible limitation of the duties to supply could thus be interpreted (resource egalitarian) as the assumption of personal responsibility when residing in these areas.

The aspect of services of general interest (Daseinsvorsorge) is relevant in other European states as well: in France as "service public", and based thereupon in the Treaty on the Foundation of the European Community as "services publics" in Art. 86(2) "Services of general economic interest" (Boysen & Neukirchen, 2007).

12.4.4 The Provision of Infrastructures by Private Enterprises

It has already been outlined that the provision of infrastructures on a municipal level is carried out primarily by public utility companies. On the one hand, they have to fulfill duties to supply – as was outlined in the previous section:

[6]Legal ordinance of general conditions for a network connection and utilisation of electricity supply in low voltage (Niederspannungsanschlussverordnung – NAV) 2006.

§3 Consequential cost	*§ 3 Folgekosten*
(1) The urban administration is allowed to request the change of public services in public places from public utility companies, if this is required for the implementation of public duties. Public utility companies bear the costs.	*(1) Die Stadt ist berechtigt, von den Stadtwerken die Änderung der in den öffentlichen Verkehrsräumen liegenden Versorgungsanlagen zu verlangen, soweit dies zur Erfüllung öffentlicher Aufgaben notwendig ist. Die Kosten tragen die Stadtwerke*[7]

On the other hand, they have to respect municipal regulations[8] to achieve positive profitability of their activities:

§109 Economic principles	*§ 109 Wirtschaftsgrundsätze*
Enterprises and organizations have to be operated, managed and supervised in a way to implement a public goal sustainably. Enterprises should yield a profit for the municipal budget, if the implementation of the public goal is not affected.	*(1) Die Unternehmen und Einrichtungen sind so zu führen, zu steuern und zu kontrollieren, dass der öffentliche Zweck nachhaltig erfüllt wird. Unternehmen sollen einen Ertrag für den Haushalt der Gemeinde abwerfen, soweit dadurch die Erfüllung des öffentlichen Zwecks nicht beeinträchtigt wird*

If the profitability requirement is taken seriously and is seen in the context of the prohibition of cross-subsidies,[9] demography-caused adjustments of the cost of infrastructures must be absorbed by price increases. However, if it is assumed that the "*completition of a public duty*" is impeded, subsidies from communal budgets could be used to finance demography-caused infrastructure adjustment cost.

Hence it can be concluded that by organising the provision of municipal infrastructure, profitability has been established as additional normative factor. From the point of view of an idealising economic perspective, this could be seen as a step towards efficient resource allocation. Nevertheless, it does not accommodate the previously composed normative context. Furthermore, via the choice of the legal

[7] Contract between the urban administration Schorndorf as the responsible body for the municipal utility and the municipal utility Schorndorf (May, 2010 http://www.schorndorf.de/ceasy/modules/ebs/main.php5?view=publish&item=statute&id=65)

[8] Extracts from municipal code of North-Rhine Westphalia for municipal companies: (http://www9.im.nrw.de/imshop/shopdocs/kommunalrecht_nrw.pdf May, 2010)

[9] Cross-subsidies of municipal utilities are not prohibited, nevertheless Matschke (2005) declares: *"... The EU puts consequently the continuation of cross-subsidization of municipal public utilities and municipal transport services into question because a public subsidization of the public transport is from the point of view of the EG-contract (Art. 73, 87, 234 EGV) regarded as competition distorting aid."*

form of the municipal utilities, the question of whether municipal activities are allowed to be subsidised enters the discussion.

12.4.5 Political Options for the Adjustment to Demographic Change

From the previously presented requirements, the cost resulting from the adjustment of infrastructures to demographic change and the normative context for political options can be deduced:

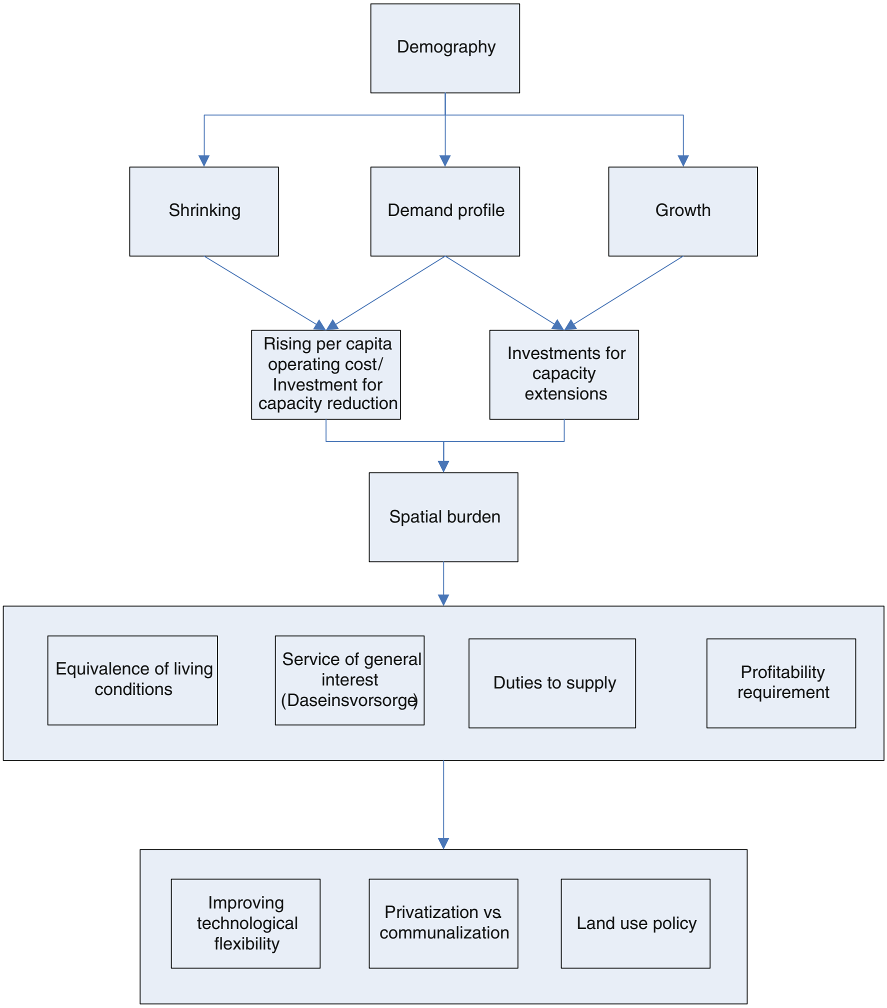

Fig. 12.1 Adjustment cost and normative context for political options

The costs of adjusting infrastructures to demographic change are influenced by several factors:

- Regional planning ("well-ordered withdrawal")
  If the population decreases without a change in the siting density, grid-bound infrastructures could be shut down and capacity adjustments could be avoided. Therefore, the prevention of an urban sprawl is a political option (Koziol, 2007) that can be operationalised by regional planning. Nevertheless, the advantages in cost prevention in the context of industrial location stand in opposition to inter-municipal competition.
- Improving the technological flexibility of infrastructure
  The installation of infrastructures that can be adjusted to different load situations at low cost can reduce the burden of demography-caused adjustments. Another way to meet infrastructure provision duties without unacceptable investment and operation costs is the technological transition from large-scale infrastructure grids to isolated applications.
- Communalising vs. privatising adjustment cost
  Profitability requirements of municipal utilities can serve as the basis for 1. limiting the duties to supply and 2. absorbing the cost of infrastructure adjustment caused by demographic change in the form of price increases. Both measures can be interpreted as the privatisation of adjustment cost.

In regions with above-average adjustment costs, horizontal fiscal transfers in their contemporary form offer the possibility to communalise such adjustment costs. Horizontal fiscal transfers are based on financial capacity. If the population in a federal state decreases, so too do tax revenues, even after fiscal transfers. At the same time, shrinking could cause increases in per capita expenditure to finance adjustments and maintain operation ability. This could in turn lead to an underfunding of infrastructure expenditures.

However, the Federal Constitutional Court[10] states that the shrinking of the East-German federal states by east-west migration could affect the implementation of municipal duties to supply. Therefore deviations of the equalisandum financial capacity could be justified in the sense that special costs have to be considered.

The same argumentation could be used for special adjustment costs for demographic transition. Special adjustment costs could therefore be accepted as part of the equalisandum and thus communalised. A change would have to be verified and evaluated according to the law on equalisation payments (Länderfinanzausgleichsgesetz).

As an alternative to the privatisation of municipal cost, the federal states could be publically subsidised via the municipal financial equalisation. The resulting funds

[10] BVerfG, 2 BvF 2/98 of 11.11.1999, Paragraph (321), http://www.bverfg.de/entscheidungen/fs19991111_2bvf000298.html

(bb) Already the decision of the senate from 27.05.1992 (BVerfGE 86, 148 <236>) has instructed the legislator to extensively verify the criteria that are supposed to support an abstract additional requirement for the implementation of municipal duties of larger municipalities. If the benchmark of population is to be modified even in future, the instruction to verify is even more pressing as:	*(bb) Bereits das Urteil des Senats vom 27. Mai 1992 (BVerfGE 86, 148 <236>) hat den Gesetzgeber mit der umfassenden Prüfung der Kriterien beauftragt, die einen abstrakten Mehrbedarf größerer Gemeinden bei der Erledigung kommunaler Aufgaben stützen sollen (§ 9 Abs. 3 FAG). Soweit der Einwohnermaßstab auch in Zukunft modifiziert werden soll, wird dieser Prüfungsauftrag umso dringlicher, als*
– the requirements of the neue Länder Brandenburg, Mecklenburg-Vorpommern and Thüringen will carry less weight by the contemporary weighting of residents,	*– der Bedarf der neuen Länder Brandenburg, Mecklenburg-Vorpommern und Thüringen durch die gegenwärtige Einwohnerwertung weniger Gewicht erhält (vgl. Tabelle, S. 45, Zeile 116),*
– the costs of many public services in less densely populated areas can exceed the cost in urban areas,	*– die Kosten vieler öffentlicher Leistungen in dünn besiedelten Gebieten deutlich höher liegen können als in den Städten,*
– furthermore communal costs have to be shared by a smaller population.	*– zudem die Gemeinkosten auf eine geringere Kopfzahl umgelegt werden müssen (vgl. Carl, Bund-Länder-Finanzausgleich im Verfassungsstaat, 1994, S. 87).*

could be shared via horizontal fiscal transfers between the federal states which could then claim extra money as a result of demography changes. However this approach would require highly coordinated political action between federal states and municipalities. It is questionable as to whether this high degree of coordination can be reached because it can be assumed that adjustments and the resulting cost will emerge slowly and on a municipal level.

12.5 Implications for Infrastructure Planning

Demographic change is a society-wide phenomenon with important effects on many aspects of the economy. This has been demonstrated by the input–output analysis outlined in Chapter 4, which showed that the structure of consumption expenditure by households is significantly affected by demographic change. However, in the case of infrastructure, demographic change plays a special role because of the longevity of infrastructure capital. Since the lifetime of technical infrastructure components such as highways and power plants is much longer than that of most consumer items, infrastructure planners need to plan much further ahead into the future than producers of consumer goods. The analyses described in the previous chapters clearly show that demographic change will have a significant effect on the demand for infrastructure services within the relevant planning period.

A major theme taken up in many of the previous chapters is the observation that demographic trends are subject to regional disparities within a country. This means that one cannot easily use findings from studies of demographic change at the national level to draw conclusions on the regional level. For example, it would be extremely difficult to come up with a universal statement like "demographic change causes an increase in the demand for infrastructure of type x", because this depends on regional characteristics. Our study shows that the impact of demographic change on infrastructure use in the case of Hamburg is very different from the case of Mecklenburg-Western Pomerania.

The regional variation in demographic change and its impact on infrastructure use also implies that studies performed at the national level are of limited use for infrastructure planning, because the national impact is simply the average of the individual regional impacts. If, for example, demographic change increases the demand for a certain type of infrastructure by $\times$ percent in one region and reduces it by $\times$ percent in another region of similar size, the national demand for that infrastructure neither rises nor falls, and one may falsely conclude that demographic change does not affect the demand for that infrastructure. Such a conclusion would be incorrect, because infrastructure is regionally bound due to its very nature, and transportation infrastructure in Hamburg is not a substitute for transportation infrastructure in Mecklenburg-Western Pomerania. In the case of electricity, regional infrastructure planning is not as strongly affected, because electricity can be transported across the country at a relatively low cost. For district heat, the regionalisation of demand and supply plays a much greater role, as shown in Chapter 8. These considerations suggest that regional studies of demographic change are indispensable for good infrastructure planning, especially with respect to transportation and heat provision and to a somewhat smaller extent in the case of electricity.

Unfortunately, regional studies of demographic change may not be feasible because the data requirements are not always fulfilled. A thorough analysis requires regional age-specific consumption data, regional demographic projections, and regional input–output tables. If these data requirements cannot be met, a thorough analysis is not possible. However, this does not mean that infrastructure planners in regions that do not meet the data requirements must remain totally uninformed of the impact of demographic change. Although, as argued above, it is impossible to generalise statements about the impact of demographic change on infrastructure use and to extrapolate these to *all* regions, it may be possible to generalise findings for different *types* of regions. Thus, a typification of regions would be helpful. Possible dimensions for such a typification could be the degree of urbanisation (urban versus rural regions) and the regional economic climate (growing versus stagnating regions). The two regions studied in the course of the InfraDem project would fit comfortably into such a typification, Hamburg is an urban region with a rapidly growing economy, while Mecklenburg-Western Pomerania is a rural region with a stagnating economy. Thus, it may be possible – with due caution – to extrapolate our findings for Hamburg to other urban, growing economies and those for Mecklenburg-Western Pomerania to other rural, stagnating economies.

However, in order to arrive at more robust conclusions, it will be indispensable to study the region of interest more closely. In this case, the methods deployed for the InfraDem project may be useful in many cases. For example, the effects of demographically induced changes in consumption expenditure by households can be studied using the methodology described in Chapter 4. To a certain extent, this is already being done. A number of researchers are currently constructing regional input–output tables using methods inspired by the InfraDem approach (Kronenberg, 2009; 2010). Although constructed for other purposes, these tables may also serve as the basis for a regional analysis along the lines of Chapter 4 in the future. Ideally, however, regional input–output tables should be provided by the statistical offices of the federal states in order to facilitate regional studies.

12.6 Implications for Sustainable Development

The relationship between demographic trends and sustainable development has been a topic of interest for a very long time – at least since the days of Thomas Malthus, who pointed out the problems that may arise if a growing population has to earn its living off a given supply of arable land. Interestingly, earlier researchers were usually worried about the problems caused by a *growing* population, whereas currently many economists warn about the problems that will be caused by a *shrinking* population. It appears that the field of economics is trying to do justice to its nickname of “the dismal science”.

In the nineteenth century, many classical economists agreed with Malthus, who had argued that agricultural production, being subject to diminishing returns to scale, cannot keep up with the exponential growth of the population in the long run. They did not foresee, however, that technological change would greatly increase agricultural productivity during the nineteenth and twentieth century. Pasinetti (1977) argues in his discussion of the classical theory of production that David Ricardo, one of the most influential classical economists, was writing under “strong Malthusian influence”, which led him to arrive at “pessimistic conclusions [that] have not been borne out in the economic history of the industrial countries”, where “increasing (not decreasing!) returns to scale by now prevail in many fields of production” (Pasinetti, 1977, p. 17). Thus, the growing population of Britain was spared the mass starvation feared by Malthus. Although poverty never completely disappeared, the capitalist countries managed to overcome the diminishing returns to land by accumulating capital and advancing technology.

Nevertheless, population growth was still seen as problematic, as evidenced in the growth literature emerging in the mid-twentieth century. According to the growth models of Harrod (1939) and Domar (1946), population growth can lead to ever-increasing unemployment if the rate of capital accumulation is too low to maintain full employment. Trying to solve some puzzles raised by the models of Harrod and Domar, Solow (1956; 1957) and Swan (1956) developed what later became known as the neoclassical theory of growth. In the Solow-Swan model (see Chapter 2), an increase in the population growth rate does not lead to unemployment (since full employment is assumed), but it does reduce the level of output per capita. This was interpreted as an explanation for the persistent differences in GDP per capita between rich and poor countries. Thus, neoclassical growth theory still sees population growth as an impediment to development, although its conclusions are much less pessimistic than that of the classical economists. During the 1960s, however, there was a resurgence of pessimism about population growth, culminating in the publication of Paul R. Ehrlich's *The Population Bomb* (Ehrlich, 1968) and increasingly loud calls for birth control. During the following decades, the debate has again calmed down to a certain extent, but the central dilemma – how to fulfil the needs and desires of a growing human population in a finite ecosystem – is still subject to debate.

At least in some countries, however, the discussion on population growth has entered a new stage, in which worries about the problems caused by population *shrinking* play a central role. Special attention has been paid to the sustainability of pay-as-you-go (PAYG) pension schemes. While the number of employees is shrinking, the number of pensioners is growing, and this raises difficult questions of distribution, equity, and efficiency. Since intergenerational justice is an important aspect of sustainable development, the distribution of income between employees and pensioners should not be ignored in discussions of political strategies for sustainable development.

As the focus of InfraDem was on grid-bound infrastructure, the issue of income distribution has received comparatively little attention. However, the GDP projections constructed in Chapter 2 show that despite the shrinking labour force GDP per capita still grows in real terms. Thus, the size of the total "pie" to be divided increases over time, which means that the distribution problem can, in principle, be solved.[11]

This discussion shows that concerns about financing the needs of pensioners with a shrinking labour force might be just as premature as worries about the feasibility of feeding a growing population with limited natural resources. In the former case, it is the scarcity of labour which gives cause for concern, whereas in the latter case natural resource scarcity is seen as a problem. However, since scarcity is a relative concept, the increasing scarcity of one primary input (labour or natural resources) always makes the other primary inputs less scarce. Modern economic systems incorporate mechanisms which accommodate for changes in the relative scarcity of primary inputs and thereby ameliorate some of the problems which might otherwise emerge.

Furthermore, it is important to realise that sustainable development is a multidimensional concept which can never be fully captured in a single statistic. For this reason, the approach adopted in Chapter 11 relies on a set of indicators reflecting

[11] In the debate on ecological sustainability, it has been argued that "we do not have to worry so much about how an expanding pie is divided, but a constant or shrinking pie presents real problems" (Costanza, 1989). Therefore, an increase in real GDP per capita ameliorates the conflict over income distribution.

various aspects of sustainable development. It was shown that demographic change affects some facets of sustainable development in a favourable way, for example through a slight reduction in households' energy use and GHG emissions. On the other hand, in some areas demographic change may generate challenges to sustainable development, for example the provision of basic infrastructure services in rural areas with decreasing population density. The studies described in this book show that the demographic developments expected in Germany up to 2030 have significant implications for sustainable development, but the general impression they leave is neither excessively pessimistic nor optimistic.

12.7 Relevance of Results for Other Countries

Although the focus of InfraDem was on Germany, the findings of the project are also relevant for decision makers in other countries. Virtually all developed countries are currently undergoing a similar demographic transition as Germany. In some cases, populations are ageing and shrinking less rapidly and to a smaller extent, but the major trends are the same in virtually all OECD countries: birth rates are below the reproduction level while life expectancy is increasing. Therefore, many other countries will face similar challenges. In fact, a group of Portuguese researchers is currently conducting an analysis of the economic effects of demographic change in Portugal (Albuquerque and Lopes, 2010).

Moreover, other countries are also characterised by significant regional disparities. The prime example of regional disparities is Italy, with its highly industrialised northern regions and the economically lagging *Mezzogiorno*. However, regional disparities also continue to exist in many other parts of the developed world. In terms of population density, significant disparities can be observed in countries such as Sweden, Finland, or the United States of America. Therefore, the regions that were closely studied in this book share some similarities with other typical regions in other countries. In principle, regions in other countries can also be classified according to the regional typography suggested above in Section 12.5.

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