Chapter 2

Economic aspects of household metabolism: historical analysis[1]

2.1 Introduction

One does not need to invoke the microeconomic theory of consumer behavior to ascertain that prices have a large impact on consumption. As each guilder or Euro can be spent only once, a very high price per unit of a good forces consumers to consider carefully their decision to purchasing that good.[2] On the other hand, a very low price per unit may induce consumers to act almost as if the good is for free. These observations are just as valid for household metabolic flows, such as natural gas, electricity and water, as they are for other goods and services.

In this diagnostic research carried out within the framework of the economic aspects of household metabolism, we focus on the prices paid by households in the Netherlands for natural gas, electricity, and water over the period 1950 ¡ 1990. To obtain a clear picture of real prices, three adjustments need to be made. The first, and most trivial, is correction for inflation. Inflation is measured from the changes in the prices of a fixed 'basket' of goods over the years. Figure 2.4 shows, for example, that average nominal electricity prices increased only slightly between 1950 and 1994, whereas the general price level

[1] This Chapter is based on Linderhof and Kooreman (1998).

[2] From the year 2002 the Euro replaces the guilder as official currency in the Netherlands. In this thesis we have still used the Dutch guilder as currency but the currency change is unlikely to have any effect on our results.

increased substantially. As a result, the real electricity price in 1950 was more than double that in 1985. Second, the costs of services such as gas, electricity and water are influenced by changes not only in the price level, but also by changes in tariff structures. In the Netherlands there have been several such changes over the last four decades; for natural gas supplied to small consumers, for example, the tariff structure was changed from a regressive to a progressive one. These aspects are analyzed in section 2.2.

Third, when investigating the consumption of natural gas, electricity, or water, the price per service unit of domestic appliances is the most appropriate concept to explain the household consumption of services. We have analyzed this aspect of the price for using refrigerators, freezers, washing machines and dishwashers. These appliances have become more energy efficient in recent years, so that the electricity price per service unit decreases even if the real electricity price per kilowatt-hour remains constant. Moreover, to take into account the possible changes in the *quality* of these appliances (in terms of their energy efficiency and other attributes), we estimate hedonic price equations that relate electricity and water consumption to their characteristics and a trend. This allows us to elicit a quality-corrected price per service unit (section 2.3). In Chapter 3 the hedonic regression technique, the data and the estimation results are discussed more extensively.

Within the HOMES project, two other areas of interest are domestic waste and the ownership and use of cars per household, both of which are major areas of government policy. This are summarized in sections 2.4 and 2.5, respectively, over the period 1950 ¡ 1990. Some concluding remarks follow in section 2.6.

2.2 Household consumption, prices and tariff structures of energy and water

2.2.1 Natural gas

A major aspect of household metabolism is the consumption of natural gas by private households and the corresponding prices. We have used data on natural gas consumption and prices over the period 1950 ¡ 1990 compiled by the Statistics Netherlands (see CBS, 1995a).[3] Annual data on prices and consumption of natural gas are available only from 1961, when natural gas was

[3] CBS ('Centraal Bureau voor de Statistiek') is the Dutch acronym for Statistics Netherlands.

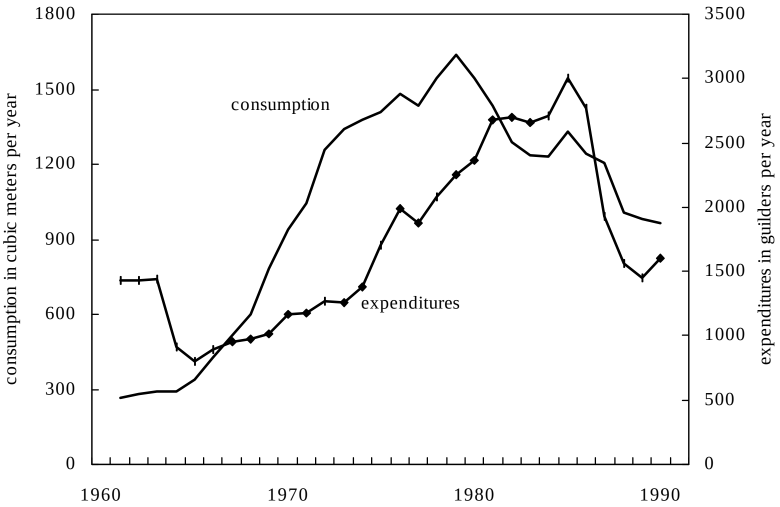

Figure 2.1: *Annual natural gas consumption and annual expenditures on natural gas consumption by households,* 1961 ¡ 1990*.* Source: CBS (1995a).

substituted for oil and coal. The precursors of natural gas and household consumption were discussed in detail in Van der Wal and Noorman (1998); here, we only provide only a brief summary.

Environmental scientists, as Van der Wal and Noorman (1998), usually express natural gas consumption in gigajoules (GJ), but for our purposes it is more suitable to analyze the changes in natural gas consumption in cubic meters (m^3), although the observed trends are similar.[4] Figure 2.1 shows household consumption and expenditures on natural gas; after 1961 consumption increased steadily, except for a brief fall after the 1973 oil crisis. The peak (so far) was reached in 1979, when the second oil crisis caused a general downward trend.

Figure 2.1 also shows that in 1961 households spent an average of 740 guilders (in real prices) on natural gas, but in 1964 expenditures declined sharply due to a major price reduction. Expenditures gradually fell until 1973, and then increased to an average of 1,540 guilders in 1985, and then fell to 823 guilders in 1990, again due to a substantial reduction in prices. Figure 2.2 shows the nominal and real prices of natural gas from 1961 to 1990. Real prices declined steadily until the oil crises of the 1970s, and then increased sharply until 1985.

[4] 1 m^3 natural gas $\approx$ 31.65 MJ; 1 GJ $\approx$ 31.60 m^3:

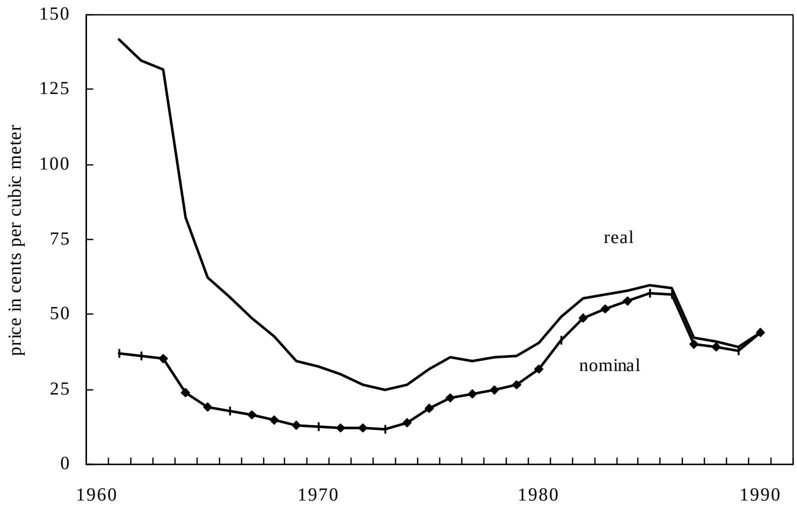

Figure 2.2: *Natural gas prices for households,* 1961 – 1990*; base year is* 1990*.* Source: CBS (1995a).

Only recently have prices been increasing again.

In 1990, the real price of natural gas was about 44 cents per cubic meter, less than one-third of the 1961 price of 142 cents per cubic meter, and about the same as in 1980. Booij *et al.* (1992) estimated that the (short-term) price elasticity for household natural gas consumption lies in the range -0.4 to -0.1. Thus, a 10 percent increase in the gas price corresponds to a decline in consumption of 1–4 percent.

Tariff Structure for Natural Gas

Here we have used data on the natural gas tariff structure over a 30-year period from *EnergieNed*, published by the energy supply companies in the Netherlands. Between 1967 and 1980 a *regressive block tariff* was charged, in which the first 300 m^3 of natural gas were the most expensive. In 1967 – 1975 natural gas consumption was divided into four blocks, and after 1975 the two smallest and two largest blocks of consumption were combined and a regressive two-block tariff structure was maintained until 1980. In 1975, the first 600 m^3 of natural gas cost 27 cents per cubic meter, and additional units 16.7 cents. In 1980, the tariff structure was changed from a regressive block tariff to a *proportional* *tariff*, so that all households paid a fixed charge and a price per unit of natural gas consumed.

Independent of the tariff structure, a number of tax changes have also affected the price of natural gas. In 1978 the rate of value added tax (VAT) on natural gas was raised from the low level (then about 4 percent) to the high level of 17.5 percent. In 1967 an environmental consumption tax was introduced at 0.03 cents per cubic meter, but in 1990 this was increased to 2.08 cents. In 1991 the gas supply companies introduced an Environmental Action Plan tax ('Milieu Aktie Plan', or MAP tax) of 0.5–2 percent of the natural gas price, to finance their environmental activities.

In 1996 the so-called 'ecotax' was introduced as a means of reducing household natural gas consumption. This new tax transformed the proportional tariff structure into a progressive tariff structure, since it is charged on gas consumption over 800 m^3 per year. This is being introduced in stages; for 1996 the ecotax was set at 3.8 cents per cubic meter, and will be raised to 11.2 cents in 1998. The expected increase in household energy expenditures will be offset by lower income taxes.

2.2.2 Electricity

For household electricity consumption, we have used data published in *EnergieNed* (several volumes) between 1950 and 1993 (see figure 2.3). Electricity consumption increased steadily for almost 30 years, except for a slight fall immediately after the 1973 oil crisis. In 1979 – 1988 consumption declined, but since then has been rising again (for details of household electricity consumption, see Van der Wal and Noorman (1998).

Expenditures on electricity grew steadily until 1973. In the years following the two oil crises, expenditures continued to grow, but fell steeply in 1987 due to a large price reduction. Figure 2.4 shows the nominal and real prices of electricity between 1950 and 1993. Real prices fell steadily until 1973, and then increased for some years. After the 1979 energy crisis the real price started to fall, and is still decreasing, whereas the nominal price of electricity has remained constant in the last few years.

Electricity Tariff Structures

There have been no major changes in the tariff structure of electricity since the introduction of the two-part tariff in 1950. Since 1984, some households have

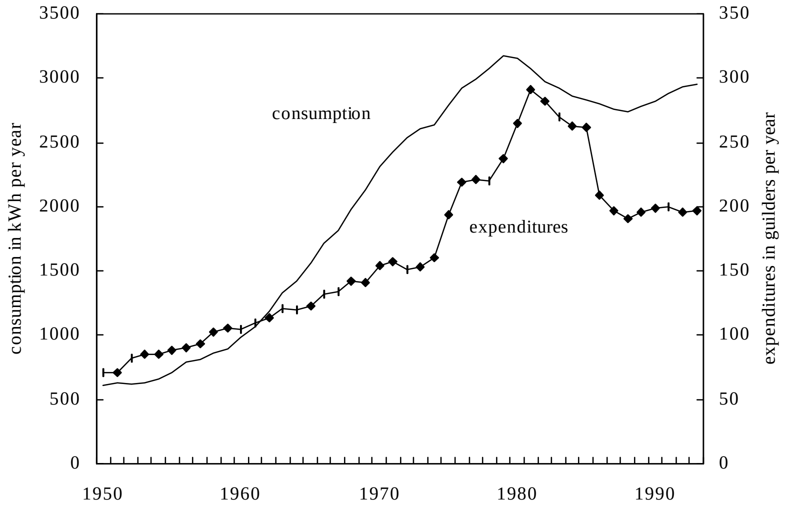

Figure 2.3: *Electricity consumption and expenditures for households,* 1950 – 1993*.* Source: EnergieNed (several volumes).

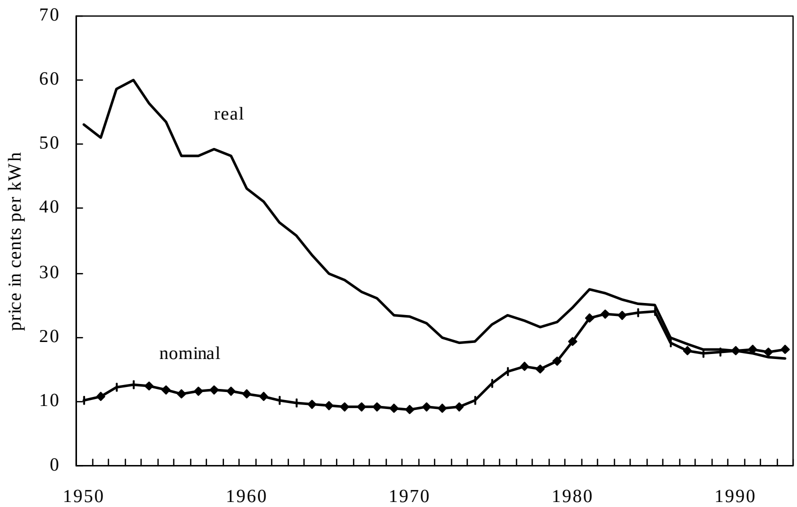

Figure 2.4: *Electricity prices for households,* 1950 – 1993*; base year is* 1990*.* Source: EnergieNed (several volumes).

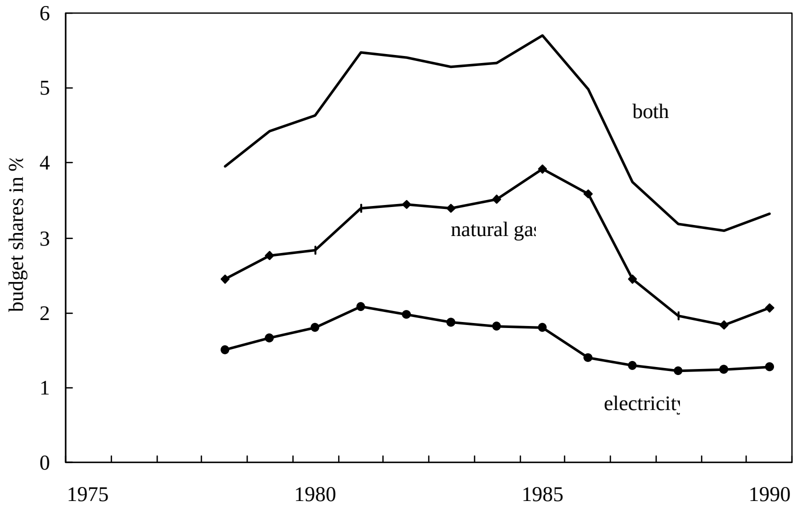

Figure 2.5: *Budget shares of energy in household expenditures,* 1978 ¡ 1990. Source: Booij *et al.* (1992).

been able to choose whether to be charged the two-part tariff (peak-hour rate on weekdays, and half that rate during the night and at weekends), or a proportional tariff (approximately the 'peak-hour' rate); the latter is often charged when an electric boiler is present. According to Van Oortmarssen (1991), 30 percent of Dutch households were charged this tariff in 1987. The penetration of this two-part tariff varied from 5 to 95 percent among the regions of the electricity distribution companies. Booij *et al.* (1992) showed that the price elasticity for electricity in the case of the peak-hour tariff hardly deviated from that in the single tariff case; both elasticities were about ¡ 0.15. The peak-hour tariff structure was introduced to improve load management by smoothing out the fluctuations in the demand for electricity throughout the day, allowing for more efficient production.

Budget Shares of Natural Gas and Electricity

Separate information on budget shares (the shares of net income spent on particular commodities) of natural gas and electricity has been available only since 1978. Prior to 1978, data on the joint budget shares of heating and lighting were published (it fell from 5 percent in 1964 to 4 percent in 1974), so that the

Table 2.1: *Water prices in the Netherlands,* 1970 ¡ 1995 *(guilders per* 200 m^3; *base year is* 1990*)*

		WLF		WOG (East		PWN (North		DZH	
	Price	(Friesland)		Gelderland)		Holland)		(The Hague)	
Year	index	nom.	real	nom.	real	nom.	real	nom.	real
1970	38	134	353	133	350	192	505	118	311
1975	59	227	385	182	308	348	590	220	373
1980	78	277	355	197	253	390	500	354	454
1985	96	363	378	238	248	379	395	398	415
1990	100	389	389	243	243	407	407	412	412
1995	114	510	447	411	361	562	493	627	550

Sources: VEWIN (several volumes).

contributions of natural gas and electricity separately are not known. Figure 2.5 shows that the combined budget share of natural gas and electricity over the period 1978 ¡ 1990 (calculated from CBS annual budget surveys) fluctuated considerably, reaching a peak of 6 percent in 1985, and a low of 3 percent in 1989. These results correspond with the findings of Booij *et al.* (1992).

Figure 2.5 shows that the budget share of natural gas has always been larger than that of electricity. The largest share for natural gas was reached in 1985, when households spent twice as much on natural gas as on electricity. The largest share for electricity was reached in 1981. In 1990 households spent about 3 percent of their net income on natural gas and electricity.

2.2.3 Water

For a long time water has been available at relatively low cost. In the absence of 'water crises' analogous to the oil crises of the 1970s, there has been little political and scientific interest in economic aspects of water provision and charges. Only in recent years have water services and water prices become recurring items on the political agenda, as a result of the steady growth in water demand and increasing supply problems (associated with adverse environmental effects and rising costs).[5] Over the period 1965 ¡ 1990 domestic water consumption increased steadily by 1.1 percent per capita per year (see Van der Wal and

[5] This is not only the case for the Netherlands. Since the water companies in the UK were privatized in 1989, average household charges for water in England and Wales have shown substantial real increases. As pointed out by Rajah and Smith (1993) the debate over the level and structure of residential water charges is likely to continue, as the 1989 Water Act prohibits, after the end of the century, the current practice of levying water charges based on imputed market rental values of domestic properties.

Table 2.2: *Descriptives statistics water,* 1986 ¡ 1991 *(guilders per* 200 m^3; *base year is* 1990*)*

Year	1986	1987	1988	1989	1990	1991
Number of companies						
	58	61	61	61	50	39
Residential water use (liters per capita per day)						
mean[a]	124.0	124.0	128.0	131.0	130.0	128.0
min	90.0	90.0	93.0	96.0	95.0	91.0
max	196.0	183.0	168.0	177.0	181.0	184.0
1990 Metered households (percent)						
mean[a]	84.7	88.1	89.2	88.7	91.0	93.0
min	4.0	4.0	4.0	3.9	3.9	4.6
max	100.0	100.0	100.0	100.0	100.0	100.0
Population in district of company (in thousands)						
mean	228.0	230.1	239.7	241.0	298.0	369.6
min	9.9	10.0	10.0	10.0	10.4	10.5
max	1,196.0	1,212.0	1,212.0	1,225.0	1,237.0	1,242.0
Marginal water price (for metered households) (Dfl/m^3)						
mean	1.157	1.162	1.135	1.156	1.167	1.218
min	0.616	0.626	0.660	0.680	0.680	0.740
max	2.450	2.450	2.450	2.410	2.350	2.350

[a] Weighted according to the population in the district

Noorman, 1998), and further increases in total water demand are expected until the year 2010, as a result of both demographic factors and behavioral changes.

Table 2.1 shows the domestic water price index in the Netherlands between 1970 and 1995 for a household using 200 m^3 per year, together with the nominal and real prices charged by the supply companies. There were substantial regional differences in the real prices. For two companies (WOG and PWN) real prices are the same now as they were 25 years ago, while those of the other two companies increased substantially, especially the company supplying The Hague. The differences in price reflect the different water sources (ground or surface water).

Tariff Structures for Water

Traditionally, water company tariff structures have been based on cost-effectiveness, i.e. the companies set their rates such that the revenues will cover their costs. The use of water meters is usually advocated on the grounds of equity and efficiency. The equity argument is that it is reasonable that households that use more should pay more, and those that conserve water should be rewarded. Whether the installation of water meters is efficient at an aggregate level will depend on the cost of installation, and on the price sensitivity of water use. Only if the latter is sufficiently large will the costs of metering be justified by the savings in water supply. Recently, some companies have introduced progressive rates explicitly to encourage water conservation. One water supply company, for example, charges 1.22 guilders per cubic meter for the first 120 m^3 per year, and 1.47 guilders thereafter (table 2.2).

Table 2.2 shows that water meters have been installed in about 90 percent of the households in the Netherlands. In some large cities, such as Amsterdam, Rotterdam and Groningen (although Groningen started to introduce metering in 1996) there are hardly any or no water meters installed. For households without meters, the rate is fixed according to the number of rooms, the number of faucets, baths, showers or garden, or the size of the water supply pipe.

Figures 2.6 and 2.7 show the theoretical relationships between the cost of water and the amounts used by unmetered and metered households under various tariff schemes. In figure 2.7 the effects of a proportional tariff (the real price per unit) and a progressive rate are shown. In the case of a progressive rate the price per unit is higher at higher levels of consumption . Whether a progressive rate is an effective means of reducing water consumption is again a matter of price sensitivity. Kooreman (1993) estimated the (short-run) price elasticity of domestic water use in the Netherlands to be -0.10 (a 10 percent price increase induces a 1 percent reduction in consumption), close to estimates reported by Herrington (1987) for Finland and Sweden. This implies that the effect of a progressive rate will be small. It would be much more effective to make all water-related charges completely dependent on use, since this would imply a multiplication of the nominal marginal price by a factor of 3 to 4 (see Kooreman, 1993).

2.3 Possession rates and the energy and water use of appliances

The increased demand for energy and water for domestic use coincided with the introduction of various appliances. Figure 2.8 shows the possession rates of some domestic appliances over time (CBS, 1995a; Van Ours, 1986). In this case the possession rate is defined as the number of households owning an appliance, divided by the total number of households. However, Van Maanen

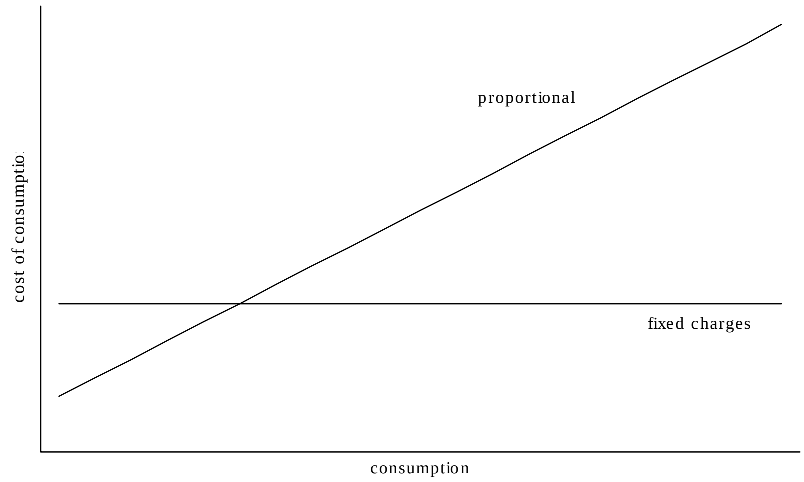

Figure 2.6: *Total proportional costs and fixed charges per consumption level*

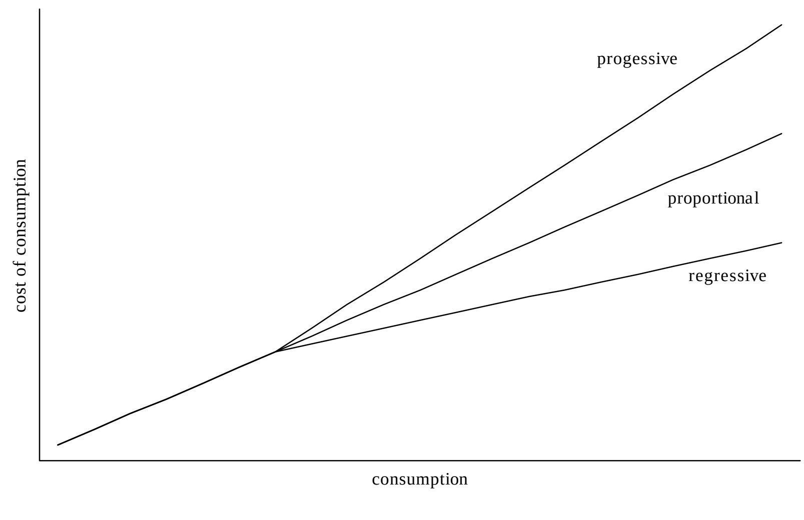

Figure 2.7: *Total progressive, proportional and regressive costs per consumption level*

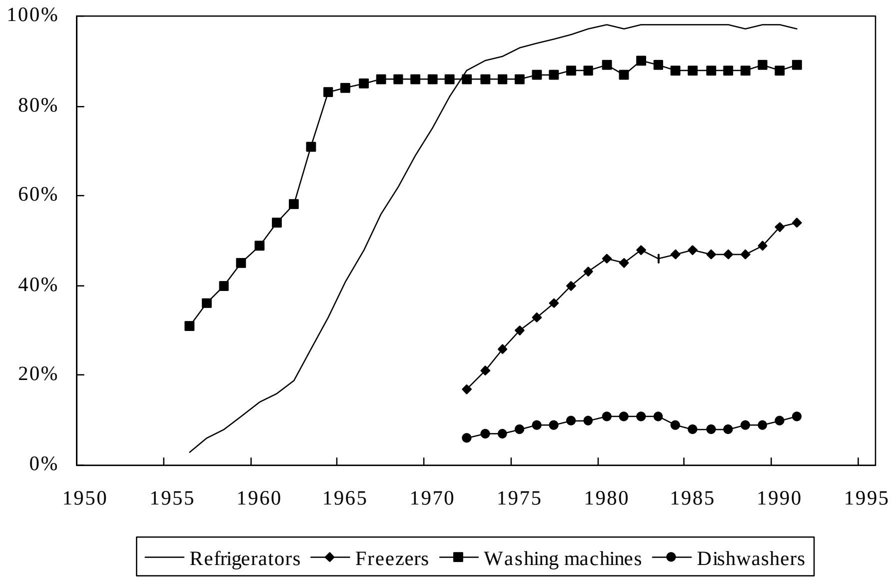

Figure 2.8: *Possession rate of household appliances in the Netherlands*, 1956 – 1990. Sources: Van Ours (1986) and CBS (1995a).

(1994) and Van der Wal and Noorman (1998) used the penetration rate, defined as the number of appliances owned by households divided by the total number of households. Thus, if a household has two refrigerators, both are included.

In 1990, 98 percent and 95 percent of households owned a refrigerator and a washing machine, respectively, about 50 percent had a separate freezer, and only 11 percent a dishwasher. Figure 2.8shows that the possession rates of these four appliances have been stable over the last decade. These appliances account for a substantial part of domestic electricity consumption, which is about 3,132 kWh per household per year (Van Maanen, 1994, pp. 29–32). Of this, refrigerators and freezers account for 17.7 percent and laundry equipment 16.1 percent, more than one-third of the total. Table 2.3 shows the average shares of domestic appliances in the total electricity consumption.

Domestic appliances use either electricity or both electricity and water. Below, we summarize the changes in the electricity and water use of these appliances, adjusted for quality improvements. For this purpose we have used data on household appliances published in the Consumer Report for 1964 – 1992 (Consumentenbond, several volumes); and for more details, see Chapter 3.

Table 2.3: *Electricity use of some consumer durables and their shares in household electricity consumption,* 1993

Consumer durables	Electricity use in kWh per year	Share of electricity consumption (percent)
Refrigerator	368.0	11.7
Freezer	186.6	6.0
Washing machine	232.7	7.4
Dishwasher	220.0	7.0
Tumble dryer	52.9	1.7
Total	1,060.3	33.8

To analyze the electricity use and water use of appliances, we applied the hedonic price equation technique, which relates electricity use of refrigerators to their characteristics, and we added a time trend as well. With this method we can disentangle the effects of changing characteristics (e.g., the increasing average volume of refrigerators) on electricity use from the effects of pure increases in energy efficiency. We calculate the quality-corrected electricity and water use of domestic appliances keeping the characteristics constant over time. Chapter 3 summarizes the hedonic regression technique and the estimation results in more detail.

2.3.1 Refrigerators

In 1966 only one type of refrigerator was available, a cabinet-sized model, whereas today many models have separate freezer compartments, placed either above (top freezer) or below (bottom freezer) the refrigerator compartment. In the latter case the two compartments have separate compressors. The volume of refrigerators has increased over time.

Figure 2.9 shows that electricity use of refrigerators decreased steadily until the early 1970s when wardrobe-size models were introduced.[6] In 1989 the electricity use of refrigerators was the same as in 1966, despite the increase in volume. The electricity use per unit volume of the cooling compartment was also similar to that in 1966. We calculated the electricity use of refrigerators per service unit (the cooling unit in the case of the refrigerator) by multiplying the volume by the difference between room temperature (18°C)

[6] The average annual electricity use data here are five-year moving averages. For example, the average use in 1966 is based on the data from 1964-1968.

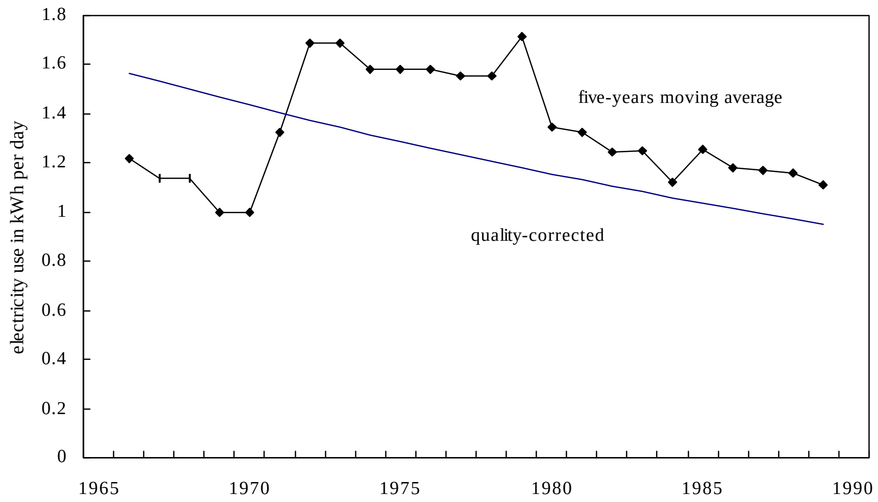

Figure 2.9: *Average daily electricity use of refrigerators in the period* 1964 − 1991.

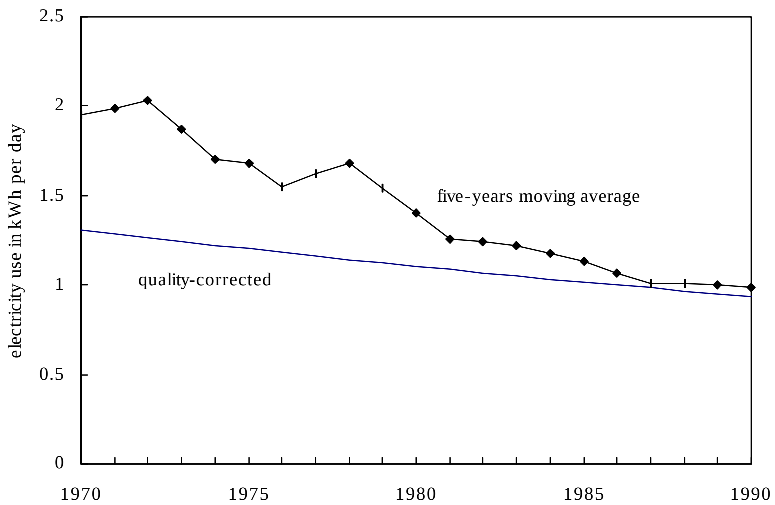

Figure 2.10: *Average daily electricity use of freezers in the period* 1970 − 1990.

and the cooling/freezing temperatures (5 and −12°C, respectively). Again, the electricity use per cooling unit shows a trend similar to that shown in figure 2.9 (the trends per cooling compartment volume and per service unit are not shown). After 1973 the electricity use of refrigerators per service unit declined steadily.

Figure 2.9 also shows the quality-corrected electricity use per service unit, which has also decreased steadily. Over the period considered, the electricity use of refrigerators decreased by 2.1 percent per year.

2.3.2 Freezers

Freezers can also be divided into three types: chest-type (the most common model in the tests), cabinet-size and wardrobe-type freezers (note that the freezer compartments of refrigerators are not considered here).

Figure 2.10 shows that between 1970 and 1990 the electricity use of freezers fell from about 2.0 to 1.0 kWh per day. We also calculated the electricity use per service unit (not shown). We defined a service unit (or freezing unit) as the volume multiplied by the difference between room temperature (18°C) and the desired freezing temperature (−12°C). The electricity use per freezing unit shows a trend similar to that shown in figure 2.10. As with refrigerators, we also calculated the quality-corrected electricity use by estimating a hedonic price regression that relates the electricity use of freezers to their characteristics and a trend. Figure 2.10 shows that the quality-corrected use is decreasing, as in the case of refrigerators.

2.3.3 Washing machines

In 1990, almost all (95 percent) households possessed a washing machine. We examined three models: a front-loader (including a spin dryer), a top-loader (without a spin dryer), and a twin-tub (top-loader with separate spin dryer). The electricity and water use of these models are shown in the figures 2.11 and 2.12. Efficiency improvements due to technological changes were not taken into account in these calculations.Over the years the use of both electricity and water has declined. We used a hedonic regression to relate both electricity and water use to the characteristics of the washing machines as well as a time trend. These characteristics include the capacity (weight of dry laundry), the washing program temperature, the time per run, the presence of a prewash, and the type of machine. With the results of the regression we calculated the electricity

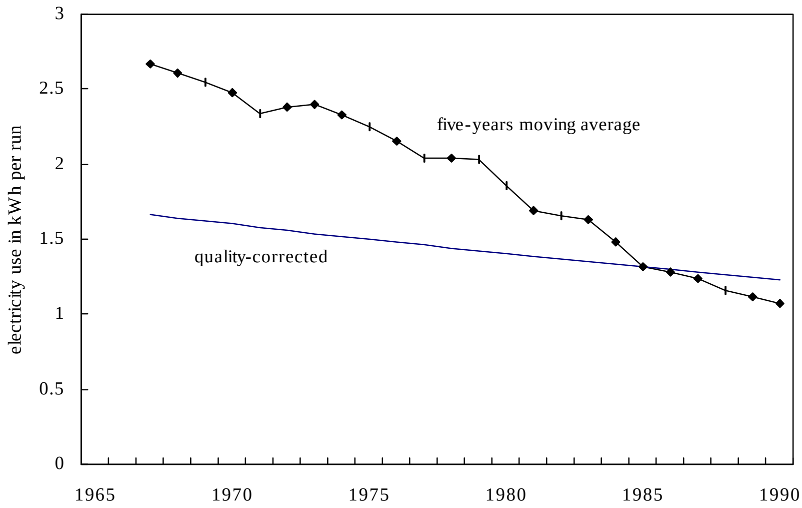

Figure 2.11: *Average electricity use of washing machines in the period* 1965 – 1992.

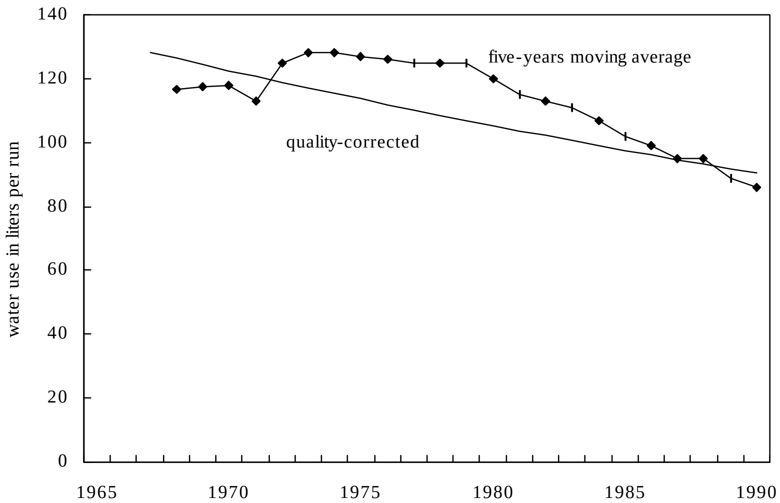

Figure 2.12: *Average water use of washing machines in the period* 1965 – 1992.

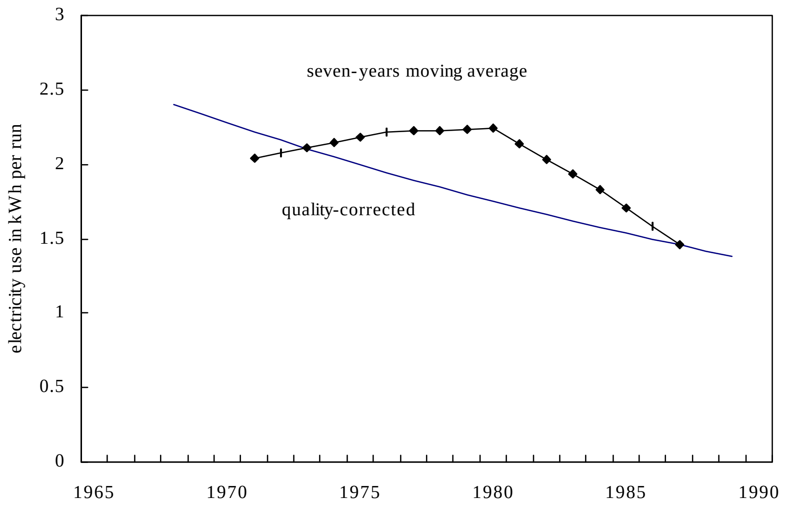

Figure 2.13: *Average electricity use of dishwashers in the period* 1968 − 1989.

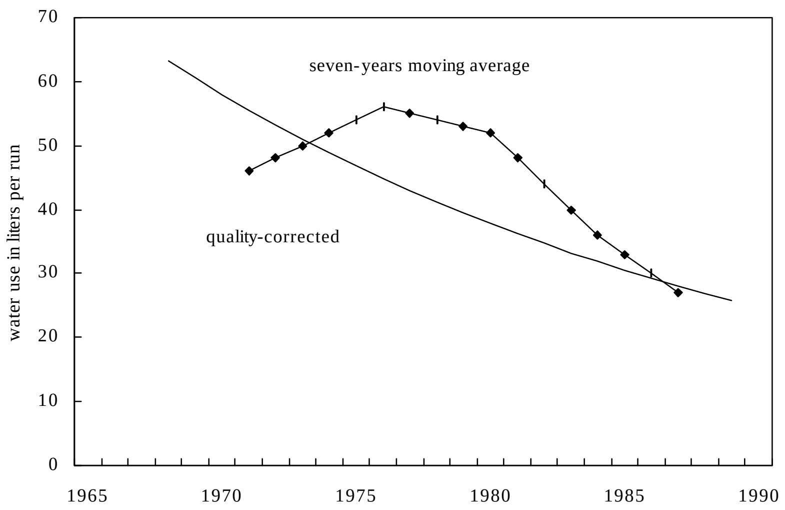

Figure 2.14: *Average water use of dishwashers in the period* 1968 − 1989.

and water use of the washing machines at a washing program temperature of 60°C and the average of the other characteristics. The results of the regression imply that electricity use declined by 2.3 percent per year, and water use by 1.6 percent per year.

2.3.4 Dishwashers

In 1990, only 11 percent of households in the Netherlands owned a dishwasher. It has also been the least tested appliance. The results of the first tests comparing three different types were published in 1968. The portable dishwasher, which could be placed wherever needed, was included only in the test in 1968. The other two types tested were the cabinet-sized top-loader and front-loader. The electricity and water use for our data set of 129 machines are presented in figures 2.13 and 2.14.

To get a clear picture of the electricity and water use we corrected for quality changes. Electricity and water use were related to the characteristics, temperature, and the trend using a two-equation hedonic regression. The relevant characteristics were the capacity (number of baskets), the run time, the type of the model, the presence of an energy saving-program, and the option to add water softener. Figures 2.13 and 2.14 show the quality-corrected (calculated) electricity and water use. The electricity use of dishwashers has fallen by an average of 2.6 percent per year, and water consumption by 3.6 percent per year.

2.4 Household waste

This section focuses on household waste, another important aspect of household metabolism. We summarize the changes in the amounts of household waste generated and the costs of collection per kilogram (in real terms).

Figure 2.15 shows the amounts of household waste collected by local authorities in the Netherlands in the period 1950 – 1993 (CBS, 1995a). The waste per capita almost tripled, from 140 kg in 1950, to 400 kg in 1988, and since then has remained constant. Society has an increasing concern for the reduction of waste, particularly household waste, which in 1991 accounted for 71 percent of all waste collected by local authorities (CBS, 1993). The Dutch government is now trying to stem the growth of the 'waste mountain' by encouraging recycling (closing material and energy cycles). In the case of house-

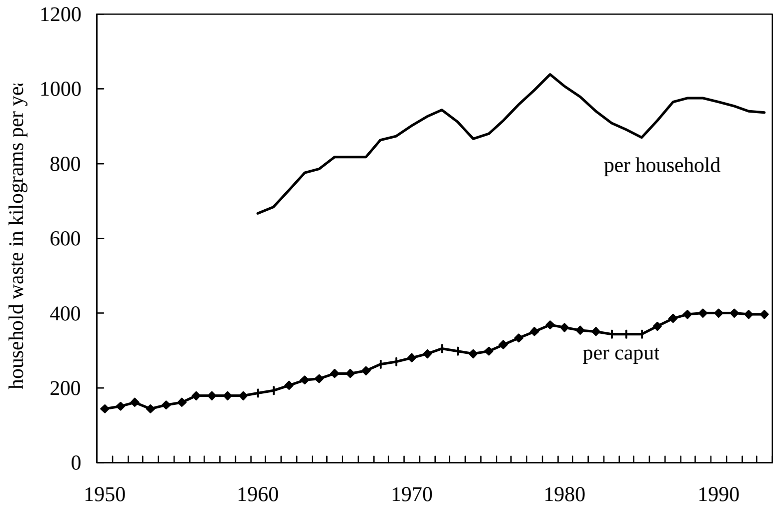

Figure 2.15: *Household waste in the Netherlands in the period* 1950 − 1990*.*

hold waste, the main policy instrument has been the tax on waste, which is charged per capita (see table 2.4). The rate of this tax has increased steadily over the last 20 years, from 21 guilders per capita in 1972, to 98 guilders in 1993. Since 1988 the amount of waste has been roughly constant, so the revenue per kilogram of waste has almost doubled.

There were also changes in the tariff structures. In the past, the municipal taxes on domestic waste were charged per household, although the level of tax varied across the municipalities. With the introduction of the National Environmental Plan (cf. Nationaal Milieubeleidsplan 2, VROM, 1994), the reduction and/or recycling of waste have been major policy goals. The price and the tariff structure are potentially important policy instruments for (local) governments, and there have been a number of experiments with financial instruments based on the 'polluter pays' principle, as adopted in the NMP. Some of these experiments have attempted to find a more flexible tariff structure for waste (IPH, 1995) , where the costs depend on the container size, the frequency of collection, and the weight of the waste, see Chapter 5.

The main purpose of tariff differentiation is to encourage households to separate their waste for recycling, and to reduce the volume of non-recyclable waste. In one experiment in the municipality of Oostzaan, for example, households

Table 2.4: *Taxes on household waste in real terms,* 1972 – 1993

Year	Waste tax (Dfl. per capita)	Revenue (ct/kg)	Year	Waste tax (Dfl. per capita)	Revenue (ct/kg)
1972	21.22	7.0	1983	43.32	12.6
1973	25.79	8.6	1984	44.23	12.8
1974	27.75	9.6	1985	44.05	12.8
1975	27.73	9.3	1986	45.74	12.5
1976	n.a.	n.a.	1987	49.40	12.4
1977	29.91	9.0	1988	50.72	12.8
1978	30.94	8.8	1989	54.08	13.5
1979	36.58	9.9	1990	56.40	14.1
1980	36.60	10.1	1991	70.44	17.6
1981	39.98	10.9	1992	81.66	20.7
1982	41.66	11.9	1993	98.07	24.8

Source: CBS (1995a)

were charged according to the amount of waste collected (see Chapter 5). The conditions of the scheme were that the cost of living should not rise (ensuring a fair distribution of the costs) and that negative effects, such as 'waste tourism' (householders from outside the town coming to dump waste illegally in local woods or open water) would be controlled. Within the first year, the annual costs per household had fallen, and the amount of waste requiring collection fell by 38 percent (see PME Adviesbureau, 1994).

2.5 Car ownership and use

The ownership and use of the car represent important components of household energy consumption, because high levels of car ownership indicate high fuel consumption. In the period 1962 – 1989, transport by car increased by 3.7 percent per year (Bennis *et al.*, 1991, p. 1). In this section we analyze passenger transport, including transport by private car, for which the population and thereby households are responsible. The share of transport by private car in the total passenger transport has grown steadily (see Van der Wal and Noorman, 1998). Between 1960 and 1979, the number of cars per thousand households rose from 160 to 900, and then remained approximately constant (see figure 2.16). Since 1994 the penetration rate has been more or less constant, with about 65 percent of households owning at least one car (CBS, 1995b).

A second aspect of transport by private car is the distance driven. This declined slightly over most of the period, but has increased again in recent

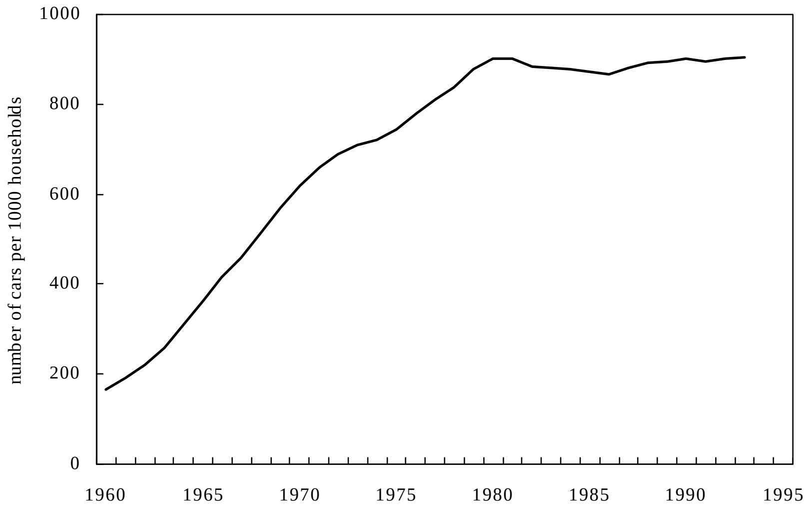

Figure 2.16: *Car ownership: number of cars per* 1,000 *households,* 1960 − 1990. Source: CBS (1995a).

years. It is important to distinguish between the use of the car for different purposes, because the costs to the consumer may differ; for example, if an employer reimburses the costs of traveling to work, then for the commuter the marginal costs of commuting are zero.

With the strong increase in car ownership, the private use of the car has increased sharply. The distance driven for private purposes is defined as the total distance driven, excluding business use, but including commuting. In 1963, 42 percent of the distance driven was for private purposes, but by 1993 this had doubled to about 81 percent (CBS, 1995a). However, growth has slowed in the last few years and there has even been a slight decline. Figure 2.17 shows that between 1963 and 1993, the average distance driven for private purposes increased from 7,800 to 13,600 kilometers per year.

Figure 2.18 shows the changes in the real and nominal prices of fuel. Here, we focus on the real price of high-octane fuel ('super'); the fluctuations in the prices of other fuels, such as LPG and diesel, have been similar (for more details, see Van der Wal and Noorman, 1998; and Bennis *et al.*, 1991, p. 11). The lowest price, 156 cents per liter, was reached in 1969 and 1978, and the highest price, 203 cents per liter, in 1981. De Wit and Van Gent (1986) calculated

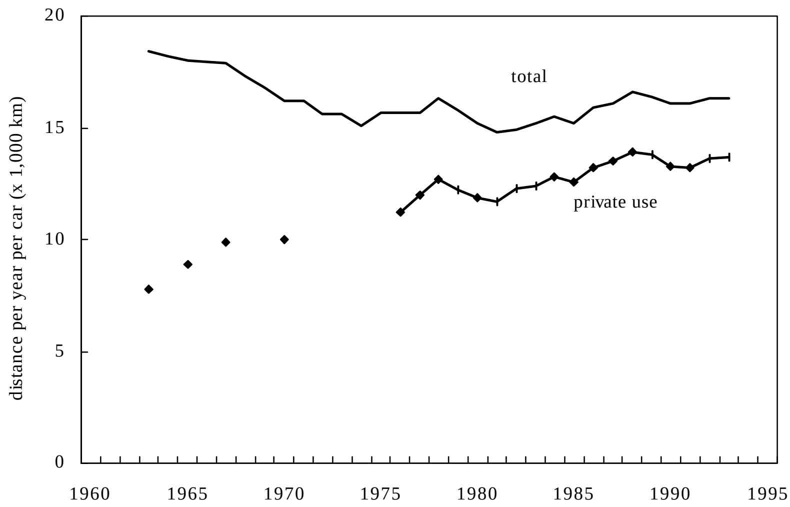

Figure 2.17: *Car use: total distances driven per year, and shares for private use,* 1963 – 1993. Source: CBS (1995a).

that the (short-term) price elasticities for fuel in the period 1955 – 1980 were approximately −0.1; they concluded that an increase in fuel prices would have a greater effect on car ownership than on the distances traveled by car. More recently, Van Staalduinen and Rouwendal (1994), using monthly data, showed an elasticity of −1.0, so that a 1 percent increase in fuel prices would reduce monthly car use by 1 percent. De Jong (1990) found a fuel price elasticity of −0.65.

Finally, car fuel consumption has decreased over time. This was demonstrated in a case study of Bennis *et al.*(1991), who analyzed changes in fuel use and other characteristics of the Opel Kadett in the period 1962 – 1990.[7] From their data we have calculated the five-year moving averages of fuel use for the Kadett, from which we find that fuel use decreased slightly over time. The quality of the Kadett has improved, according to the study of Bennis *et al.* (1991). This quality index was calculated with the hedonic price regression. The quality improvement of the Opel Kadett indicates that the fuel use per service unit fell even more sharply.

Bennis *et al.* (1991) also analyzed the annual costs of running a car. These

[7] The Opel Kadett is known as the Vauxhall Astra in the UK.

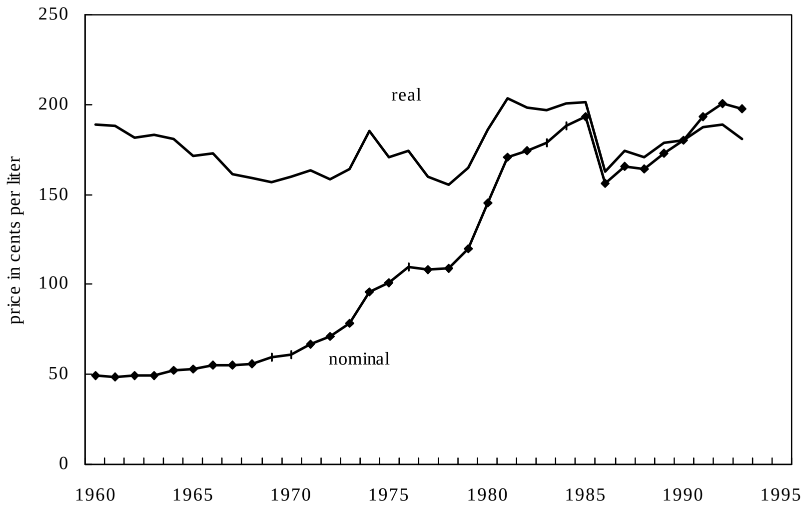

Figure 2.18: *Nominal and real prices of high-octane fuel in the period* 1960 − 1993.

include the fixed costs (depreciation, insurance, taxes, loan interest, etc.), and variable costs, which depend on the distance driven (e.g., servicing, repairs, fuel). The fixed costs (in real prices) account for most of the total annual costs. According to Bennis *et al.*, the costs fluctuated but did not increase much; every increase in cost was compensated in subsequent years. If the costs are corrected for efficiency improvements, the fluctuations were even stronger (p. 47).

2.6 Conclusions

In this chapter we have focused on the prices and consumption of electricity, gas and water in the period 1950 − 1990. The government's growing concern for the environment has been reflected in its energy-saving measures and the use of price as a major policy instrument. The rates of VAT on energy, and of various taxes on energy and water consumption (the 'ecotax') have been increased, and an extra tax (the MAP tax) has been introduced to finance environmental activities of the energy supply companies. Although all of these taxes increased nominal prices, the real prices fell in the period considered. In 1979, for example, electricity consumption per household was five times higher than in 1950, yet the real price fell from almost 60 to 20 cents per kilowatt-hour. On the basis of the price elasticities presented in Chapter 5 and reported in other studies (see Chapter 4 for an overview) we conclude that these declining prices have contributed significantly to the increase in household metabolic flows.

The possession rates of a number of appliances have increased, as have their energy efficiency. The number of service units per appliance has also increased. Thus the energy consumption per service unit declined, but the number of services per appliance and per household increased.

The government's concern for the environment has been reflected in policies aimed at reducing domestic waste and the use of the car. The sharp increases in charges for collecting waste, as with the waste taxes in the early 1990s, seem to have been effective in curbing the increase in the amount of domestic waste. The use of the car increased enormously between 1960 and 1990; the number of cars per household doubled between 1960 and 1980, while the real cost of fuel fell between 1954 and 1990. From the results of other studies we conclude that higher fuel prices have two effects: the distance driven falls, and consumers postpone the decision to purchase a new car or replace an old one.

We conclude that the falling real prices seem to have encouraged household metabolism in recent decades. It is therefore important to analyze the potential effectiveness of price instruments such as taxes and subsidies, as means of implementing and achieving government policy. In the remaining Chapters of this thesis we will analyze the effects of prices and income on the demand for energy, water and household waste collection.