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The Impact of Demographic Change on Infrastructure Use: An Input-Output Approach

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Contents

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Executive Summary

This paper estimates the impact of demographic change on the demand for energy and transportation infrastructure in Germany. The ageing of the population affects the composition of households' consumption expenditures, which in turn affects the use of infrastructure directly and indirectly via industrial backward linkages. The impact on consumption structures are modelled on the basis of consumption survey (EVS) data and household projections up to the year 2030. The resulting vectors of final demand are entered into an extended input-output model, which allows the estimation of energy use and road use. The model results suggest that demographic change affects the composition of the energy mix, raises the demand for railway services, and reduces road use. Since most OECD countries face similar demographic trends, these findings may be extrapolated – with all due caution – to those countries.

Keywords

Demographic change, infrastructure, energy, transport, input-output

Contribution to

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I Introduction

In most economically advanced countries, increasing life expectancies coupled with low fertility rates are causing a development termed *demographic change*, which comprises the ageing and shrinking of the respective populations. So far, the economic literature on demographic change has been dominated by concerns about the strain on public pension systems, which may face difficult times as the number of people in working age declines relative to the number of pensioners[1]. As a result of this focus on pension systems, other aspects of demographic change on the economy have received less attention than they deserve [Yoon & Hewings, 2006].

In order to broaden our understanding of the economic impact of demographic change, this paper focuses on the impact of demographic change on the demand for infrastructure. This is an important issue, because due to the longevity of infrastructure its provision requires careful planning with a time horizon of several decades. During that period of time, demographic change may become an important factor influencing the demand for infrastructure services, since old people tend to consume other goods and services than young people and accordingly differ in their use of infrastructure. Therefore, infrastructure policy should be aware of any forthcoming effects of demographic change on infrastructure use [Kuckshinrichs et al., 2006].

A related stream of literature has concerned itself with the effects of demographic change on the structure of consumption expenditures, for example the study by Buslei et al. [2007]. These studies show that demographic change will indeed have significant impacts on the composition of final demand. However, an examination of final demand does not go far enough to evaluate the total demand for infrastructure, because households use infrastructure both directly and indirectly. Thus, any attempt to estimate the impact of demographic change on infrastructure use must take the indirect use of infrastructure into account.

In this paper, we estimate the impact of demographic change on infrastructure use in Germany, a typical example of an economically advanced country experiencing demographic change. We adopt a methodology consisting of three stages. In the first stage, a statistical analysis of consumer survey data is employed to identify differences in the consumption behaviour of households in different age groups. Consumption coefficients are calculated for three age groups and 133 consumption purposes. In the second stage, they are used along with household projections provided by Kühntopf and Tivig [2007] to produce a projection of households' consumption expenditure up to the year 2030. This allows an assessment of the direct impact of

[1] This development is partly offset by the falling number of children, which means that the overall dependency ratio is barely affected [Bofinger, 2004].

demographic change on households' consumption of energy and transport services. In the third stage, the consumption forecast is entered as a demand impulse into an extended input-output (EIO) model, which allows the calculation of the indirect effects on infrastructure use caused by changes in sectoral production. Data from the German Environmental Economic Accounts are used to calculate changes in energy use and transport. These calculations take place at a disaggregation level of 71 production sectors (production) or 58 production sectors (energy use and emissions). For practical reasons, we focus on two types of infrastructure: energy and transportation.

This paper is structured as follows. In Section 2, data from the German household consumption survey (*Einkommens- und Verbrauchsstichprobe – EVS*) are analysed to identify the different consumption patterns of different age groups. In Section 3, the research methodology is laid out in detail. Section 4 presents the results of the EIO model, which show are then discussed in Section 5. Finally, Section 6 concludes.

II Why would Demographic Change affect Infrastructure Use?[2]

Since old people have different needs than young people, they consume different types of goods and services. The consumption behaviour of households from different age groups in Germany can be studied using data from the EVS, in which more than 50,000 German households report their consumption expenditure on 133 distinct categories of goods and services. The classification of consumption expenditure is based on SEA, the German implementation of the international COICOP standard. For the calculations presented in this section, we have used the scientific use files of the EVS, which offer a differentiation by 133 consumption categories (Table A1).

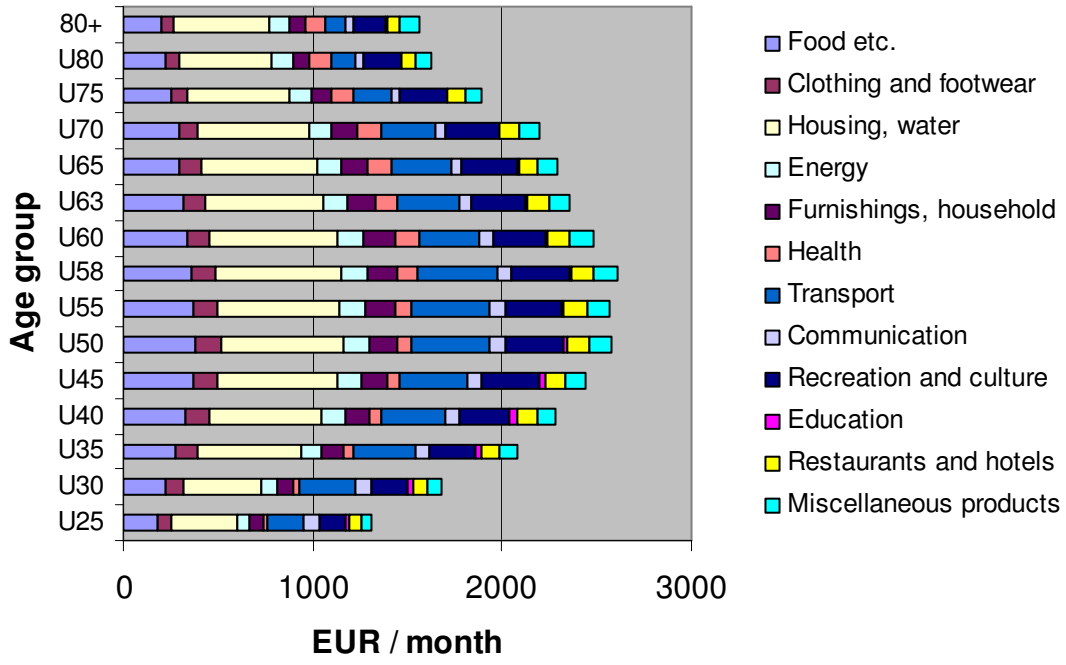
Consumption purpose	Share (%)
Food, beverages, tobacco and narcotics	13.9
Clothing and footwear	5.1
Housing, water	26.4
Energy	5.5
Furnishings, household	5.8
Health	3.9
Transport	14.0
Communication	3.2
Recreation and culture	12.0
Education	0.9
Restaurants and hotels	4.6
Miscellaneous goods and services	4.6

Source: Author's calculations based on EVS 2003 data

Table 1: Consumption expenditures of the average household in 2003

[2] This section provides a very brief overview over the consumption patterns in different age groups. For a more detailed analysis, see Kronenberg [2008].

In order to place the analysis in a more general context, Table 1 shows the general distribution of household consumption expenditures over 12 broader consumption categories. The average household spends 2178 Euros per month. Table 1 shows that the largest consumption category was housing and water (26.4 percent), followed by transport (14.0 percent), food etc. (13.9 percent) and recreation and culture (12.0 percent). Energy as a consumption purpose accounts for 5.5 percent of total consumption expenditure[3].



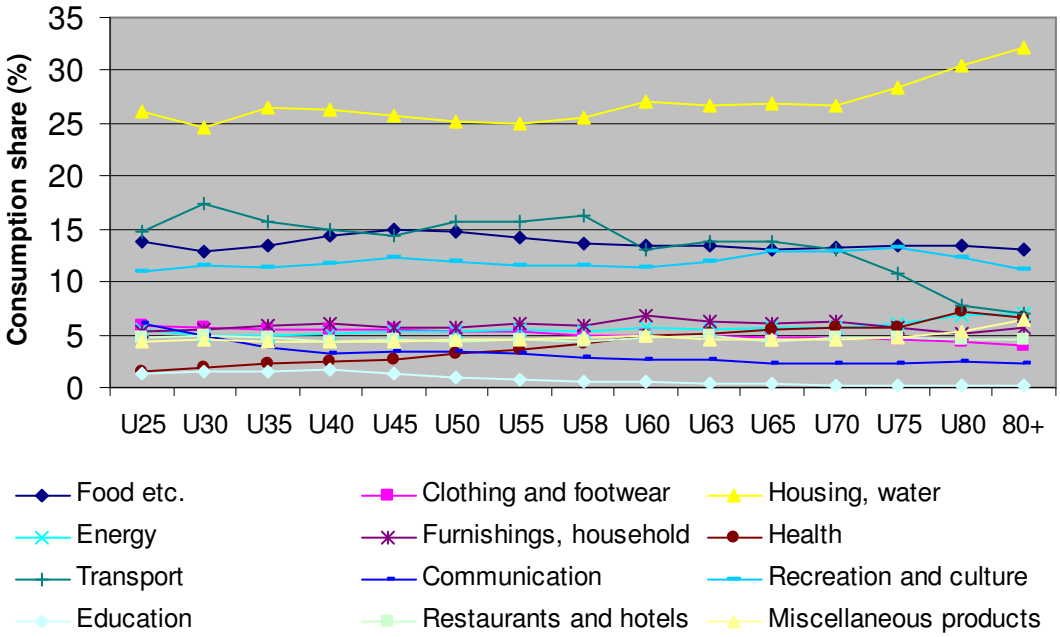
Source: author's calculations

Figure 1: Composition of consumption expenditures in different age groups

Since we are interested in the effects of demographic change, we have to look at the differences between households in different age groups. As distinguishing characteristic, we use the age of the household's main income earner. Figure 1 shows the composition of consumption expenditures in households by age group, where U25 means 'younger than 25', U30 means 'between 25 and 29 years' and so on. A glance at Figure 1 reveals that the amount of consumption expenditure differs considerably among age groups. In general, the relationship between household age and consumption expenditure is hill-shaped. The lowest consumption expenditure is observed for households of the youngest age group (under 25 years), which spend only 1,310 Euros per month on average. Middle-aged households, whose main income earner is between 55 and 57 years old, spend 2,607 Euros per month on average,

[3] It should be noted, however, that the consumption purpose 'energy' does not contain the gasoline used in cars. Since consumer expenditures are classified by consumption *purpose*, gasoline is included under 'transport'. This problem will receive further attention in section IV.2.

more than any other age group. Households of the oldest age group (80 years and older) spend 1,562 Euros on average, slightly more than the youngest households but significantly less than the middle-aged households.



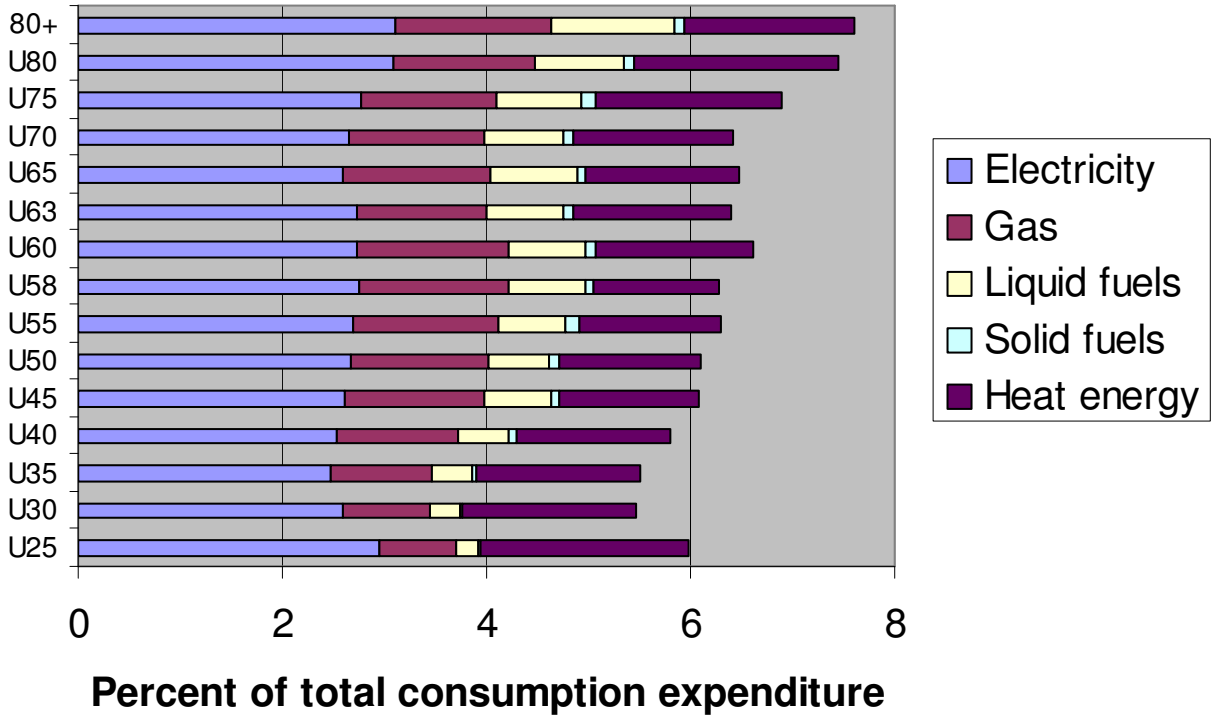
Source: author's calculations

Figure 2: Relationship between household age and consumption coefficients

More interesting than the total amount of consumption expenditure, however, is the distribution of that expenditure over the individual consumption purposes. One can see from Figure 1 already that the share of transport, for example, decreases with age, whereas the share of health increases. The development of these consumption shares can be seen more clearly in Figure 2. That figure shows that the shares of some consumption purposes differ considerably among households of different age groups. For the purposes of the present paper, it is important to note that the share of energy is clearly higher for households in the age groups above 75 years, whereas the share of transport is substantially lower among older households. This observation suggests that demographic change may cause an increase in the demand for energy infrastructure and a decrease in the demand for transport infrastructure.

Figure 3 provides a more detailed perspective of the rather broad consumption category 'energy', distinguishing between electricity, gas, liquid fuels, solid fuels and heat energy. It confirms our previous assertion that older households tend to allocate a larger share of their total consumption expenditure to energy – the total share of energy increases from less than six percent in the younger age groups to almost eight percent in the oldest age group. One interesting observation is that the general increase in the share of energy is not reflected in every single type of energy consumed. This is probably related to the different geographical situation of young and

old households. It is likely that a significant share of the younger households lives in rented apartments situated in urban and metropolitan areas, where heat energy is quite common[4]. Older households, by contrast, tend to live in rural areas, where heat energy is less common; and many of them are likely to own a house with a heating that runs on liquid fuels (oil). Therefore, it seems natural that older households consume much more liquid fuels than young households.



Source: author's calculations

Figure 3: Consumption shares of different types of energy

To sum up the observations of this section, there are significant differences in the structure of consumption expenditures among households of different age groups. Notably, older households tend to spend relatively less money on transport and more on energy. Furthermore, older households tend to consume different types of energy than young households. Therefore, it is likely that demographic change, which increases the share of older households in the total population, will have an effect on the structure of consumption expenditures.

Thus, we should expect that demographic change will affect the economy through the channel of final demand. It will have a direct impact on the structure of final demand by households. Naturally, this direct impact will be followed by all sorts of indirect effects which work their way backward through the production chains until they

[4] The distribution of heat energy is relatively more profitable in densely populated areas. Therefore, it is more common in urban areas than in rural areas.

affect the markets for primary production factors such as labour, capital, and energy. Hence, demographic change will affect future infrastructure use in two ways, first by affecting the direct infrastructure use of households, followed by indirect effects affecting the infrastructure use of the production sectors. A comprehensive analysis of the economic impact of demographic change must therefore take both its direct and indirect effects into account. An established framework for analysing direct and indirect effects of a change in final demand is the input-output model developed by Wassily Leontief and others. The application of this model to the problem at hand is discussed in the following section.

III Research Methodology

The conclusion from the previous section is that households from different age groups differ greatly in their use of infrastructure services, and therefore demographic change is likely to affect the overall use of infrastructure. However, infrastructure services are not only used by households but also by firms, which produce output in order to fulfil other needs of households. In other words, households use infrastructure directly, for example by driving a car on the road, as well as indirectly, for example by purchasing all kinds of other goods, which are delivered to the local supermarket by truck. Thus, in order to acquire a complete picture of the impact of demographic change on infrastructure use, we need to take account of the direct and indirect use of infrastructure by private households. We do so by employing an extended input-output (EIO) model for each of the two regional economies.

The input-output model in the tradition of Leontief is essentially a demand-driven model. Therefore, it forms a suitable framework for analysing the effects of demographically induced changes in final demand. For this purpose, we proceed in three steps. First, we calculate a projection of final demand by households, depending on demographic developments. This projection is based on the household projections for Hamburg and MVP by Kühntopf and Tivig [2007]. The next step is to convert the consumption projection, in which consumption expenditure is classified by *consumption purposes*, into *commodity groups*. Finally, the projection of households' consumption expenditure by commodity group is entered into the EIO model, which makes it possible to evaluate the development of sectoral production and energy use. The following sections describe the methodology in more detail.

III.1 Projection of private consumption

In order to differentiate between older and younger households, all households are sorted into different *age groups*, depending on the age of the households' main income earner. The number of different age groups is denoted by $\tilde{g}$. At the current stage of model development, we assume that households within each age group are homogeneous. Thus, rather than differentiating households further according to the

number of household members, household income or other characteristics, we assume an 'average' household for each age group.

Total consumption expenditure by an 'average' household of age group g amounts to

$$(1) \qquad c_g = (1 - s_g)\, y_g ,$$

where s_g stands for the saving rate and y_g stands for the net income of a household in age group g.

The total consumption expenditure of a household is differentiated by different consumption purposes, and the number of different purposes is $\tilde{m}$. For each consumption purpose m, a consumption coefficient γ_g^m is defined as $\gamma_g^m = c_g^m / c_g$. This represents the share of consumption purpose m in total consumption expenditure. Thus, the total consumption expenditure of a household from age group g may be written as:

$$(2) \qquad c_g^m = \gamma_g^m c_g$$

Since we assume homogeneity within each age group by postulating a hypothetical 'average' household, we can calculate the total consumption expenditure of age group g on consumption purpose m by multiplying c_g^m with the number of households H_g:

$$(3) \qquad C_g^m = H_g c_g^m$$

The total expenditure for a consumption purpose m can then be determined by summing over all age groups:

$$(4) \qquad C^m = \sum_{g=1}^{\tilde{g}} C_g^m$$

The sum of private consumption expenditure at the macroeconomic level is:

$$(5) \qquad \overline{C} = \sum_{m=1}^{\tilde{m}} C^m$$

Equations (1) to (4) may be used to derive the following expression for consumption expenditure by consumption purpose:

$$(6) \qquad C^m = \sum_{g=1}^{\tilde{g}} H_g \gamma_g^m (1 - s_g) y_g$$

As equation (6) shows, the total consumption expenditures by consumption purpose depend on the number of households H_g, the consumption coefficients γ_g^m, the savings rate s_g, and net income y_g. Any change in these parameters leads to a change in consumption expenditures. In the present paper, we isolate the impact of demographic change by keeping γ_g^m, s_g and y_g constant[5]. For H_g, we substitute the values from the household projections by Kühntopf and Tivig [2007], as described above.

During the practical application of this procedure, an annoying problem arises, because types of consumption expenditure are notoriously underreported in the EVS household survey, for example the expenditures on cigarettes and drinks consumed in bars and pubs. In order to solve this problem, we follow the recommendation by Lehmann [2004], who suggests to calculate coverage ratios (*Deckungsquoten*) for each consumption purpose category. Based on the input-output tables of 2003[6], we calculate for each consumption purpose category m a *coverage ratio* CR_m. If this coverage ratio is equal to one, an estimation based on EVS data yields exactly the same result as the official national accounts. If it is smaller (larger) than one, an estimation based on EVS data leads to an underestimation (overestimation) of the official figure. We assume that CR_m does not change over time and divide our consumption projection for each commodity group by CR_m. As a result, we end up with a projection of consumption expenditures corrected for EVS reporting errors.

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[5] Although there are good reasons for believing that demographic change will have effects on these variables as well, those effects are outside the scope of the present paper, which focuses exclusively on the impact of differing consumption structures.

[6] The most recent EVS was conducted in 2003. Therefore, if we wish to estimate the coverage ratio, we have to compare the EVS data with the input-output tables from the same year.

III.2 Conversion into commodity groups

During the collection of the EVS data, the respondents allocate their consumption expenditure to different consumption purposes[7]. In the national input-output tables, however, products are allocated to different commodity groups[8]. Therefore, we have to convert our consumption projection into commodity groups to ensure compatibility with the input-output tables. This conversion can be achieved using the *consumption allocation table* published by the Federal Statistical Office (FSO).

The core of this table is formed by an allocation matrix V, whose structure is shown in Table 2. In this matrix, the consumption expenditure for different consumption purposes (columns) is allocated to different commodity groups (rows). For example, column 1 may contain the expenditure on consumption purpose 'food' (SEA code 011), and row 1 may contain the commodity group 'products of agriculture, hunting and forestry' (CPA code 01). In this case, the value in cell $V_{1,1}$ tells us how many products of agriculture, hunting and forestry (measured in monetary units, i. e. Euros) were bought by household for use as food. The consumption allocation table presented here identifies n different commodity groups and $\tilde{m}$ different consumption purposes. Thus, it consists of n rows and $\tilde{m}$ columns.

Consumption expenditure of private households by…		consumption purpose			
		1	2		$\tilde{m}$
commodity group	1	$V_{1,1}$	$V_{1,2}$	…	$V_{1,\tilde{m}}$
	2	$V_{2,1}$	$V_{2,2}$	…	$V_{2,\tilde{m}}$
	⋮	⋮	⋮		⋮
	n	$V_{n,1}$	$V_{n,2}$	…	$V_{n,\tilde{m}}$

Table 2: The consumption allocation matrix

In its publications, the FSO usually augments the actual allocation matrix V by including one additional row and column. In this extended table, row $n+1$ contains the sum of expenditures on the respective consumption purposes, while column $\tilde{m}+1$ contains the sum of expenditures on the respective commodity groups (Table 3). In order to prevent misunderstandings, we denote the total expenditure for a consump-

[7] The different consumption purposes are defined following the SEA classification, the German version of the international COICOP standard (see Appendix).

[8] The different commodity groups are defined following the CPA classification (see Appendix). Since some of these groups have awfully long names, we use shorter names in the text. For example, the official heading of CPA category 11 is 'crude petroleum and natural gas; services incidental to oil and gas extraction, excluding surveying', but for the sake of legibility we refer to it simply as 'crude oil and natural gas' in the text.

tion purpose by C^m, where the superscript m identifies the consumption purpose, and total expenditure for a commodity group by C_i, where the subscript i identifies the commodity group.

Consumption expenditure of private households by…		consumption purpose				
		1	2	…	$\tilde{m}$	Sum
commodity group	1	$V_{1,1}$	$V_{1,2}$	…	$V_{1,\tilde{m}}$	C_1
	2	$V_{2,1}$	$V_{2,2}$	…	$V_{2,\tilde{m}}$	C_2
	⋮	⋮	⋮		⋮	⋮
	n	$V_{n,1}$	$V_{n,2}$	…	$V_{n,\tilde{m}}$	C_n
	Sum	C^1	C^2	…	$C^{\tilde{m}}$	$\overline{C}$

Table 3: Augmented consumption allocation matrix

We define a vector C containing total consumption expenditures by commodity groups:

$$(7) \qquad C = (C_1,...,C_n)$$

As Table 2 shows, each element of C can be calculated by summing over the entries in the corresponding column of V:

$$(8) \qquad C_i = \sum_{m=1}^{\tilde{m}} V_{i,m}$$

In order to perform the conversion, we define a *consumption allocation coefficient* $v_{i,m}$ as:

$$(9) \qquad v_{i,m} \equiv \frac{V_{i,m}}{C^m}$$

The most recent consumption allocation table of the FSO is based on data from the year 2004. From these data, we calculate consumption allocation coefficients accord-

ing to (9). In the following, we assume that these coefficients do not change over time[9].

From (6), we have a projection of C^m. Re-arranging (9) then allows us to calculate a projection of $V_{i,m}$:

$$(10) \quad V_{i,m} = v_{i,m} C^m$$

Using (8) in (10) yields:

$$(11) \quad C_i = \sum_{m=1}^{\tilde{m}} v_{i,m} C^m$$

Equation (11) yields a projection of private consumption expenditure by commodity groups, which is what we need to put into the open Leontief model in step 3. Before we can actually proceed, however, we have to resolve another minor problem: the EVS consumption expenditures are expressed in consumer prices, whereas the input-output tables are available only in producer prices. In order to solve this problem, we use a table containing additional information (trade margins and commodity taxes for each commodity group) which the FSO provided to us upon request. This table makes it possible, under certain assumptions, to convert consumer prices into producer prices, which is what we need to proceed.

III.3 Projection of Sectoral Production

Our projection of households' consumption expenditures refers only to the final use of products by households, which makes up only part of the total use of products. Another important component of total use consists of *intermediate use*. In 2004, total consumption expenditures of private households amounted to roughly 1,100 billions of Euros, whereas intermediate use amounted to almost 2,000 billions of Euros. Therefore, an analysis of private consumption can only yield an incomplete picture. In order to account for the ultimate impact of the demand-induced effects of demographic change on total energy use, the indirect effects must be taken into consideration as well. For example, the aforementioned consumption projection may show that

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[9] We are not arguing that the assumption of time-invariant consumption coefficients is realistic. However, it is a useful assumption at this point because our focus is on the purely demographically induced change in the structure of consumption expenditures. We are planning to devote more attention to the development of the consumption coefficients in future work.

demographic change causes an increase in the consumption expenditures on ‘health’. This observation, although interesting, does not tell us anything about the required use of energy.

This is the point where input-output analysis comes into play. We use an open static Leontief model for impact analysis. Using this model, one can estimate how the individual production sectors react to a given change in final demand. A detailed description of the impact analysis approach in an open static Leontief model is provided, for instance, by Miller and Blair [1985].

Impact analysis allows the estimation of indirect demand-induced effects. In the aforementioned example (an increase in spending on health-related products), one may assume that the output of the sector ‘pharmaceuticals products’ (CPA code 24.4) will increase. In order to increase its output, this sector has to use more inputs. Thus, the delivering sectors must raise their output levels as well. In this fashion, the initial demand impulse sends successive waves of intermediate demand through the linkages between production sectors, until finally a new equilibrium is reached and total demand can be satisfied. This mechanism can be analysed in the demand-driven input-output model.

III.4 Indicators of Infrastructure Use

Our goal in this paper is to estimate the impact of regional demographic change on infrastructure use, with a focus on the energy and transportation infrastructures. The traditional input-output quantity model allows an estimation of sectoral production and total output. This in itself provides valuable information, because if we know the impact on, say, the production of the sector *railway transport services*, we get a pretty good idea whether the regional railway infrastructure should be extended to accomodate an increasing number of trains or whether it can be (partly) dismantled because the existing capacity will no longer be needed in the near future.

However, a more comprehensive picture of the impact on infrastructure use can be gained from non-monetary information such as the amount of energy used and the distance travelled measured in terajoules and kilometres, respectively. In order to calculate such estimates, we extend the input-output model described above by adding an infrastructure module. In the extended input-output (EIO) model, it is assumed that the energy and transport intensities for production and consumption in each product category/industry remain constant. Thus, energy use (measured in terajoules) in sector i is proportional to sector i’s production value, and the same holds for road use (measured in kilometres). In order to calculate energy and road use intensities, we use data on energy consumption by households and homogeneous branches from the FSO’s environmental accounts [Statistisches Bundesamt, 2006, Statistisches Bundesamt, 2005]. This procedure allows us to calculate the impact of

demographic change on the energy and road use of production sectors and households.

IV Findings

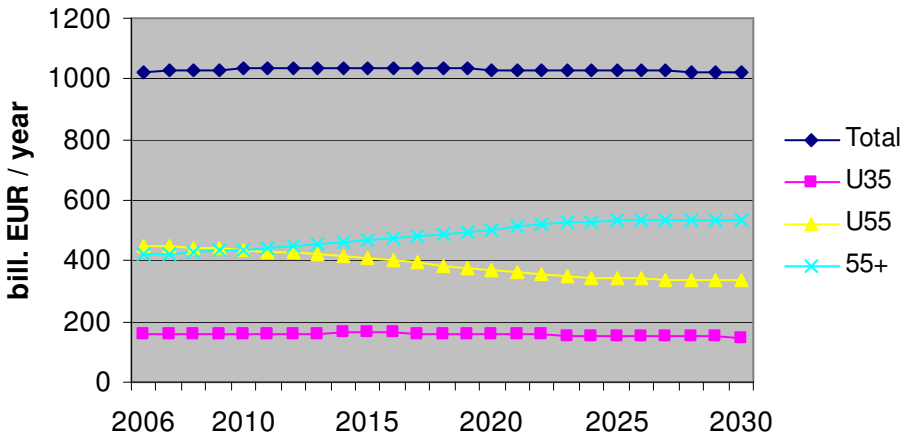
IV.1 Aggregate Consumption Expenditures

From the scientific use files of the EVS 2003, the total consumption expenditure of the average household in each of the three age groups c_g was calculated (Table 4). Total expenditure was highest in the households from the middle age group, which spent 2454 € per month on average. Among old households, total expenditure amounted to 2072 € per month on average, and among young households it was 1758 € per month. When interpreting these figures, one should keep in mind that the average size of a household (the number of persons) varies among age groups.

Age group	Consumption expenditure (EUR / month)
U35	1,758
U55	2,454
55+	2,072

Source: author's calculations

Table 4: Consumption expenditure per household by age group



Source: author's calculations

Figure 4: Aggregate consumption expenditure by age group

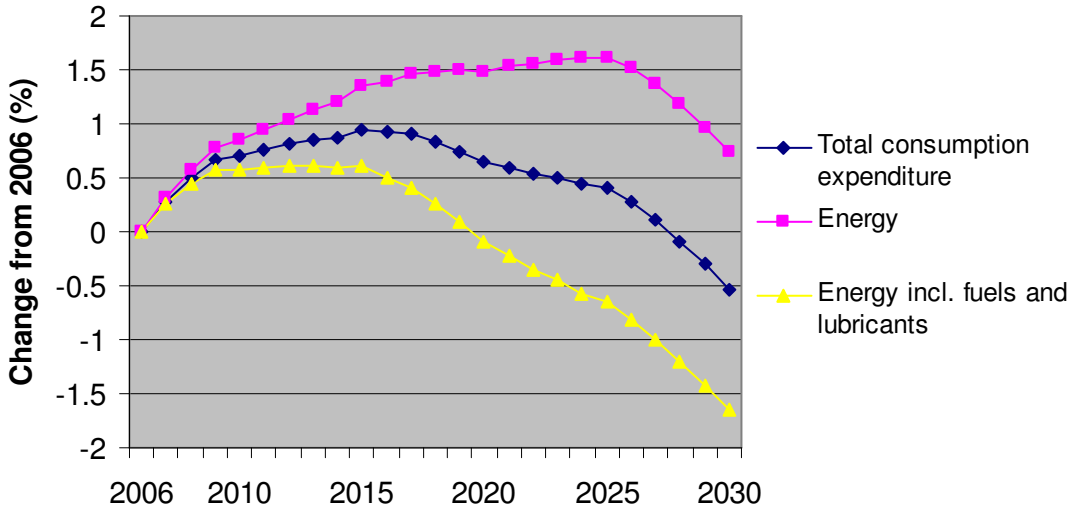
Next, total consumption expenditure by age group was forecast under the assumption that c_g remains constant. Figure 4 shows the result, aggregated consumption expenditure by age group. For individual age groups, significant changes can be observed: The consumption expenditures of old households (55+) rise from 421 billions of Euros per year to 537 billions by the year 2027, and subsequently fall to 535 bil-

lions of Euros per year in 2030. The consumption expenditures of middle-aged households (U55), by contrast, fall from 449 to 336 billions of Euros per year between 2006 and 2030. Only the consumption expenditures of young households (U35) remain roughly constant at a level of 150 billions of Euros per year.

In sum, the contrary developments in the age groups U55 and 55+ by and large cancel each other out. Total consumption expenditures rise marginally from 1,025 billions of Euros in 2006 to 1,034 billions of Euros per month in 2015. After that, they slowly fall, reaching a value of 1,019 billions of Euros in 2030. However, there are indications that the shrinkage of total consumption expenditures picks up speed at the end of the forecast period, because the consumption expenditures of age group 55+ also begin to fall at that time.

IV.2 The Structure of Consumption

The consumption coefficients which were calculated from the EVS 2003 data (see Appendix) were then used to disaggregate the forecast of total consumption expenditures (Figure 4) into different consumption purposes. The result was a projection of total consumption expenditures by 133 consumption purposes. As it would be impractical to present the entire projection, the following paragraphs focus on those consumption purposes which are directly related to infrastructure use or show some otherwise interesting developments.



Source: author's calculations

Figure 5: Consumption expenditures for energy

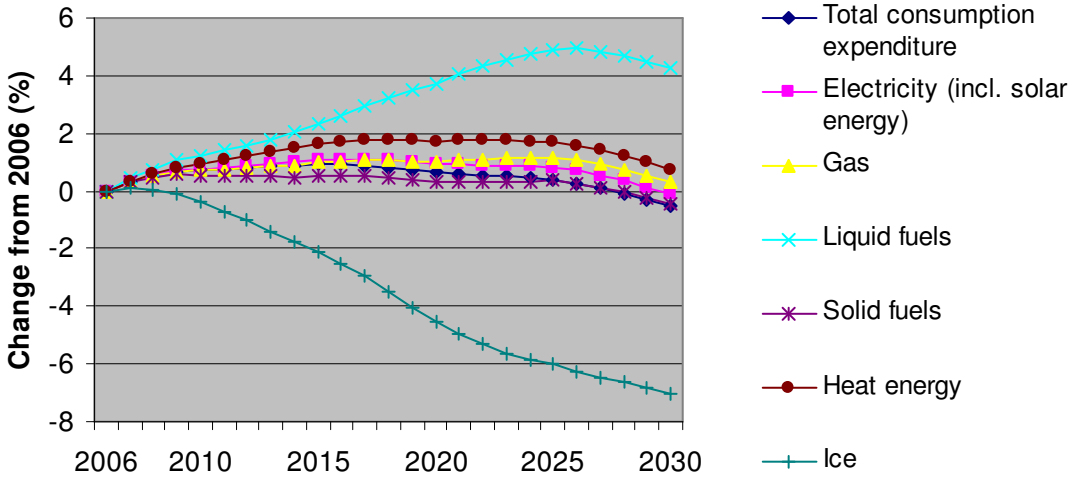
Figure 5 shows the development of consumption expenditures for energy. Note that the SEA/COICOP classification is based on allocating expenditures to different purposes, and that the expenditures on 'fuels and lubricants for personal transport equipment' (SEA code 0722) are allocated to the broad consumption purpose of 'transportation' (SEA code 07), whereas the category 'energy' (SEA code 045) contains only the expenditures on energy consumed at home, for example for heating

and cooking. Since the expenditures on fuels and lubricants for personal transport equipment, which includes gasoline, amount to almost three percent of total consumption expenditures, a superficial examination of EVS data may cause an underestimation of the importance of energy as a whole, since energy in the SEA sense accounts for only five percent of consumption expenditures [Kronenberg, 2008].

In order to prevent such misinterpretation, Figure 5 shows the expenditures on energy (SEA code 045) as well as energy including fuels and lubricants for personal transport equipment (SEA codes 045 and 0722). To put things into perspective, aggregate consumption expenditures are also shown. As mentioned above, the latter rise by one percent between 2006 and 2015, only to fall slowly afterwards, and by 2030 they are 0.6 percent lower than in 2006.

The expenditures on energy (SEA code 045) show a considerably more pronounced increase than aggregate consumption expenditures. Even in 2030, they are still clearly above the level of 2006. This means that the assumed demographic development will tend to increase the share of energy in total consumption expenditures.

However, a very different picture emerges when fuels and lubricants for personal transport equipment are considered as well. Figure 5 shows that the expenditures on energy including fuels and lubricants rise by a smaller percentage (and fall by a larger percentage) than aggregate consumption expenditures. Thus, demographic change leads to a reduction of the consumption share of energy in a broader sense. This development is quite plausible considering the fact that old households spend relatively much less money on fuels and lubricants for personal transport equipment than young households [Kronenberg, 2008].



Source: author's calculations

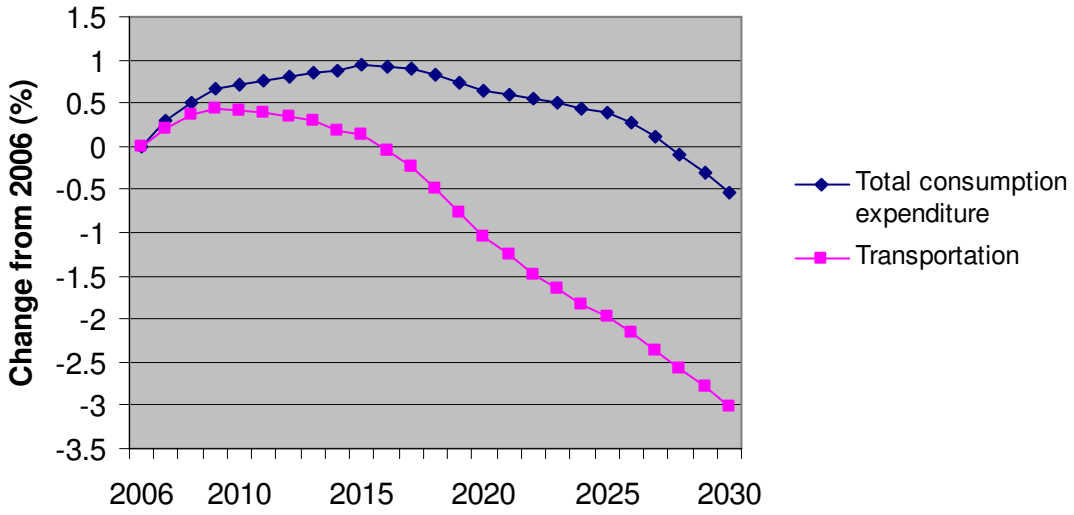
Figure 6: Consumption expenditures on specific energy sources

Figure 6 shows the projected consumption expenditures on specific energy sources, which form part of SEA category 045. As it turns out, the expenditures on liquid fuels experience the largest impact, increasing by five percent in 2026 compared to 2006.

Expenditures on most of the other energy sources are also increased. Thus, the expenditures on heat energy experience an increase of two percent, while those for gas and electricity rise by roughly one percent.

These developments must be seen in context with aggregate consumption expenditures. As Figure 6 shows, the expenditures on most energy sources rise by a larger percentage (or fall by a smaller percentage) than aggregate consumption expenditures, so their shares in total consumption expenditures rise. The only exceptions to this rule are 'solid fuels' and 'ice use for cooling and refrigeration purposes'. From a macroeconomic perspective, however, these are of little importance.

The increased expenditure shares of the important energy sources are consistent with the finding that the expenditure share of energy (in the SEA sense) rises (Figure 5). They are also consistent with the observations from Section 2, which show that the share of energy used at home, especially liquid fuels, in total consumption is far above the average among the older households.



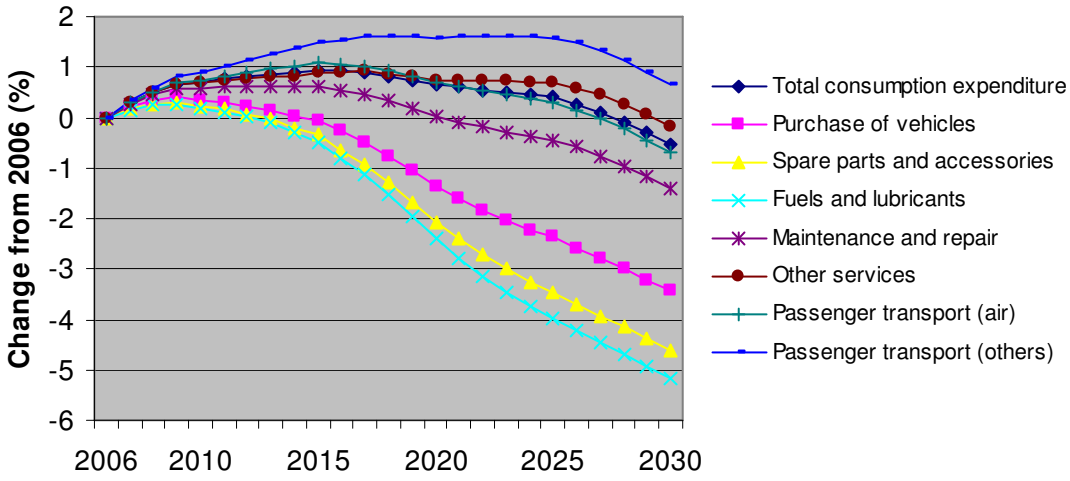
Source: author's calculations

Figure 7: Expenditures on Transportation

Figure 7 shows the development of the expenditures on transportation in relation to aggregate consumption expenditures. While total consumption expenditure rise up to the year 2015 by one percent and start falling slowly after that, the expenditures on transportation rise by merely 0.5 percent und then fall much faster than total consumption expenditures. In the year 2030, expenditures on transportation are three percent below their initial value, while total consumption expenditures have fallen by only 0.5 percent. Thus, the share of transportation in aggregate consumption expenditures clearly falls.

However, this observation requires further qualification, considering the fact that fuels and other lubricants for personal transport equipment are an important (in fact, *the*

most important) part of transportation expenditures. Therefore, it seems reasonable to have a closer look at the area of transportation.



Source: author's calculations

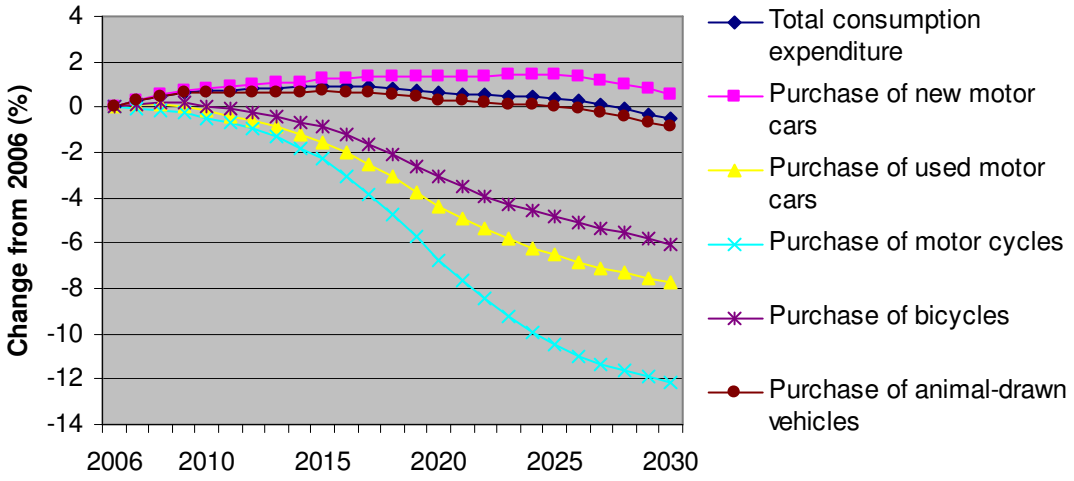
Figure 8: Expenditures on individual transportation subcategories

Figure 8 demonstrates that the expenditures on individual subcategories of transportation evolve in various ways. The expenditures on 'fuels and lubricants for personal transport equipment', 'spare parts and accessories for motor vehicles and motor cycles' and 'purchase of vehicles' are reduced by up to five percent below their level of 2006. These consumption categories are closely related to the operation of motor vehicles. Their profound contraction is likely to be associated with the fact that old households use motor vehicles much less frequently than do young households.

For some of the other consumption categories, a very different picture emerges. A comparison with the development of aggregate consumption expenditures shows that the expenditure share of 'passenger transport not by air', which includes public transport, rises sharply. The expenditure share of 'other services related to vehicle use', which mostly consists of actual and imputed rentals for garages and parking spaces, rises slightly. The expenditures on 'passenger transport by air' mostly follow the development of total consumption expenditures, so their share in the latter remains more or less constant.

However, the demand projection by 133 consumption purposes also shows that even within relatively narrow categories such as 'purchase of vehicles' there is still scope for remarkable differences. This is illustrated in Figure 9, which shows the development of expenditures on vehicles. Notably, despite the massive reduction in expenditures on vehicles as a whole, expenditures on new motor cars actually increase. The reduction in overall expenditures on vehicles is mostly caused by a massive reduction by more than twelve percent in expenditures on motor cycles, and by reductions of six and eight percent in expenditures on bicycles and used motor cars, respec-

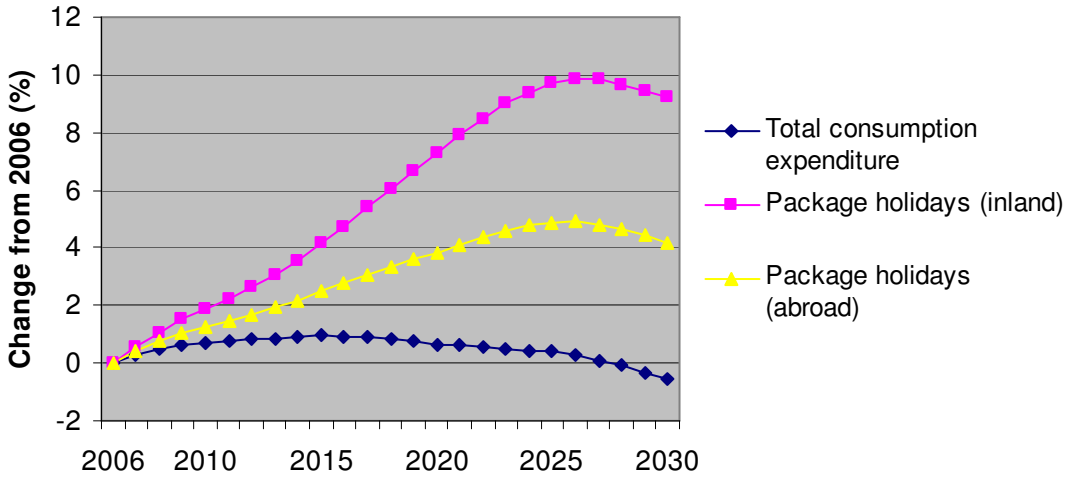
tively. Expenditures on animal-drawn vehicles are barely affected, but are not of macroeconomic importance either way.



Source: author's calculations

Figure 9: Expenditures on purchase of vehicles

Figure 10 shows the expenditures on package holidays. Following the SEA classification, these are allocated to the consumption category 'recreation and culture' (SEA code 09). However, they may also be relevant for the use of infrastructure, because a package holiday usually contains at least some kind of transportation service. As it turns out, the expenditures on package holidays increase considerably, especially for those spent inland. The reason for this is that older households tend to spend much more money on package holidays than young households.



Source: author's calculations

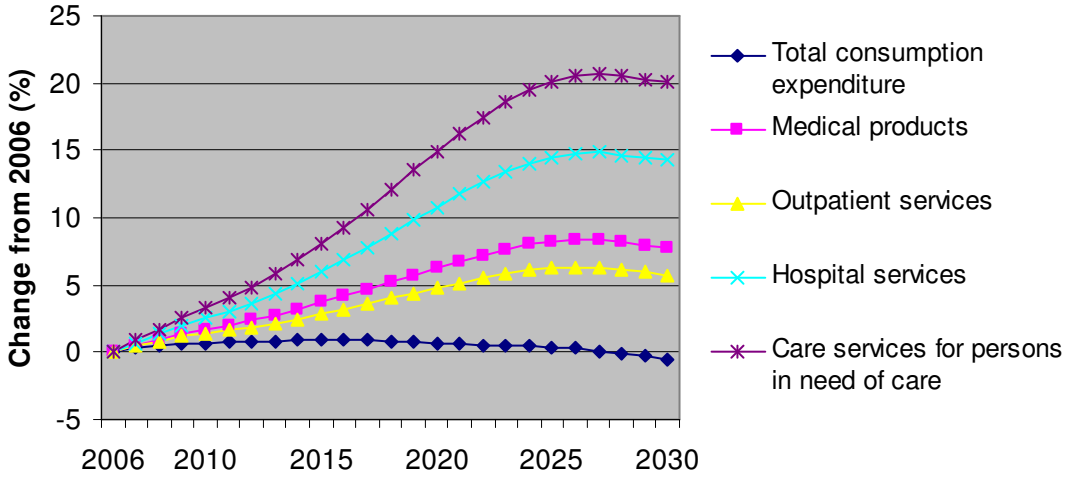
Figure 10: Expenditures on package holidays

So far, we have only regarded those types of consumption expenditures which are directly related to infrastructure services. However, as pointed out above, changes in the structure of consumption may also affect infrastructure use indirectly if they are of

a relatively large magnitude. Therefore, in order to understand the full impact of demographic change on infrastructure use, it makes sense to investigate which consumption categories are heavily affected by demographic change, even if they have no direct relation with infrastructure use.

Our consumption projections show that many of the developments which intuition suggests are indeed borne out by the data. For example, our calculations suggest that the expenditures on garments for children fall by 14 percent between 2006 and 2030, which seems only natural if the share of children in the total population falls. Also, the expenditures on tobacco fall by seven percent, because old people tend to smoke less frequently than young people. On the other hand, the expenditures on plants and flowers rise by six percent, which seems plausible, considering that gardening is *the* stereotypical hobby for pensioners in Germany. Furthermore, the expenditures on 'domestic services and household services' increase by ten percent, which may be due to the fact that older households are more likely to hire cleaning ladies and other domestic workers.

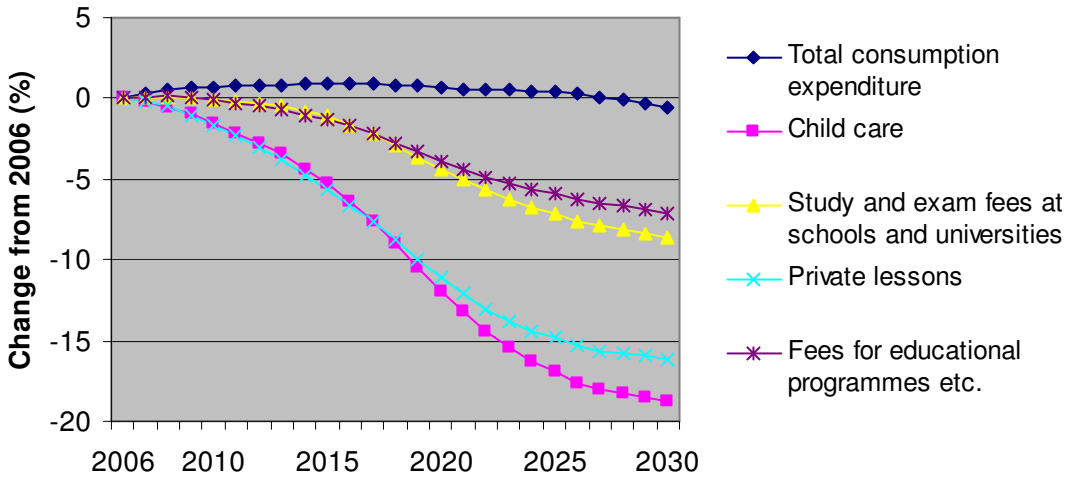
There are two other main consumption categories which are heavily affected by demographic change: health and education. Figure 11 shows the impact of demographic change on health expenditures. Most notably, the expenditures on care services for persons in need of care (mostly old or disabled people) rise by more than twenty percent. Expenditures on hospital services rise by 15 percent, on medical products by eight percent, and on outpatient services by six percent. Thus, demographic change is likely to have a tremendous positive impact on health expenditures. Although the health care system is usually considered a 'social' infrastructure, increases of this magnitude may very well trigger indirect impacts on technical infrastructures such as energy and transportation.



Source: author's calculations

Figure 11: Expenditures on health and healthcare

Figure 12 shows the impact of demographic change on education expenditures. Since education is mostly received by young people, one would expect that the ageing of the population reduces education expenditures. This expectation is clearly confirmed by Figure 12, which shows that the expenditures on private lessons and child care fall by more than 15 percent, while those on other education-related categories experience reductions between six and eight percent. Thus, demographic change has an impact on the expenditures on education, which – as in the case of health – may be large enough to trigger significant indirect effects on the demand for energy and transportation services[10].



Source: author's calculations

Figure 12: Expenditures on education

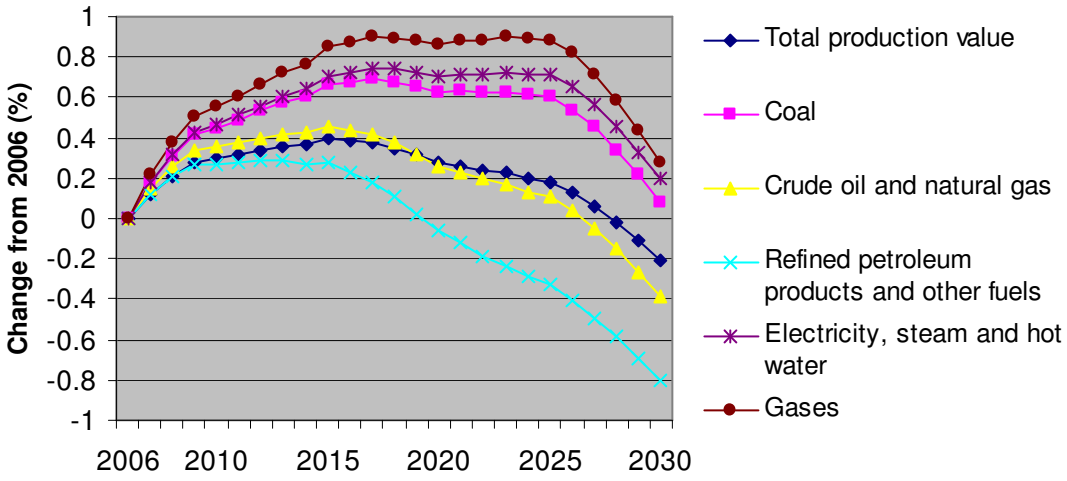
To sum up, the results presented in this section show that demographic change is likely to have a significant impact on the composition of private households' consumption expenditures, which is going to have an effect on infrastructure use. According to our calculations, demographic change is going to lead to an increased use of energy infrastructure and a reduction in the use of transportation infrastructure. It is also going to affect other types of consumption expenditures, which may trigger indirect effects on the use of infrastructure. These indirect effects can be estimated by means of an input-output analysis, the results of which are shown in the following section.

IV.3 Sectoral Production

This section presents the results of the input-output calculations as described in section III.3. These were performed at a disaggregation level of 71 sectors, but since it

[10] It should be mentioned that in 2003, when the EVS consumption survey was conducted, higher education, being regarded as a basic human right, was provided more or less for free in Germany. In the meantime, many universities have introduced substantial study fees, which are likely to affect the expenditures on education.

would be impractical to show the developments of all these sectors in this paper, the following paragraphs focus on a few selected sectors of particular interest.

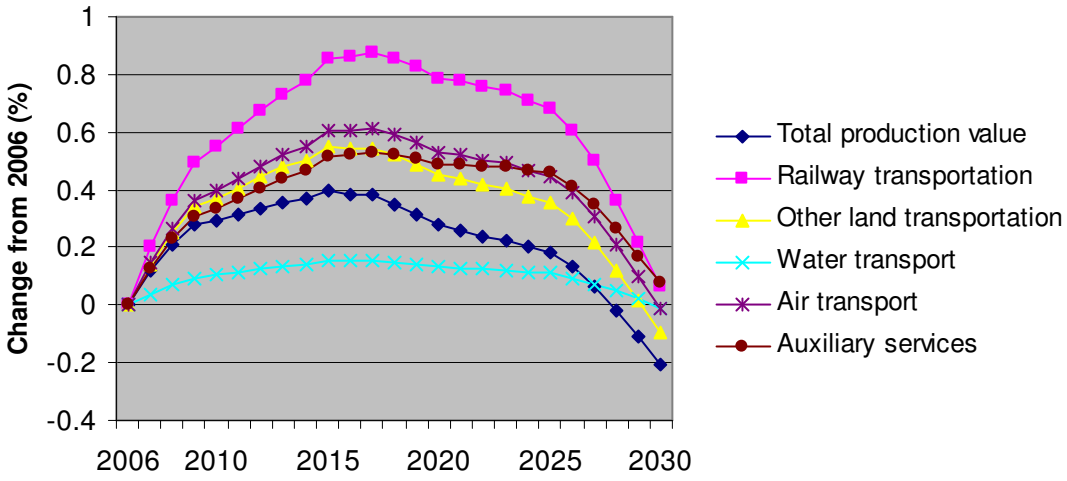


Source: author's calculations

Figure 13: Impact on the production of energy sectors

Figure 13 shows the impact of demographic change in the production levels of the energy sectors. Two sectors, *coal* and *crude oil and natural gas*, are producers of primary energy sources, whereas the other three sectors are concerned with the production and distribution of secondary energy sources. The impact on total production is also shown for reference. As shown in the previous section, demographic change initially causes an increase in total consumption, which is reflected in Figure 13 by an increase in total production, which peaks in the year 2015 and afterwards falls back to and below its initial value. In the year 2030, total production is reduced by 0.2 compared to 2006.

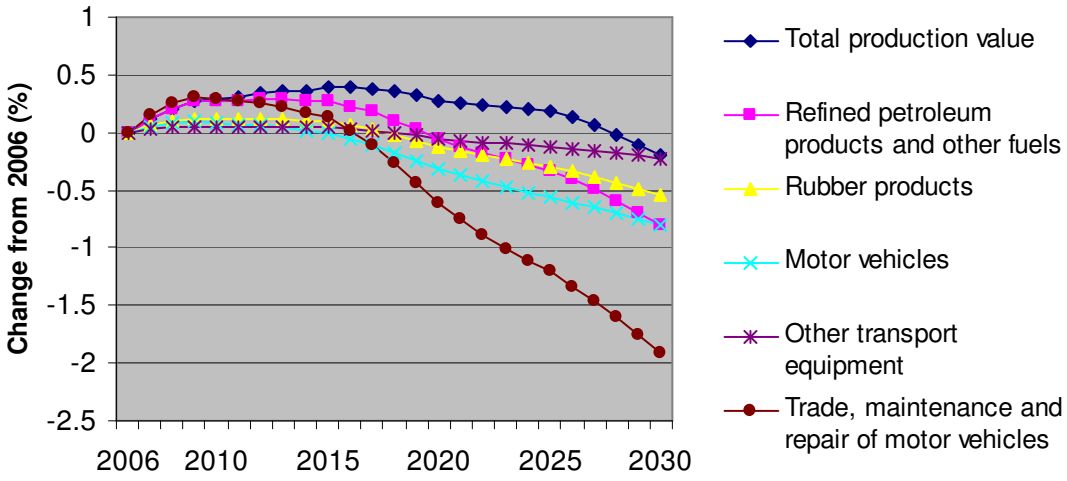
An interesting effect of demographic change is the reallocation between the primary energy sources. Whereas the production share of *coal* in total production increases, that of *crude oil and natural gas* falls. Among the secondary sectors, the production share of *refined petroleum products and other fuels* declines, while the shares of *gases* and *electricity, steam and hot water* rise. These findings show that the impact of demographic change may not only affect the amount of energy used but also its composition.



Source: author's calculations

Figure 14: Impact on the production of transportation services

Figure 14 shows the impact of demographic change on the production of transport services. Remarkably, the production share of all transportation sectors rises – with the exception of water transport's share, which is initially reduced but after 2026 is also higher than in 2006. Railway transport is the most heavily affected sector, followed by air transport, auxiliary services, and other land transportation. Figure 14 shows that even if demographic change causes a reduction in consumption expenditures on transportation (Figure 7), one should not conclude prematurely that this implies a reduction in the demand for transportation infrastructure, because the demand for public transport services may increase nevertheless.



Source: author's calculations

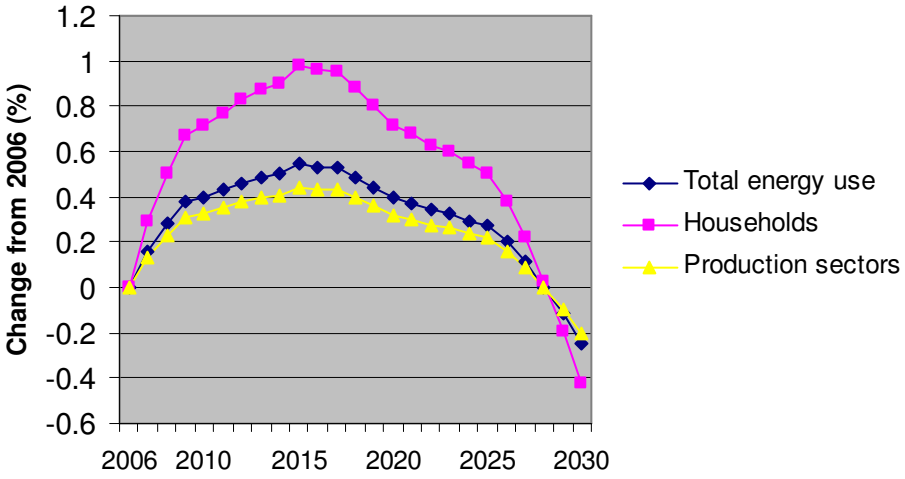
Figure 15: Impact on the production of goods and services related to personal transport vehicles

Whereas Figure 14 was concerned with the sectors producing actual transportation services, Figure 15 shows the impact of demographic change on the production of those sectors which produce goods and services related to personal transport vehi-

cles. Interestingly, demographic change reduces the production of *trade, maintenance and repair of motor vehicles* by almost two percent. Most other sectors are also negatively affected: The production of *motor vehicles*, *rubber products* (mostly car tires) and *refined petroleum products and other fuels* (mostly gasoline) is reduced by between 0.5 and 0.8 percent. These observations are doubtlessly related to the reduction in consumption expenditures on products related to the operation of individual transport vehicles (Figure 8)[11].

IV.4 Infrastructure Use

In the previous section, the impact of demographic change on the production values of different sectors was shown. The extended input-output model, using data on sectoral energy use and road transportation, makes it possible to estimate the impact of demographic change on overall energy use and road transportation. The effect on energy use is displayed in Figure 16.



Source: author's calculations

Figure 16: Impact on energy use

As Figure 16 shows, the impact of demographic change on energy use (measured in physical units, i.e. terajoules) is initially positive. By the year 2015, demographic change has increased the energy use of households by one percent and energy use of production sectors by roughly 0.4 percent, resulting in an increase of total energy use by almost 0.6 percent. After 2015, demographic change leads to a decline in energy use of households and production sectors. By 2030, energy use of households is 0.4 percent below its initial value, energy use of production sectors is 0.2 percent below its initial value, and total energy use is 0.25 percent below its initial value.

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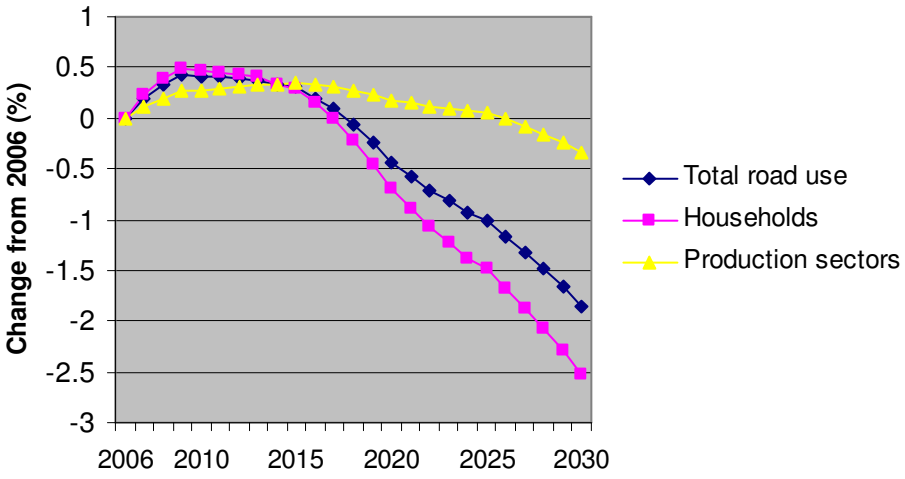
[11] The reader may wonder about the reduced production of motor vehicles, recalling that consumption expenditures on new cars do not fall (Figure 9). However, the sector *motor vehicles* also includes spare parts, and since consumption expenditures on used cars do fall, it seems reasonable that the demand for spare parts falls.



Source: author's calculations

Figure 17: Impact on road use

Finally, Figure 17 shows the impact of demographic change on road use (measured in physical units, i.e. kilometres). Since households account for almost three quarters of road use in Germany, their behaviour largely drives overall road use. Interestingly, the road use of households peaks already in 2009 and declines steadily afterwards. By 2030, demographic change has reduced the road use of households by 2.5 percent. At the same time, the road use of production sectors has been reduced by 0.4 percent, and total road use is reduced by slightly less than two percent. Thus, demographic change has had a negative impact on road use by 2030.

V Discussion

The findings from the previous section, in short, show that demographic change will cause a change in the structure of consumption. They suggest that the expenditure share of energy used at home, especially liquid fuels, tends to rise. This development is caused by the fact that older households tend to consume relatively more energy at home for heating purposes, and that they tend to live in suburban houses which are often equipped with oil-fired heating. In the area of transportation, it turns out that the share of expenditures related to the operation of motor vehicles tends to fall, while the share of expenditures on transportation services and especially package holidays (which include transportation services) tends to rise, in some cases considerably. These findings are important for policymakers and infrastructure planners, who need to estimate the future demand for infrastructures in order to ensure an efficient provision which matches capacity with demand.

However, the findings were achieved under a certain set of assumptions, which must be kept in mind when interpreting the results. Most notably, the consumption structure of each age group was assumed to remain constant over time. This means that, for example, in the year 2030 a household of age group U25 allocates its consump-

tion expenditures over the different consumption purposes in exactly the same way as a household of age group U25 did in the year 2003 (when the EVS survey was conducted). In reality, however, that allocation may change due to income effects, substitution effects caused by changes in prices, or cohort effects. An example for the latter is the observation that currently many old women have no driver's license, which partly explains why older households use cars rarely. In younger cohorts, however, most women do have a driver's license. If they continue to drive cars as they grow older, car use in the older age groups will become more frequent, and the consumption coefficients change.

Finally, one may wonder in how far the findings of this paper, which analysed the impact of demographic change in Germany, can be generalised to other countries or regions. The main features of demographic change, growing life expectancies and birth rates below the reproduction rate, are not characteristic of Germany but are also observed in virtually all OECD countries. Moreover, Tivig and Hetze [2007] argue that the *demographic transition* which most European countries underwent since the late 19th century is a universal phenomenon. Their model suggests that all countries pass through a similar demographic transition but are currently in different phases of this process. Tivig and Hetze argue that Eastern Europe and Germany are already in a very late phase ('population ageing rapidly and tending to shrink'), followed by North America ('population growing more slowly and continually ageing') and the developing countries ('population growing rapidly and beginning to age'). This suggests that the developments which we observe in Germany are likely to occur in other countries as well, only with a delay of some years or decades. Thus, the findings from the analysis presented above can probably be extrapolated to other countries with all due caution.

However, as Gans [2006] has pointed out, the diversity of demographic developments between regions is much larger than between nations, at least within Europe. This means that the findings for Germany should not be extrapolated to other regions, or even subnational regions within Germany. Since infrastructure is in many cases locally bound, the effects of demographic change on infrastructure demand should be studied at the regional level as well.

VI Conclusion

The aim of this paper was to examine the potential impact of demographic change on the demand for infrastructure services. To this end, a consumption forecast based on consumption survey data and household projections was fed into an extended input-output model. The results of this analysis show that demographic change will have an impact on the consumption patterns of households, which in turn will have an impact on the demand for infrastructure. Demographic change affects the use of infra-

structure directly by changing households' consumption pattern and indirectly through the backward linkages between production sectors.

The focus of the analysis was on two important types of technical infrastructure, energy and transport. With regard to energy, the results of the model suggest that demographic change has a relatively small impact on the *level* of energy use, but what may be more important is its impact on the *composition* of energy, i.e. the energy mix. Demographic change tends to reduce the share of gasoline while raising the shares of liquid fuels and heat energy in the energy mix of households. These findings show that the effects of demographic change should be studied at a high level of sectoral disaggregation, because otherwise important impacts may be overlooked.

With regard to transport, the results of the input-output analysis suggest that demographic change has a negative impact on the road use of households, and since these are the main users of roads, total road use will be reduced by 2.5 percent. However, this does not mean that the total demand for transportation services declines, because the use of railway services is significantly increased. Thus, as in the case of energy, the effect on total infrastructure demand may not be tremendous, but the reallocation between different types of transportation infrastructure – in this case from roads to railways – may be significant.

However, an interpretation of these findings must take into account that the consumption expenditure forecast was made under the assumption of time-invariant consumption coefficients. That is, the consumption patterns of each age group from 2003 were kept constant for a projection of consumption expenditures up to the year 2030. In reality, one may expect that consumption patterns change over such a long time period, for example due to growing incomes, changing prices, or cohort effects. Also, the input-output analysis was based on technical coefficients from the 2004 input-output table. In reality, these coefficients may be affected by technological change or substitution effects. Future research should attempt to incorporate these effects in a more general model with endogenous coefficients of consumption and production.

Since the main ingredients of demographic change, growing life expectancies and low birth rates, are not confined to Germany but are also observed in the majority of OECD countries, the findings from this paper can probably be extrapolated to many other countries in a similar situation. Within countries, however, there is a huge diversity in demographic developments between individual regions. Therefore, it would be extremely interesting and important to analyse demographic change not only at the national level but also for subnational regions.

Appendix

Code	Description
110000	Food
120000	Non-alcoholic beverages
210000	Alcoholic beverages
220000	Tobacco
230000	Narcotics
311000	Clothing materials
312900	Hosiery for men, women and children
312901	Garments for men (excl. hosiery)
312902	Garments for women (excl. hosiery)
312903	Garments for children of 0 to 13 years (excl. hosiery)
313000	Other articles of clothing and clothing accessories
314100	Darning, mending, repair and altering of garments, hire of garments
314200	Dry-cleaning, laundering and dyeing of garments
321100	Shoes for men
321200	Shoes for women
321300	Shoes for children of 0 to 13 years
321900	Shoe accessories
322000	Repair and hire of footwear
411040	Actual rentals of long-term tenants in hotels, guesthouses, etc.
411050	Sublease for main or secondary residences
411900	Actual rentals for main residence (including service and utility bills, excluding heating cost and rentals for garages)
412900	Actual rentals for secondary residences (including service and utility bills, excluding heat-ing cost and rentals for garages)
421031	Imputed rentals of owners occupying their main residence, building constructed before 1949 (excluding service and utility bills and rentals for garages)
421032	Imputed rentals of owners occupying their main residence, building constructed between 1949 and 1990 (excluding service and utility bills and rentals for garages)
421033	Imputed rentals of owners occupying their main residence, building constructed after 1990 (excluding service and utility bills and rentals for garages)
422040	Imputed rentals of households paying a reduced rental or housed free
422050	Imputed rentals for secondary residences (excluding service and utility bills and rentals for garages)
431001	Materials for the maintenance and repair of the dwelling (tenant)
431002	Materials for the maintenance and repair of the dwelling (owner-occupier)
432010	Services for the maintenance and repair of the dwelling (owner-occupier)
432900	Services for the maintenance and repair of the dwelling (tenant)
445900	Service and utility bills without heating cost for owner-occupied main residence
445901	Service and utility bills for owner-occupied real estate not permanently used
451010	Electricity (including solar energy)
452000	Gas
453000	Liquid fuels
454000	Solid fuels
455000	Heat energy
456000	Ice used for cooling and refrigeration purposes.
511900	Furniture and furnishings
512900	Carpets and other floor coverings
513900	Delivery, installation and repair of furniture, furnishings and floor coverings
520900	Household textiles
520901	Repair of household textiles
531100	Refrigerators, freezers and fridge-freezers
531200	Washing machines, dryers, drying cabinets, dishwashers, ironing and pressing machines

Code	Description
531901	Other major household appliances Sonstige größere Haushaltsgeräte
532000	Small electric household appliances
533900	Repair of household appliances and delivery and installation of major household appliances
540900	Glassware, tableware and household utensils
540901	Repair of Glassware, tableware and household utensils
551900	Tools and equipment for house and garden
552900	Miscellaneous accessories for house and garden
561000	Non-durable household goods
562000	Domestic services and household services
611010	Pharmaceutical products: only co-payment and deductibles
611900	Pharmaceutical products: without co-payment and deductibles
612010	Other medical products: only co-payment and deductibles
612900	Other medical products: without co-payment and deductibles
613050	Orthopaedic footwear (incl. co-payment)
613072	Dentures (incl. co-payments)
613090	Repair of Therapeutic appliances and equipment (incl. co-payments)
613900	Therapeutic appliances and equipment (incl. rentals and co-payments)
621000	Medical services (incl. co-payments)
622000	Dental services (incl. co-payments)
623900	Paramedical services (incl. co-payments)
630000	Hospital services (incl. co-payments)
711100	Purchase of new motor cars
711200	Purchase of used motor cars
712000	Purchase of motor cycles
713000	Purchase of bicycles
714000	Purchase of animal-drawn vehicles
721070	Spare parts and accessories for bicycles
721900	Spare parts and accessories for motor vehicles and motor cycles
722000	Fuels and lubricants for personal transport equipment
723000	Maintenance and repair of personal transport equipment
724060	Actual rentals for garages or parking spaces
724061	Imputed rentals for owner-occupied garages or parking spaces
724062	Imputed rentals for garages or parking spaces provided for free (main residence)
724900	Other services in respect of personal transport equipment
730901	Passenger transport not by air (without overnight stay)
730902	Passenger transport not by air (with overnight stay)
733100	Passenger transport by air (without overnight stay)
733200	Passenger transport by air (with overnight stay)
810000	Postal services
820000	Telephone and telefax equipment
830020	Telecommunication services - mobile telephony
830031	Telecommunication services - internet connection services
830900	Telecommunication services - telephone, telefax, telegram
911100	Equipment for the reception, recording and reproduction of sound
911200	Equipment for the reception, recording and reproduction of sound & pictures (excl. cameras)
912000	Photographic and cinematographic equipment and optical instruments
913000	Information processing equipment and software
914000	Recording media
915000	Repair of audio-visual, photographic and information processing equipment
921900	Other major durables for culture, sport, camping and recreation
923900	Maintenance and repair of other major durables for culture, sport, camping and recreation
931900	Games, toys and hobbies
932010	Equipment for sport, camping and open-air recreation
933900	Garden products and nondurable goods for garden maintenance

Code	Description
933901	Plants and flowers
934900	Pets and related products incl. veterinary services
941020	Extracurricular education in sport or fine arts
941900	Events or establishments of sport and culture
942400	Other recreational and cultural services
942900	Radio and television license fee
942901	Hire of equipment and accessories for culture
943000	Games of chance
951000	Books
952900	Newspapers and periodicals
953900	Miscellaneous printed matter
954900	Stationery and drawing materials
961000	Package holidays (inland)
962000	Package holidays (abroad)
1010900	Child care
1020900	Study and exam fees at schools and universities
1050010	Private lessons
1050900	Fees for educational programmes etc.
1111000	Restaurants, cafés and the like
1112000	Canteens
1120000	Accommodation services
1211010	Services of hairdressing salons and barbers
1211030	Other personal grooming services
1212900	Durable goods for personal case (incl repairs)
1213900	Articles for personal hygiene and beauty products
1213901	Other nondurable goods for personal care
1220000	Prostitution
1231000	Jewellery, clocks and watches (incl repairs)
1232000	Other personaleffects
1240900	Care services for old, disabled and other persons in need of care
1250900	Insurance and financial services n.e.c.
1262070	Leasing of motor vehicles and motor cycles
1270900	Other services n.e.c.

Source: Statistisches Bundesamt, authors' translation

Table A1: Classification of consumption expenditure by purpose

CPA code	Short name
1	Agriculture
2	Forestry
5	Fish
10	Coal
11	Crude oil and natural gas
12	Uranium
13	Metal ores
14	Other mining and quarrying products
15.1 - 15.8	Food products
15.9	Beverages
16	Tobacco products
17	Textiles
18	Clothing
19	Lether and leather products
20	Products of wood, cork and straw
21.1	Ppulp, paper and paperboard
21.2	Articles of paper and paperboard
22.1	Printed media
22.2 - 22.3	Printing services and recorded media
23	Refined petroleum products and other fuels
24.4	Pharmaceutical products
24 (without 24.4)	Chemical products
25.1	Rubber products
25.2	Plastic products
26.1	Glass and glass products
26.2 - 26.8	Ceramics and other non-metallic mineral products
27.1. - 27.3	Basic ferrous metals
27.4	Basic precious metals and other non-ferrous metals
27.5	Foundry work services
28	Fabricated metal products
29	Machinery
30	Office machinery and computers
31	Electrical machinery
32	Radio, television and communcation equipment
33	Medical, precision and optical instruments; watches and clocks
34	Motor vehicles
35	Other transport equipment
36	Furniture, other manufactured goods n.e.c.
37	Secondary raw materials
40.1, 40.3	Electricity, steam and hot water
40.2	Gases
41	Water
45.1 - 45.2	General construction work
45.3 - 45.5	Specific construction work
50	Trade, maintenance and repair of motor vehicles
51	Wholesale trade
52	Retail trade and repairs
55	Hotel and restaurant services
60.1	Railway transportation services
60.2 - 60.3	Other land transportation services
61	Water transport services
62	Air transport services

CPA code	Short name
63	Supporting transport services
64	Post and telecommuncation
65	Financial intermediation
66	Insurance and pension funding
67	Services auxiliary to financial intermediation
70	Real estate services
71	Renting services
72	Computer and related services
73	R&D services
74	Other business services
75.1 - 75.2	Public administration and defence
75.3	Compulsory social security services
80	Education
85	Health and social work
90	Sewage and waste disposal
91	Membership organisation services n.e.c.
92	Recreation, culture, sports
93	Other services
95	Household services

Source: Statistik Austria (modified)

Table A2: Sector classification for input-output calculations

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