The price of energy friendliness of electric household appliances

Contents

1. Introduction and summary

In this paper, The Danish Energy Agency estimates how the energy efficiency of electric household appliances affects the price of the appliances. We call this the **price premium** for good energy efficiency. Simple **payback periods** for good energy efficiency are calculated by comparing price premiums with the energy savings.

Furthermore, we test the existence of a **maturity effect**, which is the price increase of an individual appliance as a result of increase in energy standard of many other appliances on the market. The maturity effect implies that the price premium of (say) energy label A++ compared to A+ is higher, when A++ is newly introduced and rare on the market compared to a moment when A++ is common on market. The maturity effect might exist if producers gradually learn new technologies.

Data

We use the ELDA register from The Danish Energy Agency. We consider 10 types of appliances, washing machines, tumble dryers, dishwashers, ovens, electric cookers, and five types of refrigerators and freezers. For each type of appliance, information about typically 1.000 to 3.000 individual appliances is available. The appliances have been introduced on the Danish market from 1987 to 2013. The registered variables are the price of the appliance at the date it was introduced on the market, the introduction date, three measures of energy efficiency – namely the absolute energy consumption, an energy efficiency index, and an energy label – a number of characteristics of the appliance such as the size or capacity, and finally the name of the producer.

Hence, the data are very detailed. On the other hand, we do not know how many items are sold of each individual appliance and the registered price is the price recommended by the producer at the date of the introduction on the market. The actual price paid by the consumers is not known, and neither is the price dynamics of the individual products.

Method

The price of household appliances is estimated as a function of the energy standard as well a number of other characteristics of the appliance, e.g. size. Other factors are only included in order to get a more precise estimate of the effect of the energy standard. Hence, in principle the estimate is the effect on price of increased energy standard with all other characteristics of the appliance remaining constant.

Results

We find that:

- For all types of appliances, there is a price premium for high energy standard. The price premium of a 10 percent increase in energy efficiency varies from approximately 2 to 5 percent of the price of the appliance.
- For about half of the types of appliances, we find a maturity effect.
- For all types of appliances, the price premium increases with the initial energy efficiency of the appliance. This means that it is increasingly costly to improve the energy efficiency.

Using these results combined with assumptions of consumers' use of the appliances, we calculate payback periods:

- The price premium typically corresponds to the energy saved over 4 to 6 years (not considering a few outliers). This is considerably shorter than the expected lifetime of the appliances.
- For appliances with a maturity effect: If the energy efficiency is increased for a certain share of market, the payback period becomes shorter than 4 to 6 years.

Central results are given in table 1.1. If the energy efficiency increases with 10 percent, the price of appliances increases with 2.11 to 4.74 percent. Payback periods are between 2.1 and 9.0 years.

Table 1.1. Price premiums and payback periods

	Increase of price of appliance as a result of 10% increase in energy efficiency (percent)	Payback period for consumers buying A++ rather than A+ (years)**
Washing machines	2.78	5.3
Tumble dryers	4.64	9.0
Dishwashers	4.74	4.7
Refrigerator-freezers	2.42	4.4
Refrigerators	2.33	6.2
Refrigerators with freezer compartment	3.35	4.5
Upright freezers	2.24	3.6
Chest freezers	2.74	2.6
Cookers*	2.11	2.1
Ovens*	3.44	5.6

* Label A is compared to B.

** Calculated without the maturity effect.

Discussion

The statistic results are uncertain. It is possible that the estimated price premiums are to low and hence the calculated payback periods are also to low. On the other hand, the price premiums found in this paper are in line with a number of other papers where a price premium of good energy efficiency is found across various products. It is likely that we do not find the maturity effect for all appliances because of uncertainty.

Even if we accept the results statistically, the interpretation is not straight forward. **One interpretation** is that the **short payback periods** and low price premiums could suggest that **consumers are not fully aware of the future energy consumption** related to the use of various appliances and therefore **new or revised policy measures** could be appropriate. Such measures could be to raise minimum quality standards (that is, energy efficiency standards) for appliances or to revise energy labelling. **An alternative interpretation** is that the fact that **we do find price premiums** for all appliances indicates that the **"market for energy efficiency" works**, and we cannot reject the hypothesis that consumers choose appliances with full awareness of appliances' energy consumption.

EU develops energy labelling and minimum energy standards (ecodesign) for products, and The Danish Energy Agency participates in this. We hope that this report will be useful in this work. Energy labelling is mandatory in the EU for a number of electric appliances mainly used in households. Through labelling, energy characteristics of the appliance are made visible for the consumer. Ecodesign excludes appliances with too high energy consumption from the market.

When energy labelling and ecodesign are revised, it is essential to estimate the costs to develop and produce appliances with energy standard superior to existing standards. Such cost estimates are typically made with technic or engineer methods. In this paper, the method used is statistic with use of historic data.

I the next section, we describe energy labelling and ecodesign in the EU. In section 3, related literature is described. Then data is described, and in sections 5 to 7, we show the results of the analysis. In sections 8 and 9, we discuss and elaborate the results. In appendixes, detailed results are presented.

2. EU's ecodesign and energy labels

EU's ecodesign and energy labelling covers a range of energy related products, which are products that use energy, or products that affect the consumption of energy, such as windows and water taps.

Ecodesigns are minimum standards for the energy efficiency of a product. It is not legal to sell products with energy consumption above the ceiling defined by the ecodesign. The energy label makes a number of characteristics visible to the consumer. The label shows an energy label (energy efficiency class), currently running from D to A+++, and the absolute energy consumption (e.g. kWh electricity used for one wash of clothes).

Currently the rules apply to 46 products and the number is expected to increase to at least 85 products in 2020. Electric consumer goods such as white goods, televisions, light bulbs, pumps, electric motors and products with standby functions are examples.

The European Commission is responsible for proposing new or revised rules for ecodesign and energy labelling. First, products with large potential for improvements are identified. Secondly, potential ecodesigns and energy labels are proposed and subsequently all stakeholders can comment on these proposals. Revised proposals are presented to a Consultation Forum, and finally the member countries decide the rules in a Regulatory Committee.

It typically takes 3 to 6 years from the Commission's first proposal to the final decision, and after that, a period of 1 to 2 years is given before the new rules comes into force, so that producers can adapt production. This lengthy and gradual process implies that we cannot trace the effect of new rules to the exact date where new rules come into force.

For the appliances analyzed in this paper, table 2.1 shows some important dates for energy labelling. Consider for example refrigerators and freezers. On 24 January 1994 it was decided that products should be labelled on a scale from G to A from 1 January 1995. Before 1994, the labelling had been discussed for a period. Later, the scale was revised and now runs from D to A+++. The last column tells when the first preparatory study for the revision was published.

Table 2.1. Dates for energy labelling

Type of appliance	Energy label G - A		Energy label D - A+++		Remarks
	Passing the regulation	*Label comes into force*	*Passing the delegated regulation*	*Label comes into force*	*Preparatory study completed*
Refrigerators and freezers*	21 Jan. 1994	1 Jan. 1995	28 Sep. 2010	30 Nov. 2011	First meeting in CF in Dec. 2008
Washing machines	23 May 1995	30 Sep. 1996	28 Sep. 2010	20 Dec. 2011	First meeting in CF in Dec. 2008
Dishwashers	16 Apr. 1997	31 Dec. 1998	28 Sep. 2010	20 Dec. 2011	2008
Tumble dryers	23 May 1995	30 Sep. 1996	1 Mar. 2012	29 May 2013	March 2009
Ovens and cookers	8 May 2002	1 Jan. 2003	1 Oct. 2013	1 Jan. 2015	March 2012

*There was a transition period from scale G - A++ to D - A+++ from 2003/2004 to 30 November 2011.

3. Literature

At least two branches of the literature relate to this analysis, namely papers on learning curves and papers on hedonic estimation of consumers' willingness to pay.

Desroches et al. (2013) show how the price of electric appliances decreases with the accumulated historic sales of the product. A 1 percent increase in sales implies that the price of the appliance decreases with 0.29 to 0.78 percent depending on the type of appliance (this corresponds to some extent to what we call a maturity effect in this paper, see the end of section 6). The analysis is based on aggregate data for each group of appliances, e.g. refrigerators and freezers. When minimum standards are revised in the US, it is praxis to calculated life cycle costs using the actual costs of improving energy efficiency. But if the costs of appliances in general decrease over time, this praxis overestimates life cycle costs of (relatively expensive) appliances with high energy efficiency.

In this paper, we consider the prices and characteristics of individual appliances and we calculate the price premium for good energy efficiency using hedonic estimation. The maturity effect is based on a more detailed method and is specific to the price premium of good energy efficiency (see sections 5 and 6).

Consumers' willingness to pay for good energy standard is studied in many papers, some of which are based on market data, others on interview where consumers are asked to choose between appliances with different characteristics, especially energy standard and price. An example is Ward et al. (2011) that concerns refrigerators. Using the interview data, it is estimated how much the energy label affects the price that consumers are willing to pay for the appliance. The willingness to pay is considered by comparing price premiums with expected future energy savings. The paper indicates a high willingness to pay for good energy standard expressed as long payback period, in fact often longer than expected lifetime of appliances. Perhaps this surprising result is biased due to the questionnaire that clearly focused on energy.

Newell and Siikamäki (2013) use the interview method for a study about hot water boilers. As Ward et al. (2011) they find that consumers in some circumstances accept payback periods longer than the lifetime of the products. The focus of the paper is to compare consumers' response to different lay outs of labels in order to investigate how to nudge consumers to choose products with high energy standard. Labels designed as in the EU nudges consumers the most.

In a study of cars, Busse et al. (2013) use market data and data about the consumers for individual car sales. It is shown that user costs affect the car price and consumers' discount rates are calculated. Discount rates are low which means that consumers are patient to wait for the low user costs to compensate for the price premium.

Busse et al. (2013) have two advantages compared to the study in this paper, namely that consumer characteristics are included and that the data set reflects the number of sales of each individual product.

For buildings and properties, a number of studies on price and energy standard exist. This "product" is relatively complicated to study because property prices encompass the value of the location. Hansen et al. (2013) find a clear correlation between energy label of the building and the property price. To control for location, the average price per square meter of the building in each municipality is included as well as a dummy for municipality. The result is not interpreted in terms of a payback period or an implicit discount rate. For Ireland, Hyland et al. (2012) calculate a similar correlation. The study refers to a number of other studies with various conclusions. A subfield is photovoltaic installations. Hoen el al. (2011) find a price premium for houses with such installations and a payback period of 15-20 years is calculated. Hence, according to the paper, consumers are patient.

The review above is admittedly somewhat ad hoc, but shows that across the products studied and the methods used a price premium for good energy efficiency exists. A number of studies find that consumers are willing to accept relatively high price premiums and long payback periods.

4. Data

For a number of types of appliances, we know a number of characteristics for each individual appliance. Data have been collected from 1987. During the first years, data was collected by electricity companies, and later the companies cooperated with The Danish Energy Agency and Center for Energibesparelser (‘*Center for Energy Savings*’). The purpose of the register is to help to inform consumers about the electricity consumption of appliances. The information is characterized in table 4.1.

Table 4.1. Types of information on appliances and examples

Type of information	Examples
Year of introduction on the Danish market	
Price of the appliance in the introduction year The price is recommended by the producer	
Absolute energy consumption	Measured in kWh For refrigerators and freezers: Yearly consumption For other appliances: Consumption during one use, e.g. one wash of clothes at 60^{o}C.
Energy Efficiency Index (EEI)	The energy consumption relative to certain characteristics of the appliance, typically size or capacity. For example energy consumption for one wash of clothes divided by the capacity of the washing machine measured in kg clothes.
Energy label	Categorization of EEI
Other characteristics of the appliance that may affect either the price or the energy consumption	Refrigerators and freezers: Volume, built-in or detached, indicator for freezing, volumes of special compartments or zones, climate class (whether the appliance usable in the tropics). Washing machines: Capacity, spin-drying efficiency. Dishwashers: Number of plates, programme time, drying efficiency. Tumble dryers: Capacity, type, programme time, drying efficiency. Ovens: Size, noise, type of oven, type of hub.
Name of the producer	

5. Descriptive statistics and results of the price estimation

We consider 10 types of appliances, of which five are different types of refrigerators and freezers

- Refrigerator-freezers (combined)
- Upright freezers
- Refrigerators (without a freezer compartment)
- Refrigerators with a freezer compartment
- Chest freezers
- Tumble dryers
- Dishwashers
- Washing machines
- Ovens
- Cookers (only energy characteristics of the oven is registered in data and used below)

In the section, we show descriptive statistics and we give a simple presentation of the estimated price premiums. We also show the payback period for energy friendliness. In the next sections, we explain the method in detail and in appendixes, we show results in detail. In this section, we primarily show results for washing machines.

5.1. Descriptive statistics

Two measures of energy standard are shown in table 5.1 and figure 5.1 for a period of 20 years. The energy standard improved during the period, but in each year there is also some variation of the energy standard across the individual appliances.

Until mid 1990's the best label was B, see table 5.1. From the late 1980's labels C and poorer gradually vanished from the market. During 2000's label A dominated, and from 2010 labels better than A became the most common. Each year, the number of appliances introduced is high. Presumably, many new appliances are only minor adaptions of existing appliances.

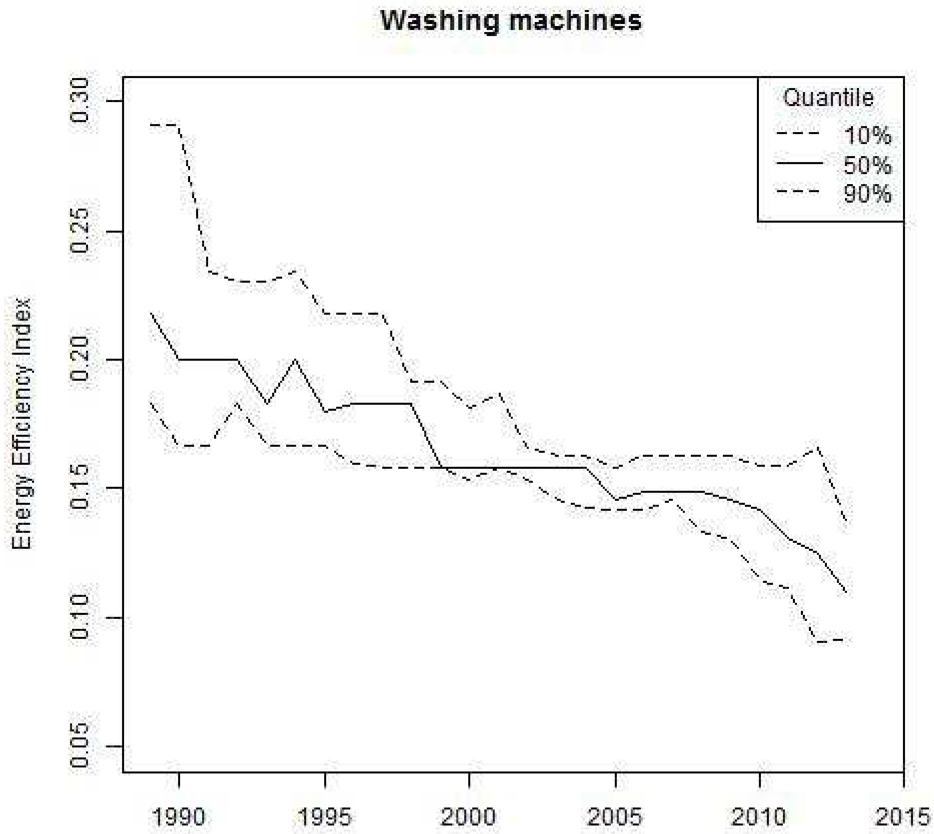
Table 5.1. Washing machines by energy label introduced on the Danish market, number 1989-2013

	A+++	A++	A+	A	B	C	D	E	F	G
1989				1	11	33	18	15	9	4
1990					25	13	13	2	7	1
1991					9	16	12	2		
1992					9	10	3	1		
1993					25	7	6			
1994					19	16	7	3		
1995					33	8	3			
1996				7	61	30	3	2	1	
1997				18	42	22	2			
1998				13	39	2	2			
1999				54	30	5	1			
2000				48	10	1				
2001				92	22	2		1		
2002				74	7	0				
2003				131	4	0	1			
2004				131	6	1				
2005				104						
2006				138	1					
2007			1	187						
2008				146	1					
2009		1		196						
2010	9		1	155	1					
2011	104	57	82	87	3					
2012	92	72	46	8						
2013	25		8							

The energy efficiency index measures the energy consumption relative to certain characteristics that affects energy consumption. For washing machines, the absolute consumption is divided by the capacity of the machine and hence the index measures the development of the energy consumption necessary to wash 1 kg clothes if the machine is filled up.

The index decreases during the period, see figure 5.1, and the variation each year is perhaps not that large.

Figure 5.1. Energy efficiency index for washing machines, median, 10- and 50-percent quantile, 1989-2013



The index is repeated in figure 5.2 and compared to the absolute consumption. Whereas the index steadily decreases, the absolute consumption increases during from 2000 to 2007. This is because the capacity of the washing machines increases, see figure 5.3.

Figure 5.2. Energy efficiency index and absolute energy consumption, average 1989-2013

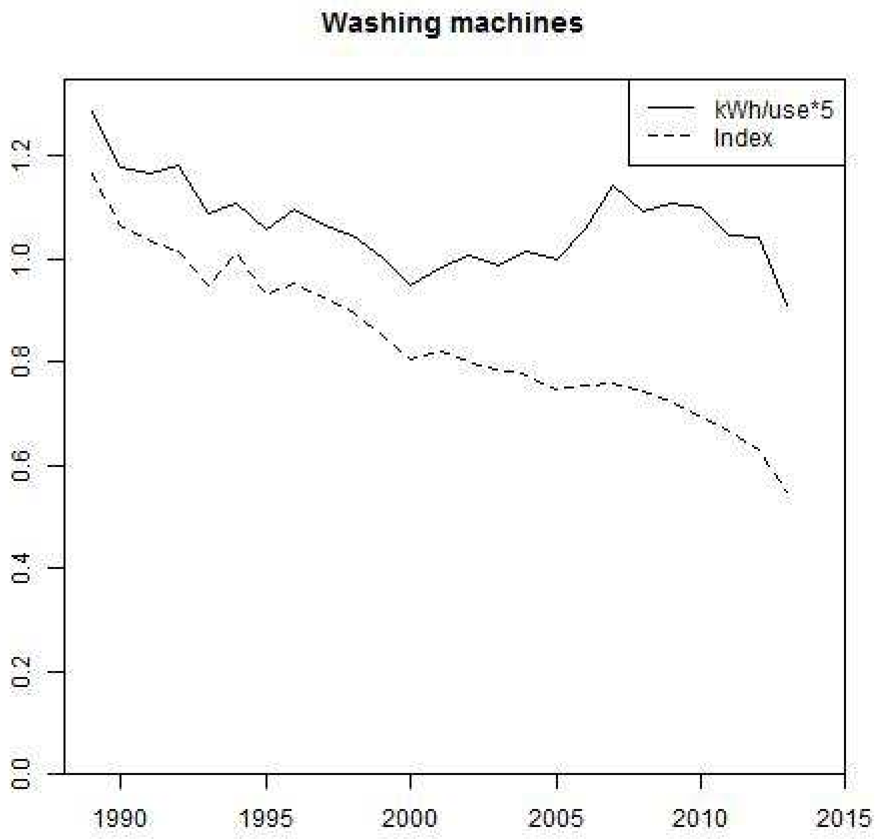
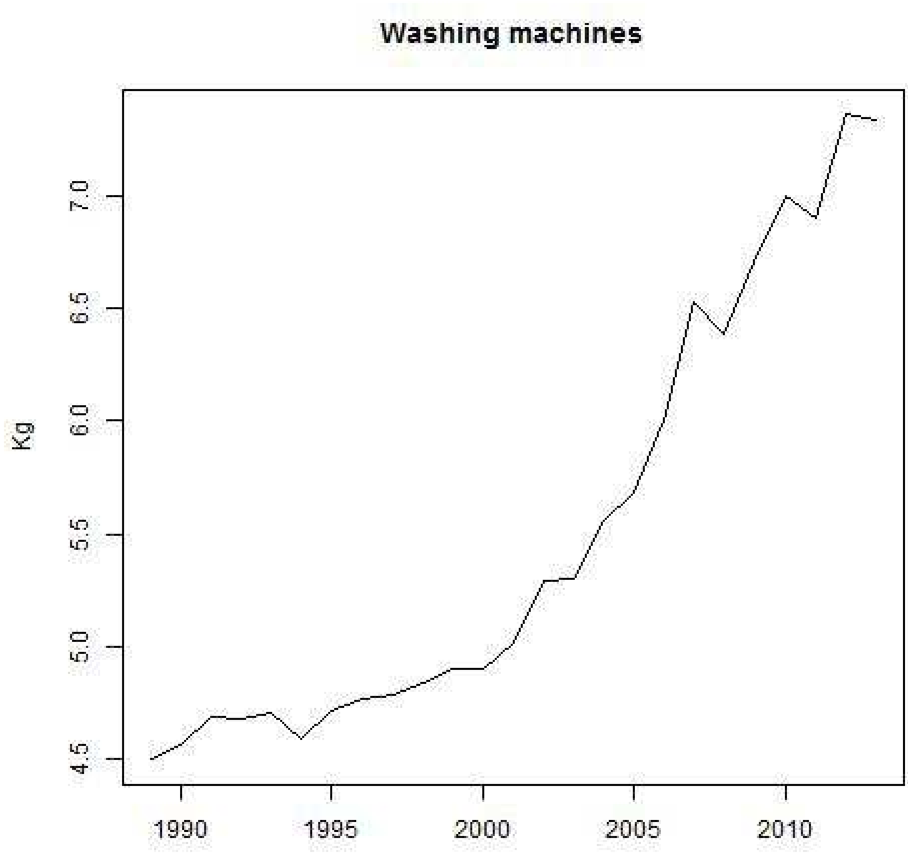


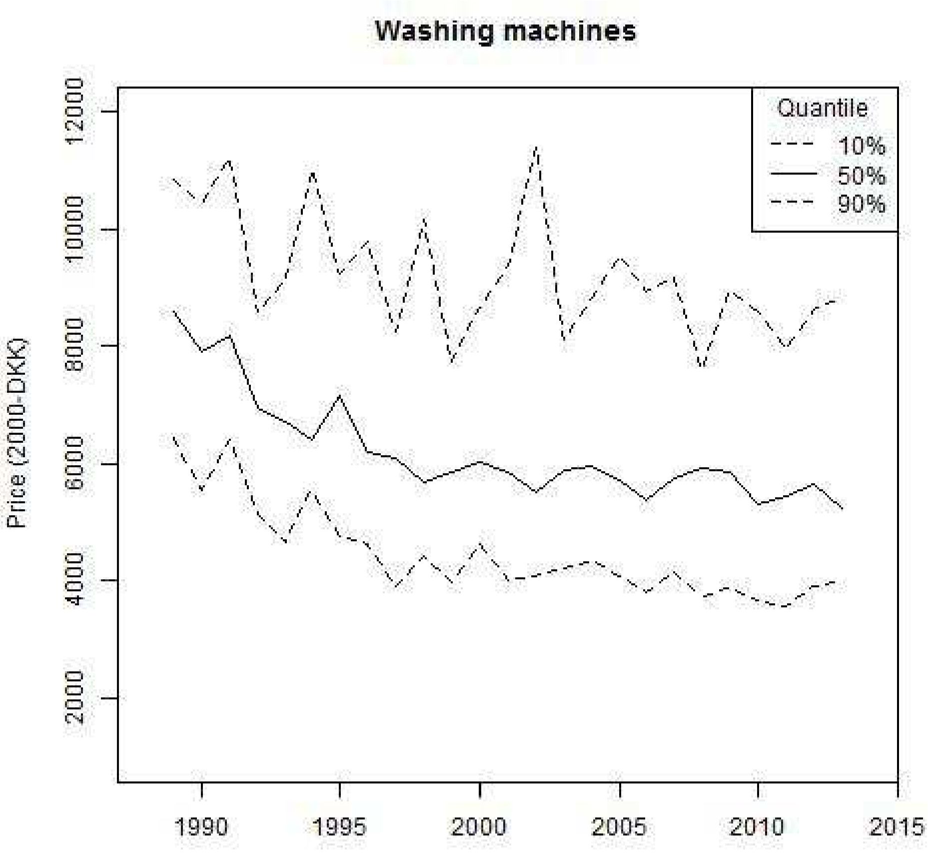
Figure 5.3. Capacity of washing machines, kg clothes, average 1989-2013



If the washing machines are filled up, the index shows that energy required to wash one kg of clothes has decreased. If, on the contrary, consumers put the same quantity of clothes in the machines, energy consumed by machines introduced 2000-2007 increased according to the figures for absolute consumption.

The price of washing machines decreased during the last 20 years adjusted for general inflation, see figure 5.4, even though machines became larger and more energy friendly. Presumably prices fell due to increase of productivity. Also, markets might have become more competitive and perhaps import from low wage countries has increased.

Figure 5.4. Price of washing machines introduced 1989-2013, median, 10- and 90-percent quantile, 2000-prices



As regards the 9 other types of appliances, the energy standard typically improved as for washing machines. Exceptions are ovens and cookers, and for tumble dryers, the standard improved only after mid 2000's. With chest freezers as exception, appliances have become larger. Washing machines illustrated above stands out in two ways. It is the only type of appliance with increase in absolute energy consumption in a period longer than a few years, and the price decrease is especially pronounced. For some of other appliances, the price figure is "u-shaped", so that the price increases in the later part of the period.

Finally, for some other appliances, data are generally more fluctuating. See the figures for all 10 appliances in appendix 1.

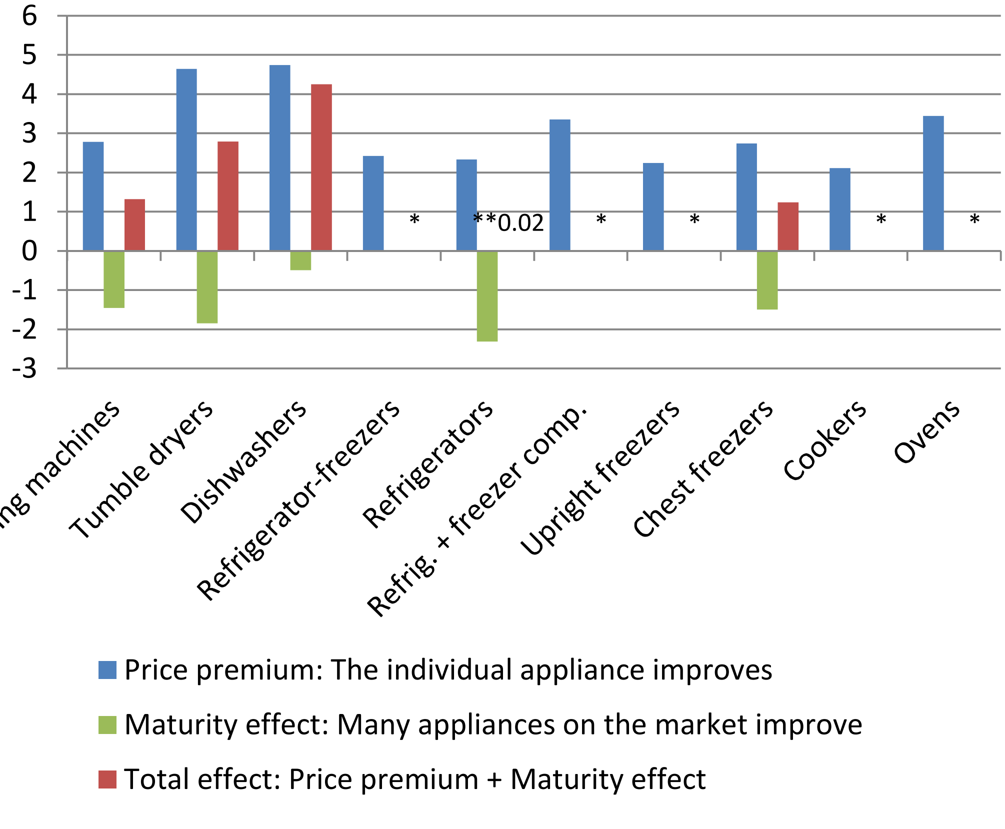
5.2. Energy efficiency and price – a simple presentation of results

We describe results in this section and explain the method in section 6. Detailed results are in appendix 2.

The most important results are:

- The **price premium** is the percentage effect on the price of a (say) 1 percent increase in the energy efficiency of the **individual** appliance.
  Figure 5.5 shows the estimated price premium. The price premium is statistically significant for all appliances.
- The **maturity effect** is the percentage effect on the price of a 1 percent increase in the energy efficiency of **many** appliances on the market.
  For some products, we estimate a maturity effect, see figure 5.5. However, for five appliances, we do not find the effect, for dishwashers the effect is small and statistically uncertain, and for refrigerators the effect is incredibly high.
- The **total effect** is the sum of the two. It says how much the price increases if the efficiency increases for the individual appliance as well as for many appliances on the market.

Figure 5.5. Price premium and maturity effect for a 10 % increase of energy efficiency, percent.



* Maturity effect cannot be estimated.

** Maturity effect is incredibly high in the sense that total effect is nearly 0 (0.02 %).

There are a number of reasons to be cautious about the results as well as interpretations of the results. The most important are

- The prices of the appliances are estimated as a function of many characteristics of the appliance, not solely the energy efficiency. Therefore, the interpretation of the price premiums is the price increases that occur as a result of increase of the energy efficiency increases with all other characteristics unchanged. However, only characteristics registered in the data are used in the estimations, and some relevant characteristics could be missed. Missing characteristics that affect price and are correlated with the energy efficiency will cause the price premium to be estimated wrongly.
  Note that the name of the producer is included in the estimation. It is possible that this name "catches" the effect of some missing characteristics: If producer X always makes appliances of high quality, we estimate a price effect for this name even though consumers actually pay for the physical characteristics with high quality, and not for the producer name.
- Prices are estimated for appliances introduced to the market, and the estimation is therefore carried out over the range of energy standards (and other characteristics) actually on the market. Even if the estimated price premium is correct for appliances on the market, the premium cannot necessarily be projected beyond the historic range of energy standards. It is very likely that the price premium (or extra costs) of a proposed increase of energy standard above the best standard actually on the market is higher than the estimated price premium.

5.3. Payback periods

Figure 5.5 showed how much consumers pay extra for an appliance with good energy standard and lower future energy bills. By estimating the annual reduction of the energy costs, a payback period can be calculated. The payback period is the number of years it takes for energy savings to equal the price premium. Note that the annual energy savings have to be calculated by assuming a specific use of the appliances (e.g. three loads of clothes to be washed each week). Details of the calculation are in section 7 and appendix 3.

The payback period is calculated for an appliance with label A++ compared to label A+. We calculate the payback period without and with the maturity effect. **Without the maturity effect**, the payback period is relevant for a **consumer who compares A++ with A+ on a market with only few A++** appliances. In this case, the price difference corresponds to the price premium in figure 5.5. **With the maturity effect**, the payback period is relevant for a **consumer who compares A++ with A+ on a market with many A++** appliances. In this case, the price difference corresponds to the total effect in figure 5.5.

Payback periods range from 2.1 to 9.0 years which is considerably shorter than expected lifetime of the appliances, and when maturity effects are included, the periods are even shorter.

Table 5.2. Payback periods for consumers buying A++ rather than A+

	Payback period relevant with few A++ on the market	Payback period relevant with many A++ on the market
Washing machines	5.3	2.5
Tumble dryers	9.0	5.4
Dishwashers	4.7	4.3
Refrigerator-freezers	4.4	
Refrigerators	6.2	0.0
Refrigerators with freezer compartment	4.5	
Upright freezers	3.6	
Chest freezers	2.6	1.6
Cookers*	2.1	
Oven*	5.6	

* Energy label A is compared to B.

** A number is shown if the maturity effect is estimated.

The short payback periods indicate that well-informed consumers are expected to prefer A++ to A+. However, for a number of years A++ and A+ have existed on the market, see figure 2.1. This might very well be in accordance with well-functioning markets for appliances and well-informed consumers. Some consumers may prefer A+ to A++ because they use the appliance relatively rarely or because they do not have the sufficient liquidity to pay for the price premium of A++.

On the other hand, short payback periods could also indicate that consumers – in spite of the EU energy label on the appliances – are not well-informed or well aware about the future energy costs related to appliances. We elaborate on this in section 8.

6. Estimation method

The price of appliances depends on a number of factors besides the energy standard. We are only interested in the effect of the energy standard on the price, but in order to estimate this effect, we have to include factors that affect both the price and the energy consumption of the appliances. For example, the size affects the price and the energy consumption positively, but if the size is excluded from the analysis, the effect of the energy standard on the price will be overestimated because energy standard will "catch" some of the price effect of the size.

An equation to be estimated is

1) $p = \alpha + \beta_y y + \beta_x x + \gamma k + \varepsilon$

Where *k* measures energy efficiency (explained below), *x* measures a range of other characteristics, *y* is the year of the introduction of the appliance, and *p* is the price of the appliances. Greek letters are parameters to be estimated, except for *ε* that is the part of the price which is unexplained by the model. Price, *p*, and efficiency, *k*, are measured in logarithms.

It is expected that an increase of the energy efficiency, *k*, will increase price, so that γ>0.

The maturity effect is estimated by including the energy efficiency of the market, k^m (explained below). An increase of k^m means that the energy efficiency increases on the market in general. The estimation equation becomes

1b) $p = \alpha + \beta_y y + \beta_x x + \gamma k + \delta k^m + \varepsilon$

We expect $\delta < 0$ because we assume that the extra costs of production decreases due to learning effects (the maturity effect). We also expect $\gamma + \delta > 0$ because quality improvements per se will never reduce costs.

In the data, an energy efficiency index is registered, and a sketch of the definition is

2) $\text{Energy Efficiency Index} = \frac{\text{absolute energy consumption (e.g. kWh pr. use)}}{a+b\cdot\text{Size (e.g. kg clothes pr. wash)}}$

where *a* and *b* are technical constants (for some appliances, the index is more complicated). The lower the index, the more energy friendly is the appliance. In the estimation, we use the reciprocal value of 2) as a measure of energy efficiency

3) $k = \log(\text{energy efficiency}) = \log(\frac{1}{\text{Energy Efficiency Index}})$

We measure the energy efficiency for the market, k^m, in two steps

a) For each year, we first calculate the 10 percent quantile of the energy efficiency according to 3)
b) Then we calculate the historic lowest value of a) to obtain k^m.

In this way, energy efficiency of the market, k^m, will each year decrease or remain constant.

Table 6.1 shows the parameters of interest for washing machines. The results mean that a 10 percent increase in the energy efficiency of the individual appliance will increase price by 2.78 percent. If the efficiency increases on the market, the price decreases by 1.46 percent. Hence, for washing machines we estimate a maturity effect. If the efficiency increases on the market and for the individual appliance, the price increases by 2.78-1.46 = 1.32 percent (= the total effect in figure 5.5).

Variables also included are the year of the introduction of the appliance on the market, the spin-drying efficiency, the size and the name of the producer.

Table 6.1. Estimation of the effect of energy efficiency on price of washing machines

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.278	0.032	<0.001
log(Energy efficiency on the market)	-0.146	0.038	<0.001

R^2=0,79, df=2147

Explanatory variables: Year, size (kg clothes), name of producer, spin-drying efficiency.

For the nine other types of appliances we estimate a price premium as for washing machines and the magnitude of the premiums are comparable, though a little higher for tumble dryers and dishwashers, see table 6.2.

We estimate a maturity effect comparable to the effect for washing machines only for tumble dryers and chest freezers. For dishwashers, there is a small maturity effect, and for refrigerators, the effect is incredible large. See detailed results are in appendix 2.

Table 6.2. Parameter estimate of the effect of energy standard and price of appliance

	Parameter	
	log(Energy efficiency)	log(Energy efficiency on the market)
Washing machines	0.278	-0.146
Tumble dryers	0.464	-0.185
Dishwashers	0.474	-0.049 (not clearly significant)
Refrigerator- freezers	0.242	
Refrigerators	0.233	-0.231
Refrigerators with freezer compartment	0.335	
Upright freezers	0.224	
Chest freezers	0.274	-0.150
Cookers	0.211	
Ovens	0.344	

Since the maturity effect is not estimated robustly across types of appliances, it might be that such an effect do not exists. Alternatively, it might be that it is too ambitious to estimate such a specific, technologic effect related to one single characteristic of the appliance, namely the energy standard, even if it exists in reality.

Note, that we do estimate how the time affects the price because the year of introduction is included as an explanatory factor. For all 10 types of appliances, we find that the price decreases annually with 0.8 to 3.8 percent. In reality, time itself does not affect price, but catches the effects of other factors that change dynamically. The most obvious of such factors is increase in productivity. With this interpretation we do find a “maturity effect”: if good energy standard causes a price premium of a certain amount, this amount decreases with 0.8 to 3.8 percent yearly. This method and interpretation is comparable to the one used in Desroches et al. (2013).

7. Payback periods - method

To calculate payback periods for investing in e.g. A++ rather than A+, we combine the price premium with the reduction of energy costs. To calculate energy costs, we have to assume a certain pattern of use of appliances by the consumer.

The labels A+ and A++ have been common during the last years. As basis for the calculation, we use average values of price, energy efficiency and absolute energy consumption for label A+. We also use the average energy efficiency index of A++ as a basis, see *-marked values in table 7.1.

From this basis we calculate the percentage increase in energy efficiency (34 percent in table 7.1). And with this percentage, we calculate the price increase using parameters in table 6.1 and subsequently we calculate absolute energy savings, see table 7.1. In this way, the price increase is due only to improved energy efficiency, while all other characteristics of the appliance remain unchanged.

Appliances labelled A++ are 34 percent more energy efficient than A+. The price premium is 448 DKK. If A++ is common on the market, the price premium is 213 DKK. Energy consumption per wash is reduced by 0.26 kWh.

Table 7.1. Average and calculated price, energy efficiency index and absolute energy consumption, washing machines introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency	Absolute energy consumption (kWh per wash)
A+	4740*		7.07*	1.01*
A++	=4740*(1+0.34*0.278) = 5188**	=4740*(1+0.34*(0.278-0.146)) = 4953**	9.49*	=1.01/1.34 = 0.75
Increase from A+ to A++	= 448 DKK	= 213 DKK	= 34 %	= -0.26 kWh

* Average values for appliances labelled A+ and A++ introduced 2011-2013.

** Calculated from the 34 percent increase of efficiency and parameters in table 6.1.

Payback periods are calculated without and with the maturity effect and for consumers and for society, see table 7.2. For society, the prices of electricity and appliances are exclusive of taxes. Admittedly, payback periods are insufficient as measures to evaluate energy standards for society.

A consumer who washes three loads of clothes each week saves 84 DKK a year with a washing machine labelled A++ compared than A+. The payback period is 448/84 = 5.3 years. The period is half as long if she considers buying A++ when this label is common on the market.

Payback periods are considerably longer for society because the costs of energy are lower. Nevertheless, if the maturity effect is included, the payback period for society is shorter than the expected lifetime of a washing machine.

Table 7.2. Payback periods of label A++ compared to A+, washing machines

		Few A++ on the market	Many A++ on the market
Price premium	Private (table 7.1)	448	213
DKK	Society*	358	170
Energy savings	Private	84	
DKK/year**	Society*	25	
Payback period	Private	5.3	2.5
Years	Society	14.3	6.8

*Exclusive of 25 percent VAT.

**3 washes/week, price of electricity=2 DKK/kWh for consumers, 0.6 DKK/kWh for society.

Table 7.3 shows payback periods for all appliances. Detailed results are in appendix 3.

Table 7.3. Payback periods for consumers of label A++ compared to A+, years

	Payback periods relevant with few A++ on the market	Payback periods relevant with many A++ on the market
Washing machines	5.3	2.5
Tumble dryers	9.0	5.4
Dishwashers	4.7	4.3
Refrigerator-freezers	4.4	
Refrigerators	6.2	0.0
Refrigerators with freezer compartment	4.5	
Upright freezers	3.6	
Chest freezers	2.6	1.6
Cookers	2.1	
Ovens	5.6	

As an alternative, the sum of investment costs and user costs during 10 years is calculated in table 7.4 for washing machines with label A+ and A++. The same assumptions as in table 7.2 are used (e.g. three washes per week). Future energy savings are not discounted, and hence the aggregated costs are simply investment costs + 10* yearly energy costs.

Aggregated costs of label A++ is lower than of A+. This is a simple mirror of the fact that the payback period is shorter than 10 years (namely 5.3 years, see table 7.3). For appliances labelled A+, energy costs make up 40 percent of all costs, which is approximately 10 percentage points higher than for A++.

Table 7.4. Aggregated costs over 10 years for washings machines labelled A+ and A++, DKK

	A+		A++		A++	
		Procent	Few A++ on the market	*Procent*	Many A++ on the market	*Procent*
Price of appliance	4740	*60*	5188	*69*	4953	*68*
Energy savings						
Energy costs over 10 years	3151	*40*	2340	*31*		*32*
Aggregated costs	7891	*100*	7528	*100*	7293	*100*
Relative aggregated costs, A+ = 100			*95*		*92*	
Aggregated costs reduction compared to A+			363		598	

In principle, it is possible to find the optimal energy consumption for washing machines defined as the energy consumption that minimizes total costs – i.e. by performing a series of calculations as in table 7.4. This is done in section 9.

8. Interpretation of the estimated price premium - theory

Statistically, we have found a relationship between energy efficiency and the price of electric appliances. There are however many possible explanations for such a relationship, and below we discuss a few. Some of the figures use concepts from economics which are not thoroughly explained.

Price premium equals extra production costs: The price premium might be necessary for the producers to cover costs associated with more energy friendly appliances. Development of new appliances and adaption of production process will require fixed costs, and there might be extra costs per unit produced with improved standard, e.g. better insulation.

This cost structure is however not necessarily reflected in the prices registered in the data set. Producers' and retailers' profits mean that prices will be higher than production costs, and profit rates could vary systematically with energy efficiency if, for example, producers require low profit rates for the most efficient appliances.

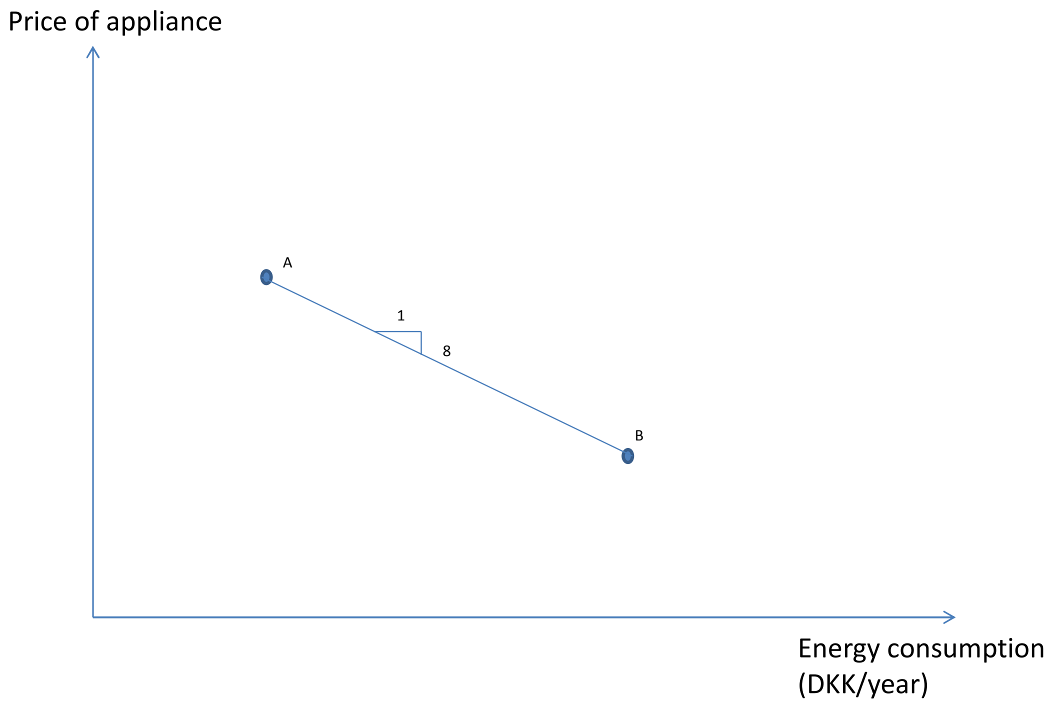
It is also possible that producers are different in the sense that some producers are specialized in the production of energy friendly appliances. In this case, we might estimate an "aggregated" cost structure that encompasses the costs of all producers on the market. Thus, the price premium does not reflect extra costs of an individual producer, but the extra costs for a producer of an energy friendly appliance compared to a producer of a normal appliance.

Price premium equals consumers' willingness to pay: The price premium could be interpreted as the amount consumers – or some consumers – are willing to pay for reduced energy consumption.

Consumers may have different preferences and therefore some consumers prefer less energy friendly (but cheaper) appliances. For example, some consumers might use the appliances relative infrequently or they might lack liquidity to pay for expensive appliances. Therefore consumers might buy appliances with different energy standard even if the consumers are fully aware of the energy efficiency of the appliances. We illustrate this in three figures below.

In figure 8.1, two appliances with different price and energy consumption are shown. The slope of the line between the appliances is the simple payback period which is 8 years in this case.

Figure 8.1. Two observations in the data set - skecth

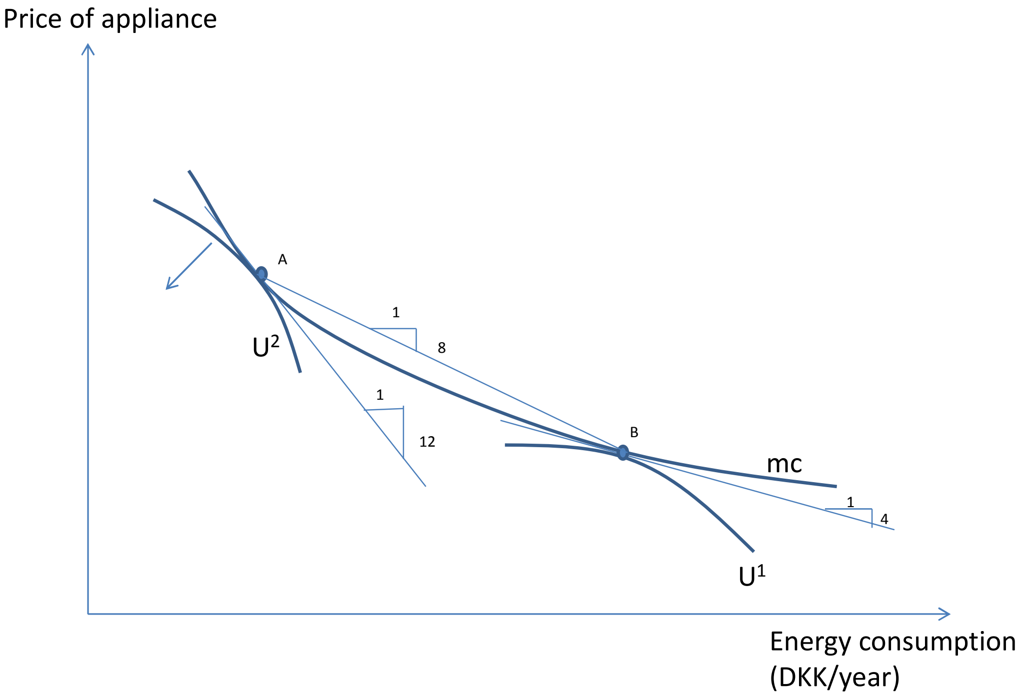


The two appliances are chosen voluntarily by producers and consumers. In figure 8.2 we add producers' marginal cost curve (mc) which – under certain assumptions – describes at what price producers are willing to sell an appliance with energy consumption depicted on the x-axis. The slope is assumed to be steeper the lower the energy consumption because it will be increasingly costly to reduce energy consumption (more on this in section 9).

Utility curves for two different consumers are drawn. Such a curve is the energy-price combinations that give a consumer a specific utility. A consumer prefers energy-price combinations inwards in the figure as indicated by the arrow. The slope of the utility curve equals the consumer's willingness to pay.

In the figure, each consumer has chosen the appliance she prefers. Consumer 1 choses B and has a low willingness to pay for energy reductions (a payback period of 4 years) and consumer 2 choses A and has high willingness to pay (she accepts 12 years payback period).

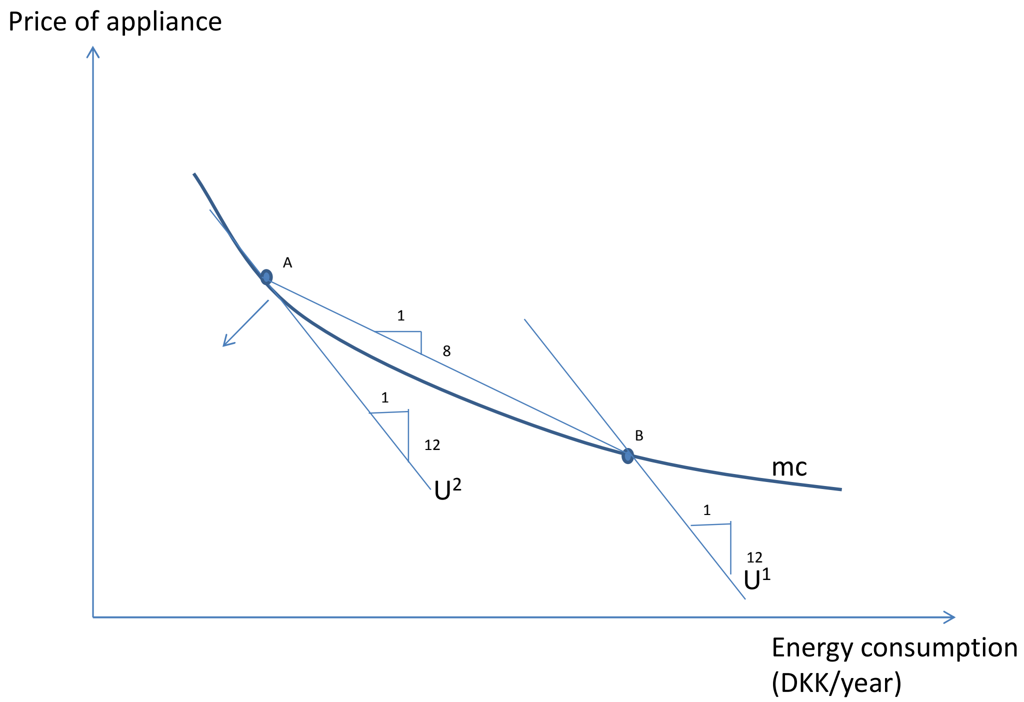
Figure 8.2. Supply curve and optimal choice of appliance for two informed consumers with different willingness to pay



If figure 8.2 reflects the real world, consumers do not need more information about the energy consumption of appliances, and mandatory minimums standard on energy efficiency will be harmful to at least some consumers. Consumer 1 would lose by being forced to buy an appliance with lower energy consumption (and higher price).

In figure 8.2, all consumers are fully aware of appliances' energy consumption, but the opposite is exactly the politic and economic basis for EU's energy labelling and – in part – minimum standards (ecodesign) for energy efficiency. In figure 8.3 consumers are – contrary to figure 8.2 – assumed to have the same willingness to pay for energy efficiency and they both always accept 12 years payback period. Hence, utility curves are assumed to be straight lines with a constant slope. But consumers are assumed to be differently informed about appliances' energy consumption. Consumer 2 is correctly informed and chooses the appliance that is best for herself, but consumer 1 only have a vague idea about the energy consumption and therefore buys an appliance that consumes much energy. Consumer 1 would be better off with better energy labels to inform her or with minimum energy standards forcing her to by a more energy efficient product.

Figure 8.3. Choice by informed and uninformed consumers



The inoptimal choice by consumer 1 could also occur if she did not have the necessary liquidity to pay for the expensive energy efficient appliance.

Unfortunately, the estimations in this paper do not reveal how well aware consumers' are about appliances' energy consumption, and hence the study cannot tell whether figure 8.2 or 8.3 is the best description of the real world.

9. Level dependence of the price premium

It is likely that the price premium increases the lower the initial energy consumption of the appliance. Such a level dependence is realistic because the energy consumption cannot be lower than a certain positive level because an amount of physical work is carried out with the appliances. In this section, we estimate this level dependence.

The method used in sections 5 and 6 actually implies a level dependence, but the level dependence follows automatically from the logarithmic expressions of the estimation equations. Hence, the estimation method cannot test whether there is a level dependence.

The estimation equation used in sections 5 and 6 is restated

1b) $p = \alpha + \beta_y y + \beta_x x + \gamma k + \delta k^m + \varepsilon$

Note that the price *p* and energy efficiencies, *k*, k^m, are in logs. To estimate level dependence freely, we use the equation

1c) $P = \alpha + \beta_y y + \beta_x x + aE + bE^2 + \delta k^m + \varepsilon$

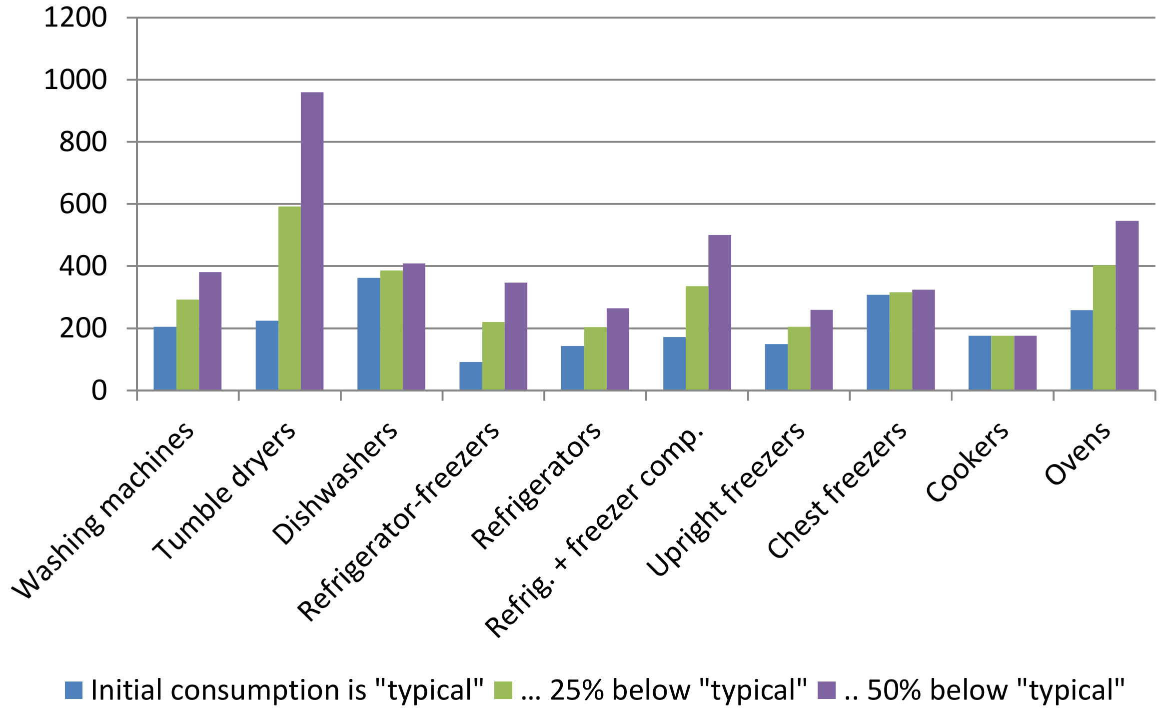
Where *P* is the price and *E* is energy efficiency index (i.e. a measure of standardized consumption), not in logs.

If the price premium is level dependent, we will estimate *b*<0 and *a*>0. (Also, for the estimations to make sense, -½*a*/*b* have to be above the energy consumption.)

With one or two exceptions, *a*- and *b*-parameters are significant and have the expected magnitudes. For cookers, we do not find a significant *b*-parameter and for upright freezers, the *b*-parameter is significant only at 10 percent level.

Figure 9.1 illustrates the level dependence as calculated using 1c). The price premium is calculated as the effect of a reduction of energy consumption equal to 10 percent of the consumption for a typical appliance. This price premium is calculated for three different appliances – an appliance with typical energy consumption, and appliances with consumption 25 and 50 percent lower than the typical consumption. The price premium is higher the lower the initial level of energy consumption (except for cookers).

Figure 9.1. Price premium depending on initial energy consumption, in DKK for a decrease of energy consumption equal to 10 percent of "typical" energy consumption



As discussed previously, the price premiums for very efficient appliances are hypothetical and presumably underestimated, at least with the currently known technology.

Finally, we calculate the total costs of buying and using a washing machine for 10 years as a function of energy consumption. We use the same assumptions as in section 7 (e.g. three washes a week) except that we use the price estimation in equation 1c.

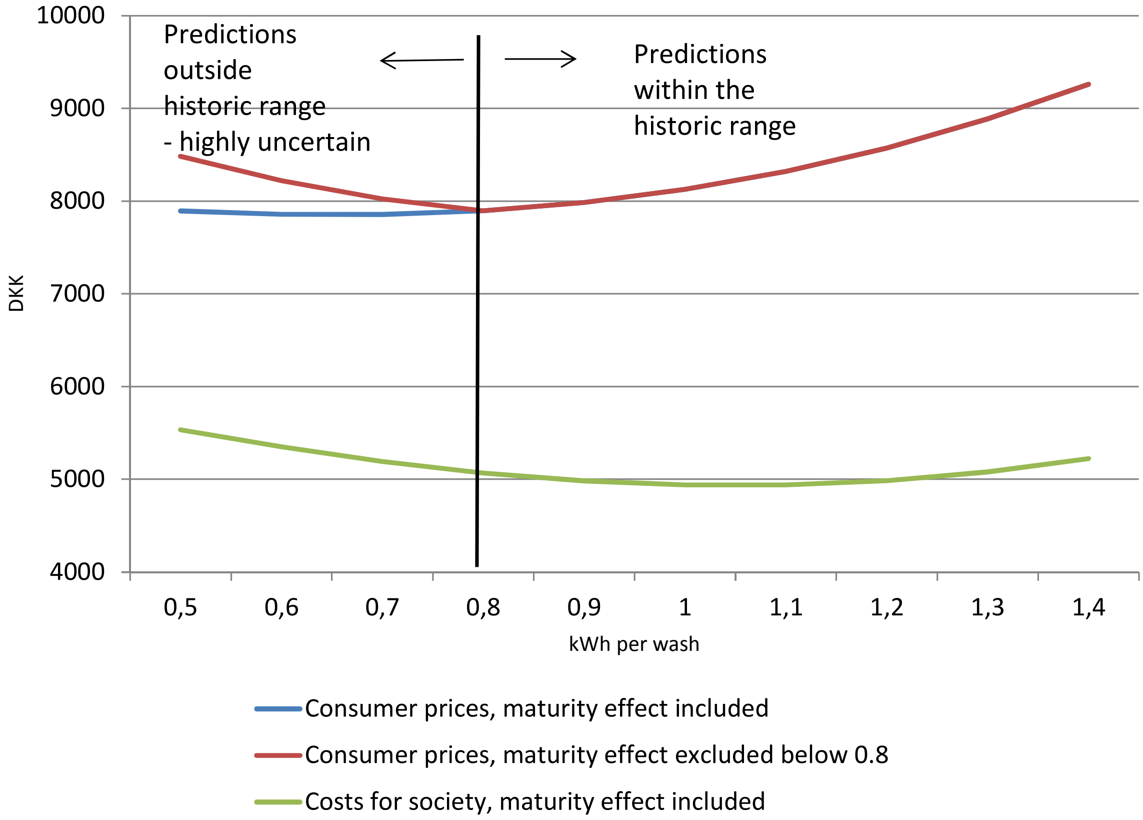
The optimal energy consumption is defined as the energy consumption that minimizes total costs. Total costs curves are calculated for levels of energy consumptions which have actually been introduce on the market, but also for washing machines with energy consumption below the most efficient machines on the market. Such predictions outside the historic data used for estimation of the price function are highly uncertain, and total costs outside the historic experience are at best informed guesses.

As a basis we consider a washing machine using 0.8 kWh per wash with a price of 5400 DKK. This corresponds to some of the most efficient machines introduced on the market in recent years. From this basis we vary energy consumption. The price effect for energy consumption below 0.8 kWh are calculated with and without the maturity effect.

For a consumer, minimum total costs are obtained with a washing machine with approximately 0.8 kWh per wash, see figure 9.1. If the consumer considers machines with higher energy consumption, the lower machine price is outweighed by the higher future energy costs. If the consumer considers machines with lower energy consumption, the total costs depend on whether such machines are common on the market. (Such machines are not common currently, but may be in the future.) If they are common, total costs are approximately equal to costs for a machine with 0.8 kWh per wash (the blue curve including the maturity effect). If such machines are not common, the price increase dominates the lower energy costs.

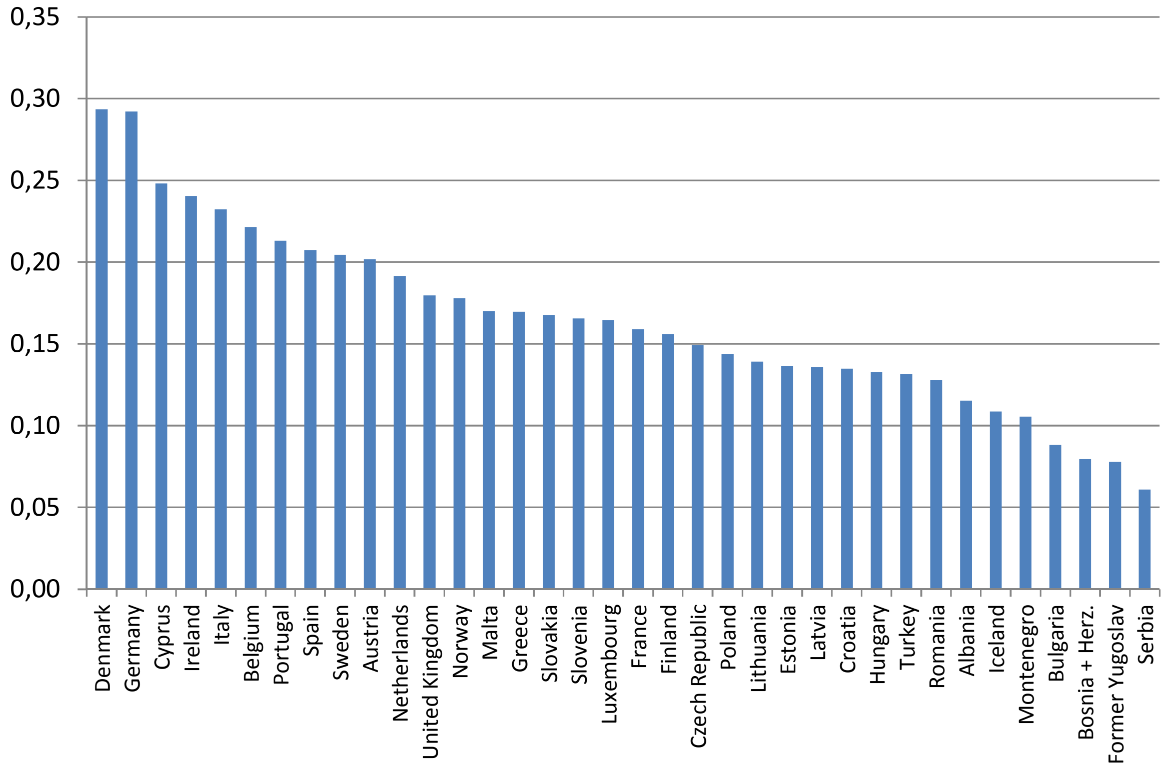
Finally, total costs are calculated using social costs for electricity and washing machines. The curve is flat within historic data, but for energy consumptions below 0.8 kWh, total costs increase the lower the energy consumption. We stress again that the curve is uncertain below 0.8 kWh, and that it is too simple from a social point of view to evaluate energy standards with this definition of total costs.

Figure 9.1. Total costs as a function of energy consumption for washings machines, DKK



The cost curves are calculated using Danish electricity prices for consumers. Danish consumer prices are high compared to other countries, se figure 9.2, and high electricity prices favors appliances with low energy consumption. Hence, for other countries, the total costs curves will have a different shape.

Figure 9.2. Consumer electricity prices, euro per kWh 2013



Source: Eurostat

Based on the total costs curves we suggest the following conclusions.

Within the historic data, total costs for washing machines decrease the lower the energy consumption is. This holds for most consumers in Denmark. For society, total costs have at least not increased the lower the energy consumption is. Hence, energy standards for appliances that exclude the poorest appliances from the market will be harmful only for consumers who use a washing machine very seldom. Standards will be beneficial to consumers who are not aware of appliances' energy consumption and who "incidentally" buy cheap appliances with high energy consumption. As concerns energy labelling, there is no or little risk that the labels encourage consumers to buy appliances with too low energy consumption (and too high total cost). Rather on the contrary, if the labels had made consumers even more aware of appliances' energy consumption, it might have been useful for many consumers.

Outside historic data, the method is only a supplement because price predictions outside historic data are uncertain.

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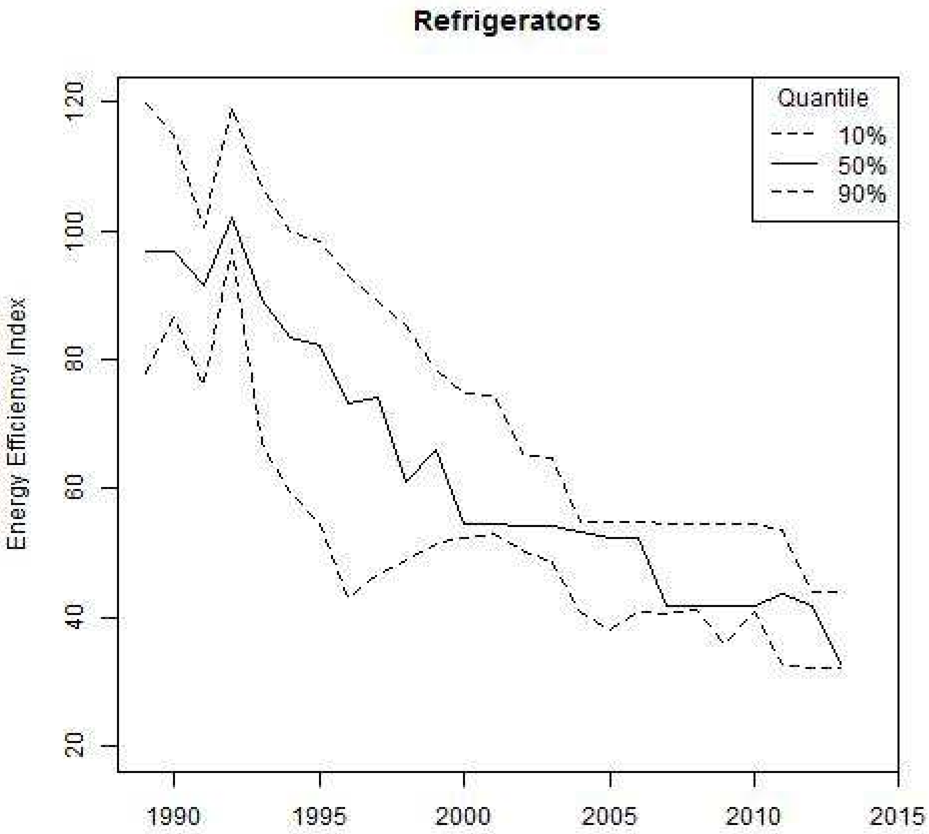
Appendix 1. Descriptive statistics for 10 types of appliances

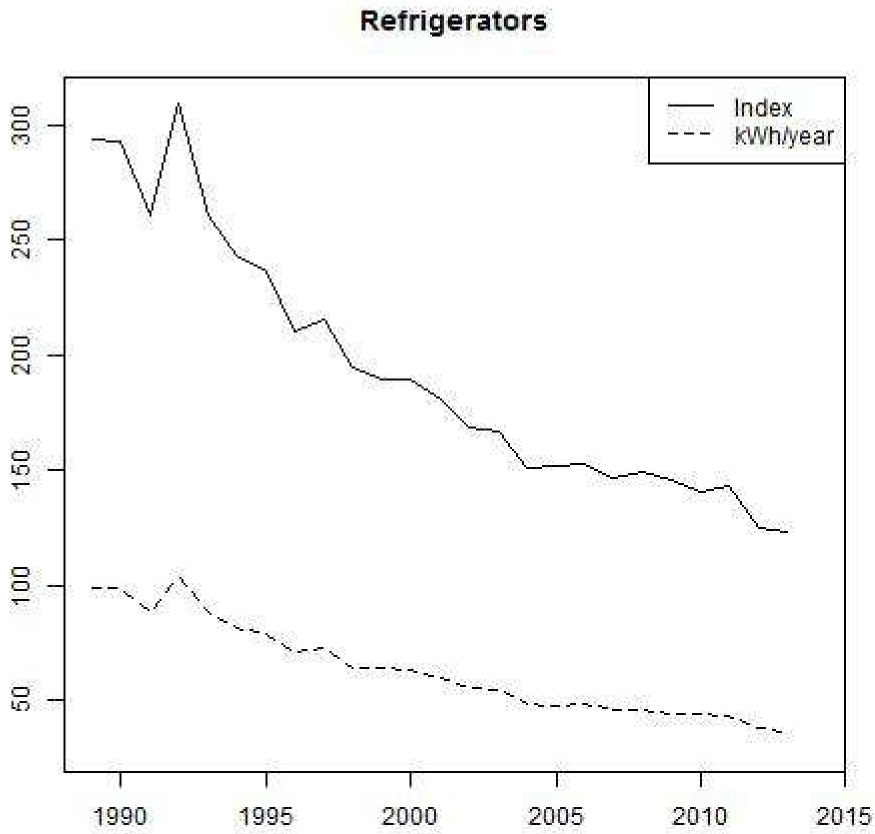
1. Refrigerators

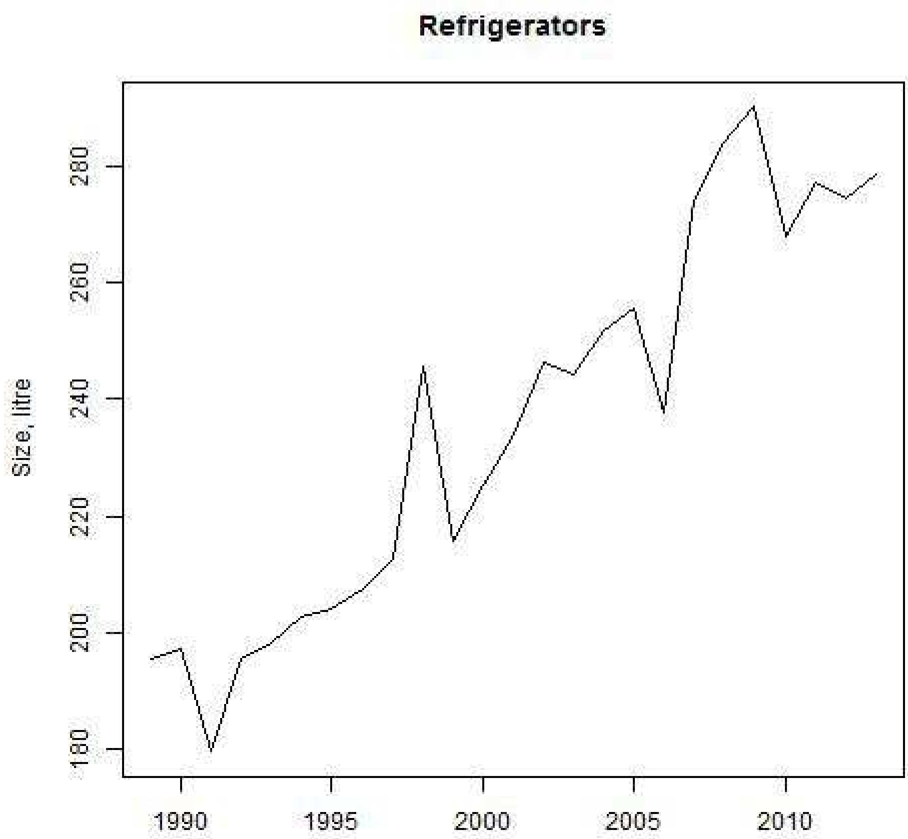
Introduced appliances by energy label, number 1989-2013

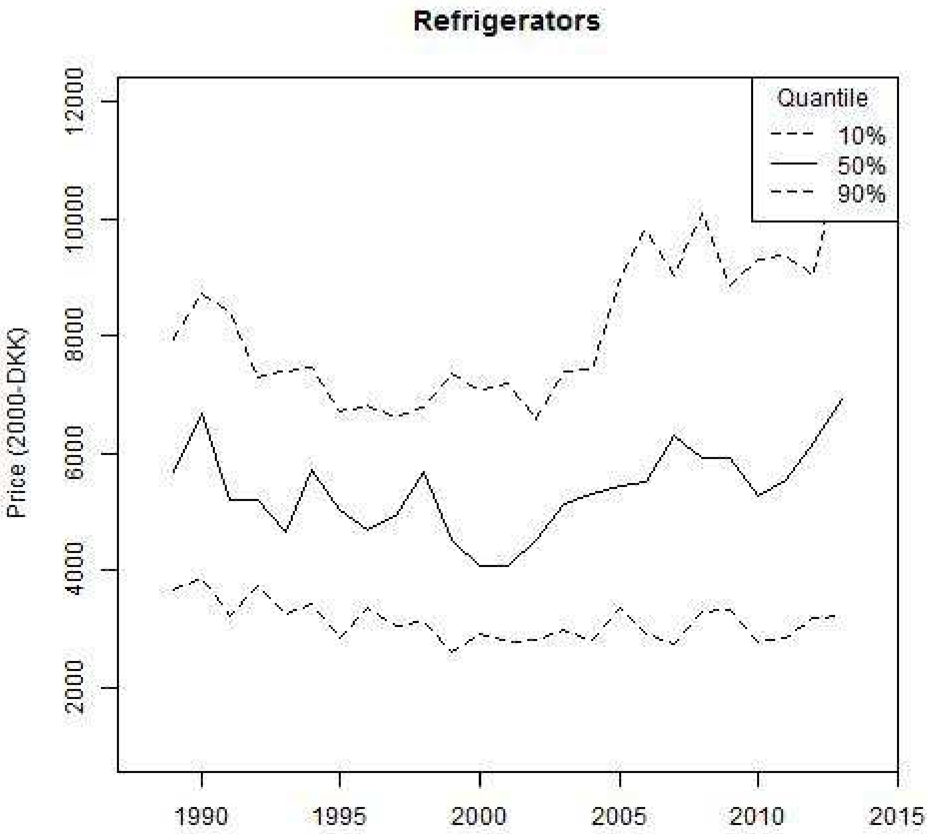
	A+++	A++	A+	A	B	C	D	E	F	G
1989					6	13	17	15	8	5
1990						7	11	6	7	
1991			1			6	1	3		
1992						1	4	5	4	
1993			2		4	18	1	5	4	
1994			5	2	25	25	18	6	2	1
1995			1	5	17	2	12	3		
1996			5	7	19	9	4	3		
1997			4	6	24	22	5	1		
1998			1	18	16	6	2			
1999			3	36	37	1				
2000				24	16	2	1		1	
2001			2	53	22	6				
2002			4	78	21	1				
2003			9	68	14				1	
2004			45	47	6					
2005		9	32	47	6					
2006		2	31	45	5					
2007			83	5	1					
2008			81	52	2					
2009		1	65	39						
2010		11	76	39						
2011		33	29	36	1					
2012	16	59	16	7						
2013	8	84	53	4		1				



Refrigerators
Quantile
10%
50%
90%
Energy Efficiency Index
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015


Refrigerators
Index
kWh/year
300
250
200
150
100
50
1990
1995
2000
2005
2010
2015

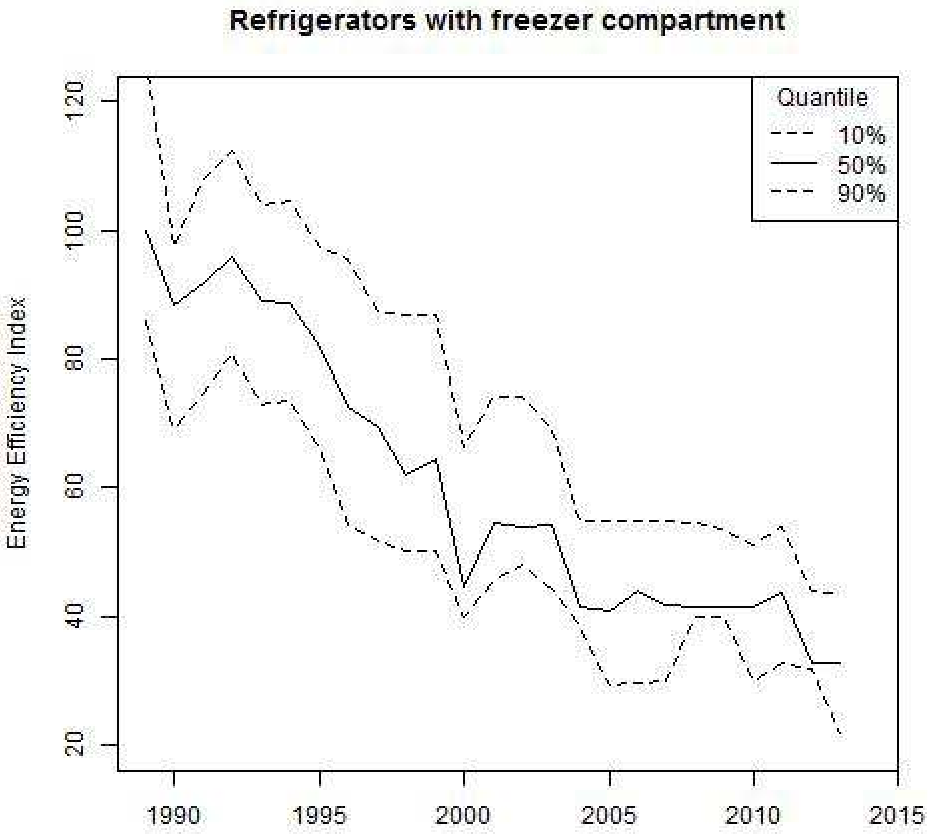

Refrigerators
Size, litre
180
200
220
240
260
280
1990
1995
2000
2005
2010

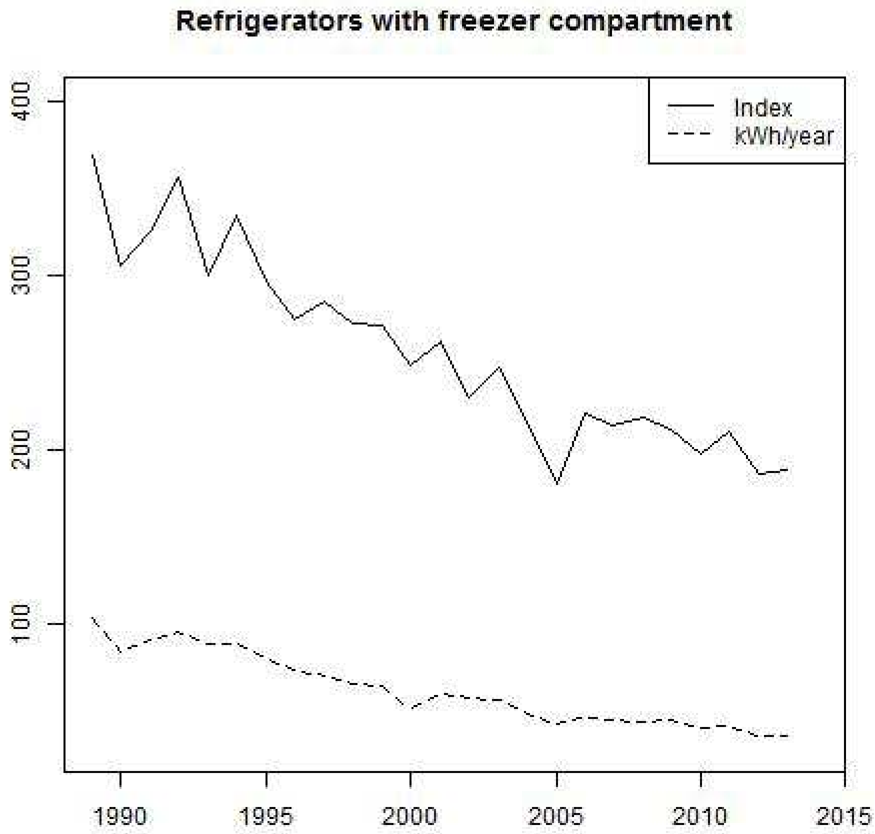

Refrigerators
Quantile
10%
50%
90%
Price (2000-DKK)
2000
4000
6000
8000
10000
12000
1990
1995
2000
2005
2010
2015

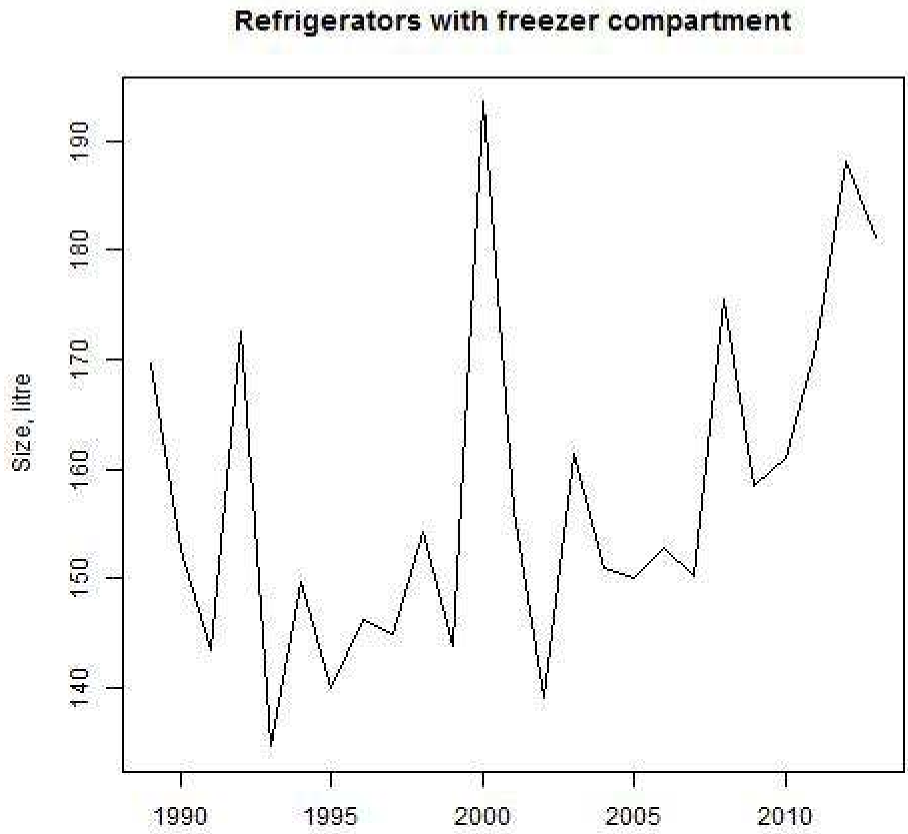
2. Refrigerators with a freezer compartment

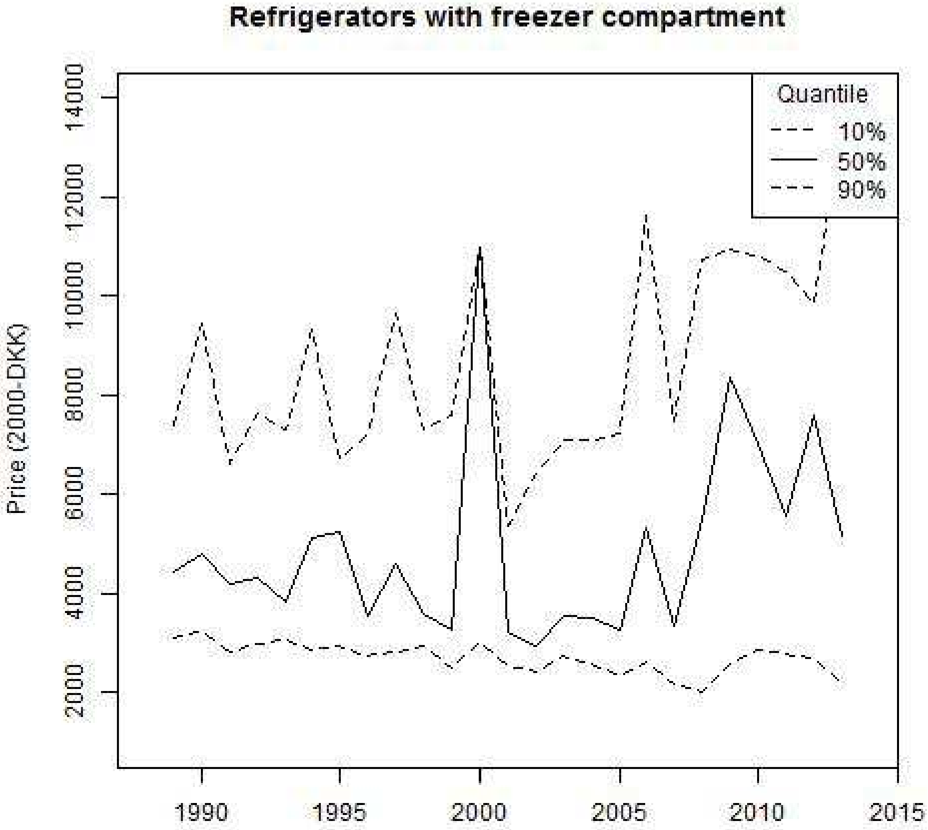
Introduced appliances by energy label, number 1989-2013

	A+++	A++	A+	A	B	C	D	E	F	G
1989					2	5	16	10	7	6
1990			1		3	6	5	2		
1991			1		2	5	7	6		
1992						4	1	3	2	
1993				1	3	12	8	3	2	
1994				1	7	21	18	2	4	1
1995				2	5	18	6	1		
1996				4	8	6	3			
1997				6	20	10	1		1	
1998				10	10	5		1		
1999			1	11	21	6	1			
2000			17	10	5		1	1		
2001			3	18	15	2				
2002			2	22	9	2		1		
2003			2	21	3	1			1	
2004		2	29	17	3		3			
2005		12	10	8	3					
2006		5	12	14	3					
2007		3	7	6	1					
2008		2	24	10						
2009			23	12	1					
2010		6	38	8						
2011		20	50	12	1					
2012	1	59	27	2						
2013	5	10	14							


Refrigerators with freezer compartment
Quantile
10%
50%
90%
Energy Efficiency Index
120
100
80
60
40
20
1990
1995
2000
2005
2010
2015


Refrigerators with freezer compartment
Index
kWh/year
400
300
200
100
1990
1995
2000
2005
2010
2015

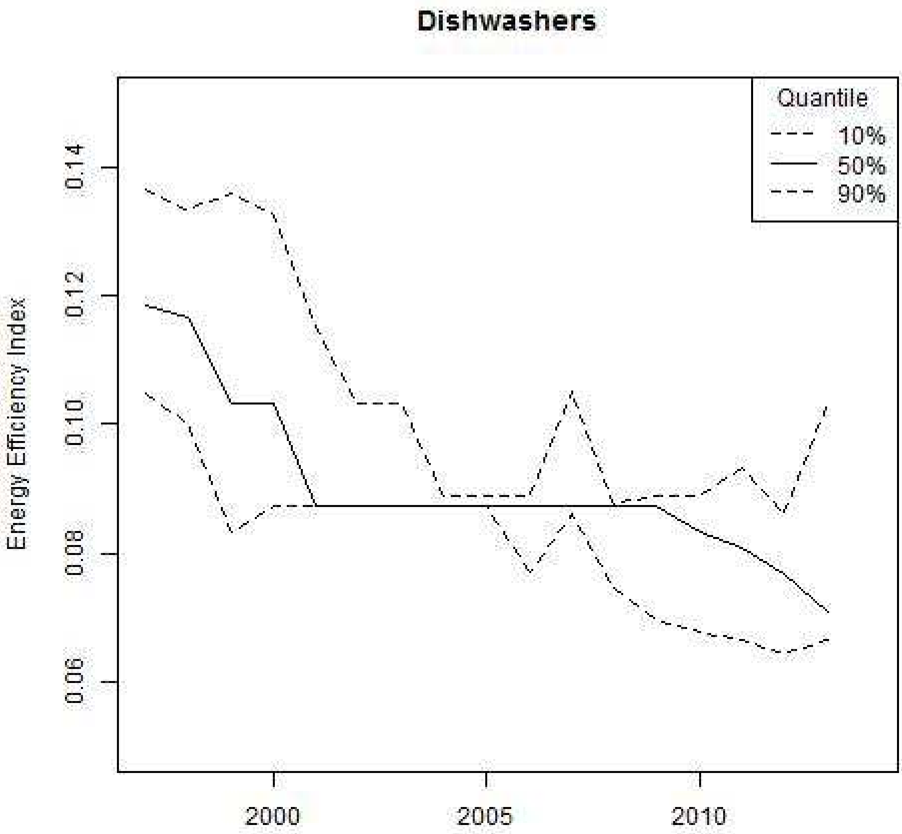

Refrigerators with freezer compartment
Size, litre
140
150
160
170
180
190
1990
1995
2000
2005
2010

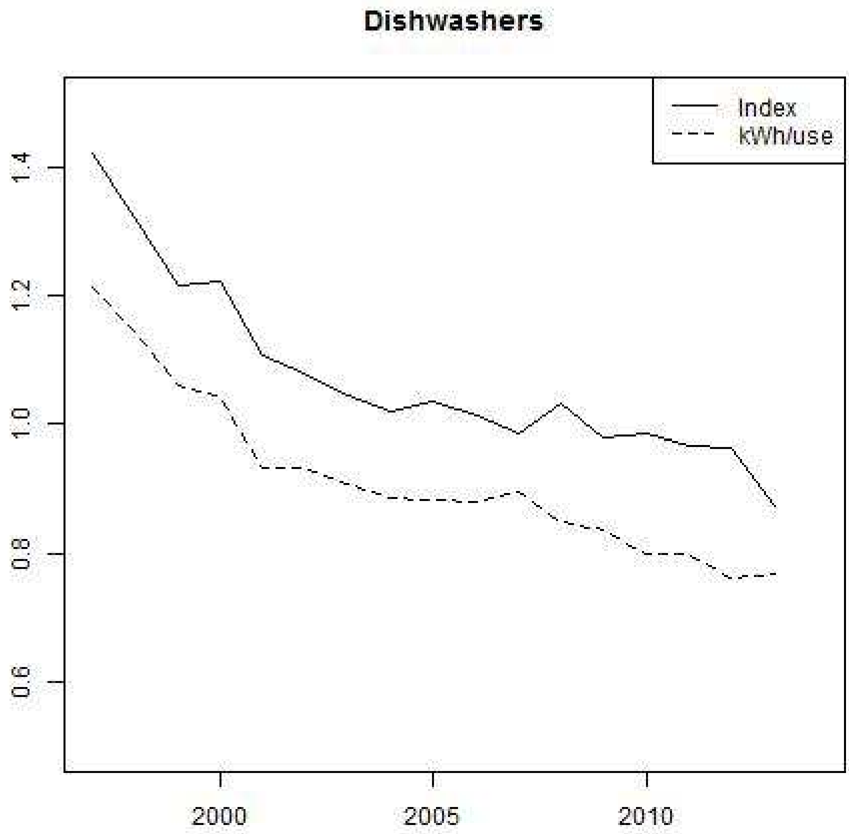

Refrigerators with freezer compartment
Quantile
10%
50%
90%
Price (2000-DKK)
2000
4000
6000
8000
10000
12000
14000
1990
1995
2000
2005
2010
2015

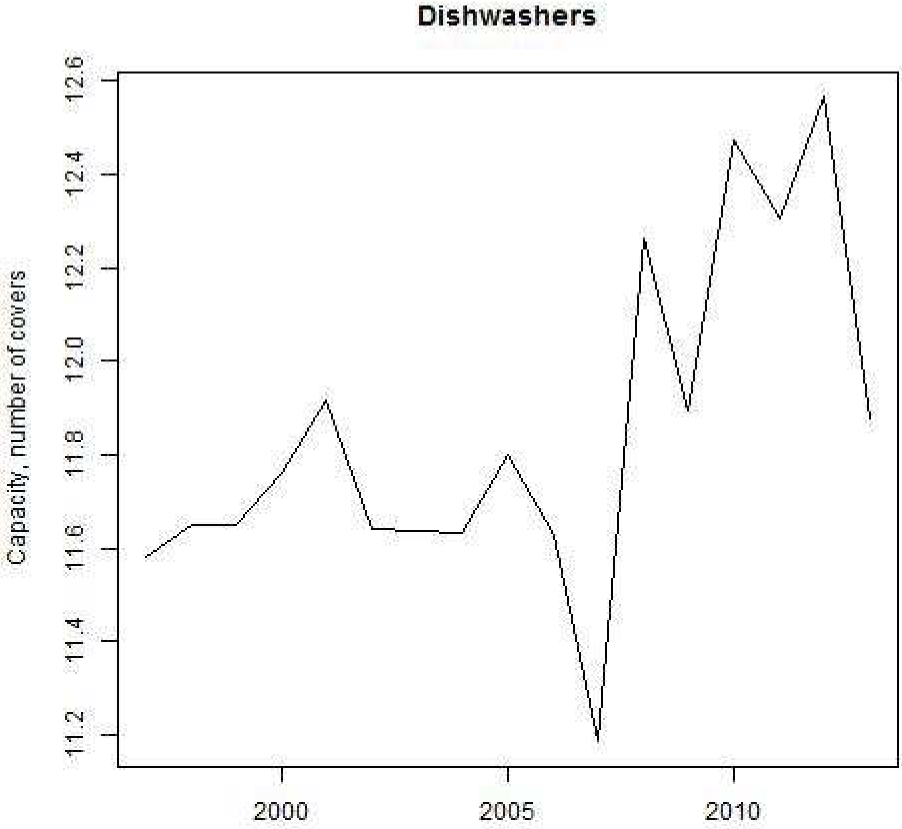
3. Dishwashers

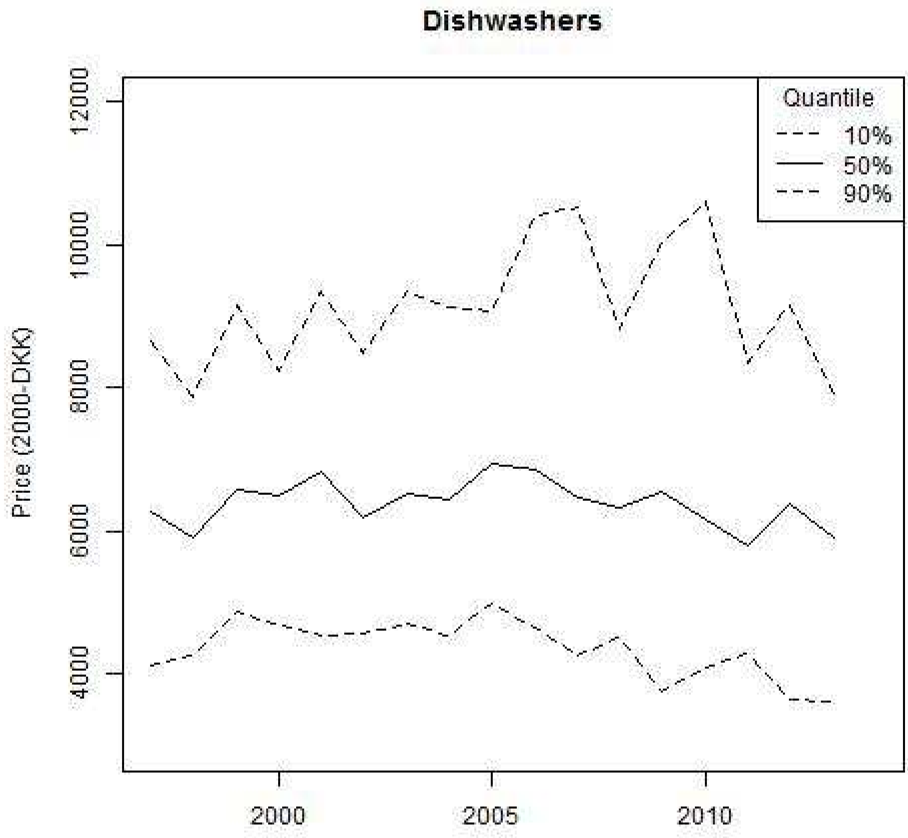
Introduced appliances, number 1997-2013

	A+++	A++	A+	A	B	C	D	E
1997					2	5	4	1
1998					8	11	2	
1999				33	10	25	8	2
2000				37	33	21	11	2
2001				96	16	12	4	
2002				87	26	7		
2003				159	16	7	2	
2004				107	5			
2005				173	6	2		
2006				195	2	2		
2007				192	3	3		
2008				175	2	2		
2009				186				
2010		1	3	165				
2011	23	79	145	94	2			
2012	22	91	121	51				
2013	3	21	17					


Dishwashers
Quantile
10%
50%
90%
Energy Efficiency Index
0.06
0.08
0.10
0.12
0.14
2000
2005
2010


Dishwashers
Index
kWh/use
1.4
1.2
1.0
0.8
0.6
2000
2005
2010


Dishwashers
Capacity, number of covers
11.2
11.4
11.6
11.8
12.0
12.2
12.4
12.6
2000
2005
2010

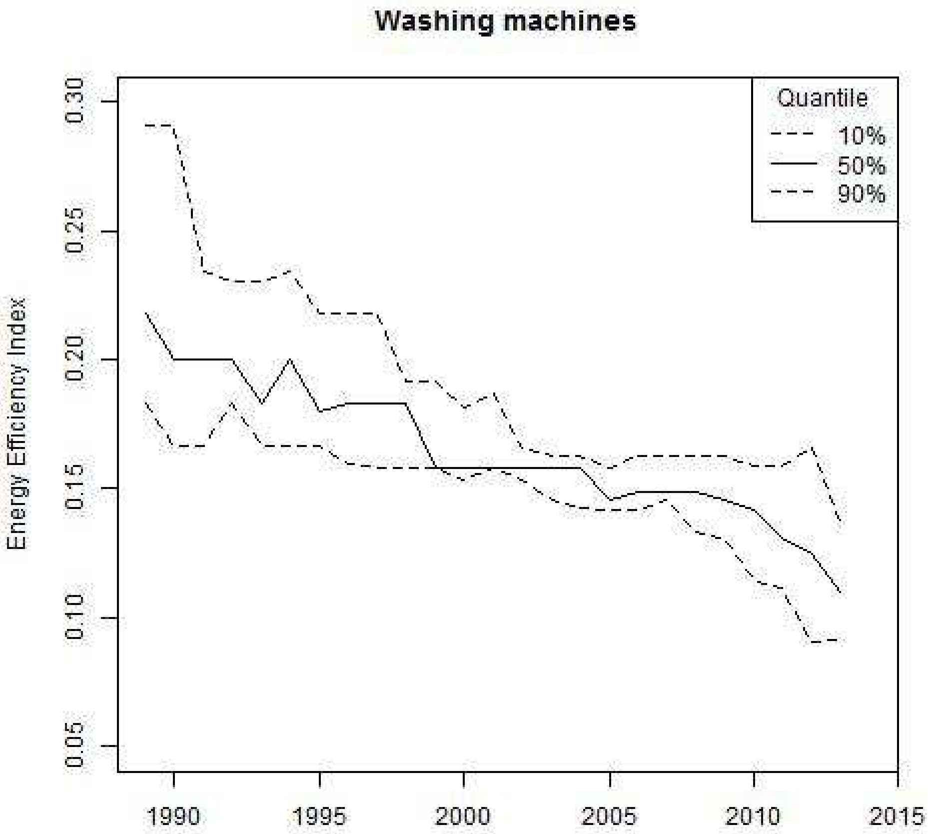


Dishwashers
Quantile
10%
50%
90%
Price (2000-DKK)
4000
6000
8000
10000
12000
2000
2005
2010

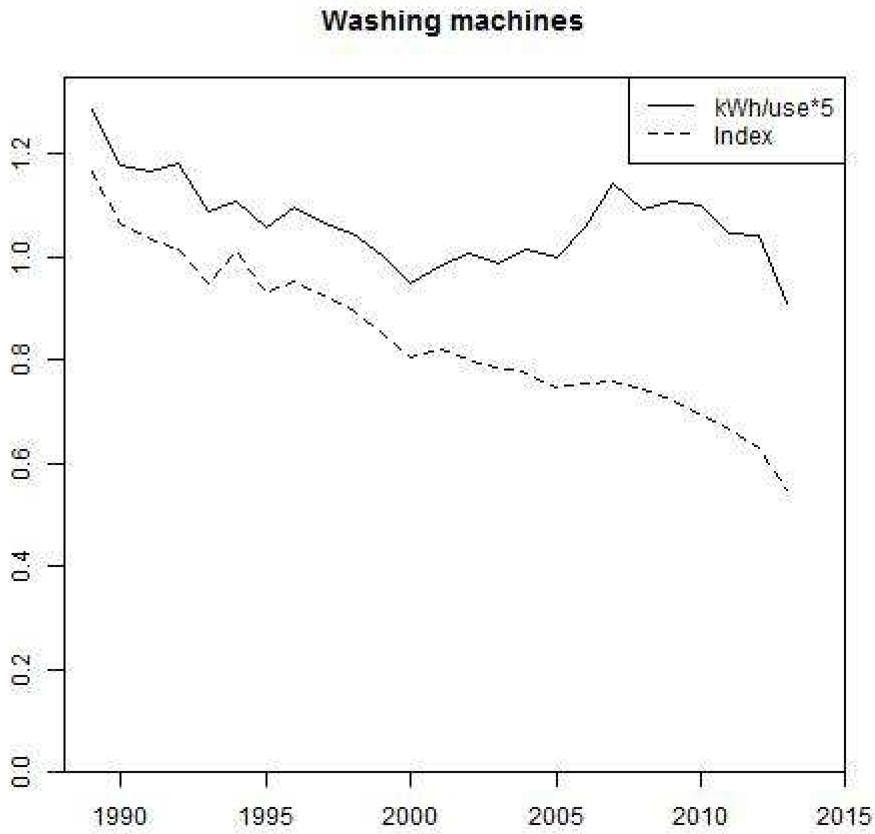
4. Washing machines

Introduced appliances by energy label, number 1989-2013

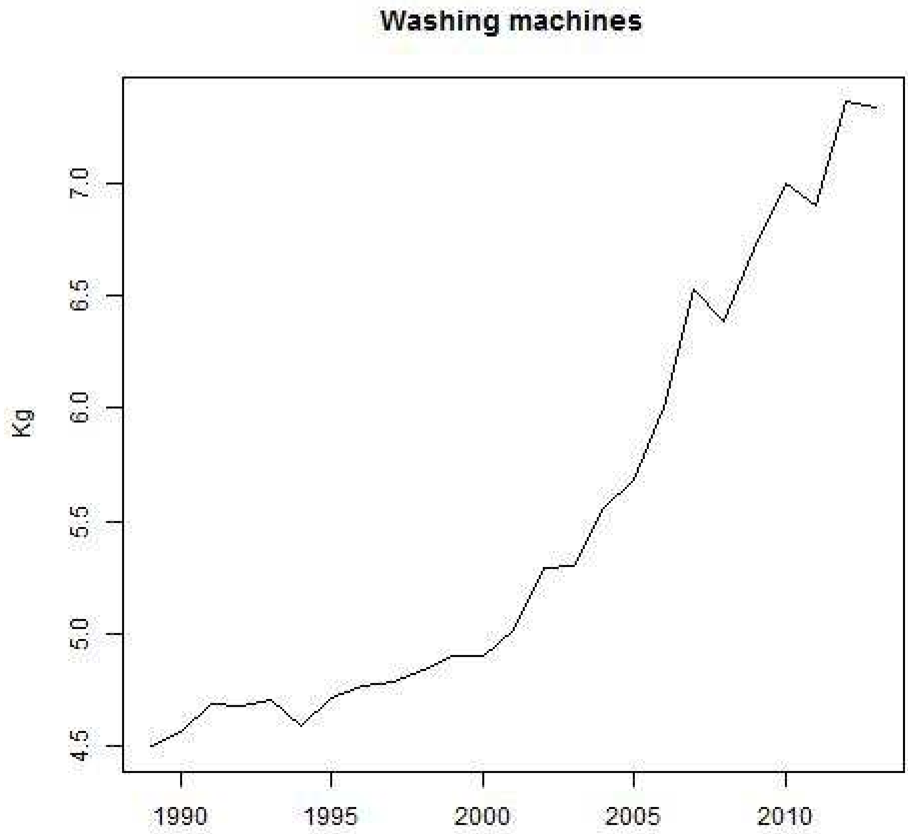
	A+++	A++	A+	A	B	C	D	E	F	G
1989				1	11	33	18	15	9	4
1990					25	13	13	2	7	1
1991					9	16	12	2		
1992					9	10	3	1		
1993					25	7	6			
1994					19	16	7	3		
1995					33	8	3			
1996				7	61	30	3	2	1	
1997				18	42	22	2			
1998				13	39	2	2			
1999				54	30	5	1			
2000				48	10	1				
2001				92	22	2		1		
2002				74	7	0				
2003				131	4	0	1			
2004				131	6	1				
2005				104						
2006				138	1					
2007			1	187						
2008				146	1					
2009		1		196						
2010	9		1	155	1					
2011	104	57	82	87	3					
2012	92	72	46	8						
2013	25		8							



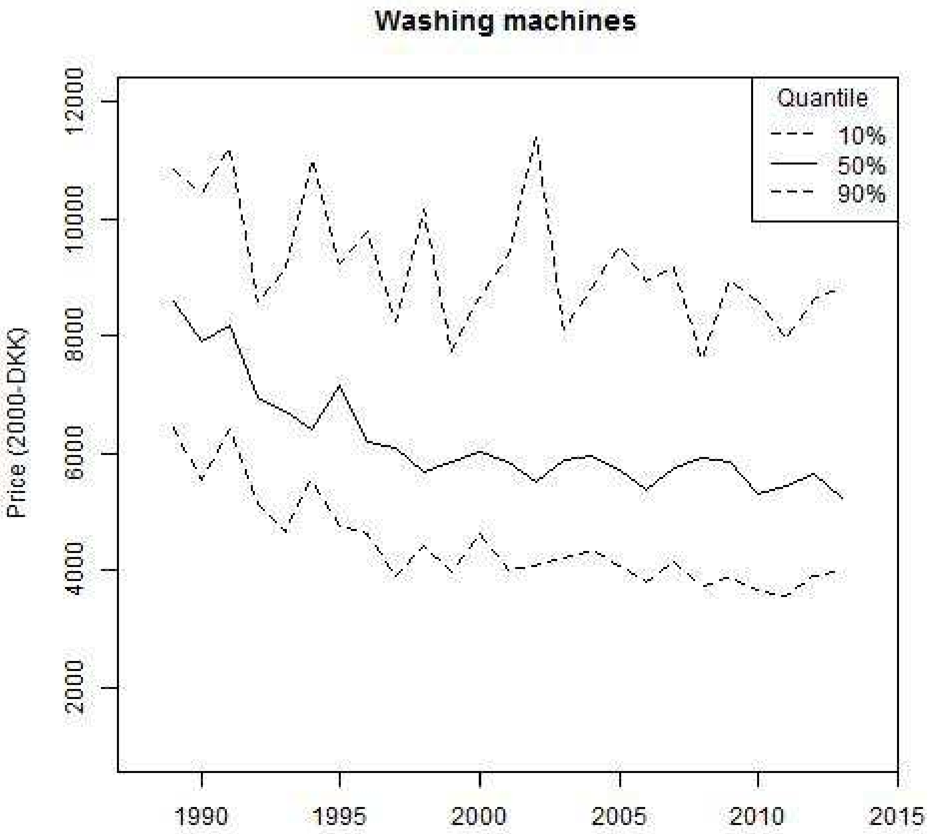
Washing machines
Quantile
10%
50%
90%
Energy Efficiency Index
0.30
0.25
0.20
0.15
0.10
0.05
1990
1995
2000
2005
2010
2015



Washing machines
kWh/use*5
Index
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1990
1995
2000
2005
2010
2015



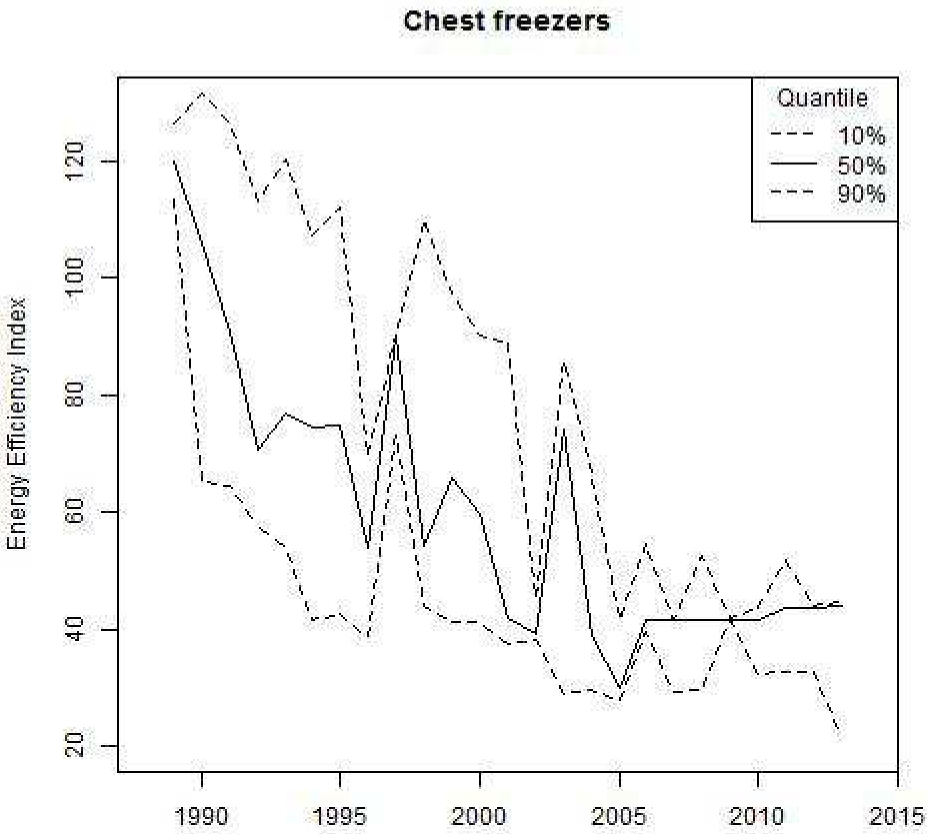
Washing machines
Kg
4.5
5.0
5.5
6.0
6.5
7.0
1990
1995
2000
2005
2010

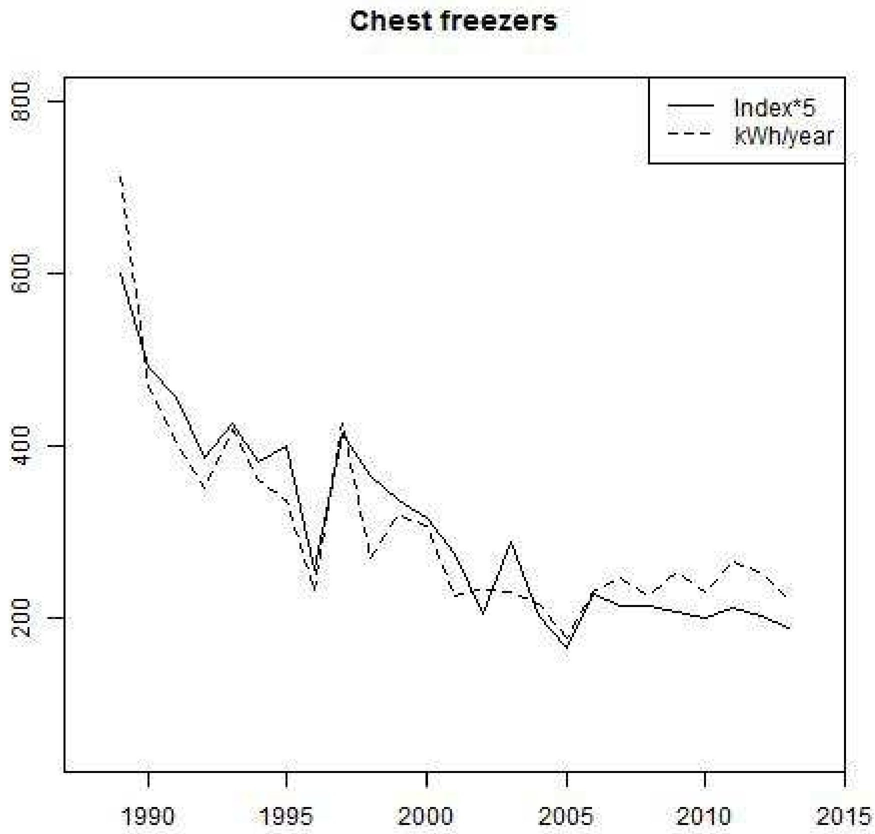

Washing machines
Quantile
10%
50%
90%
Price (2000-DKK)
12000
10000
8000
6000
4000
2000
1990
1995
2000
2005
2010
2015

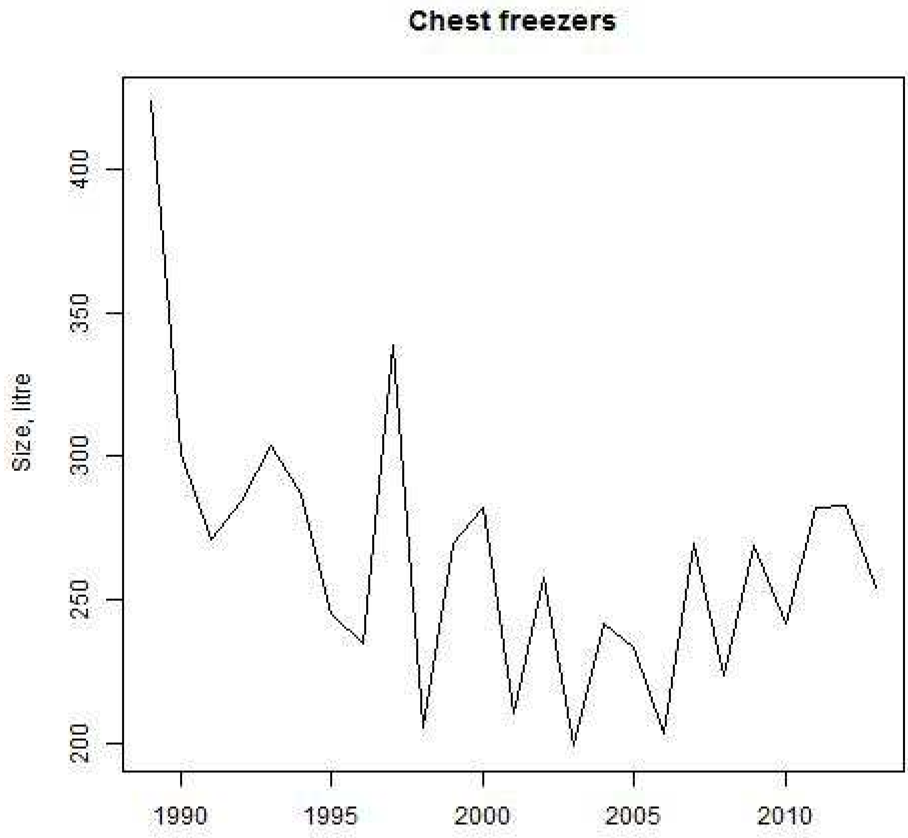
5. Chest freezers

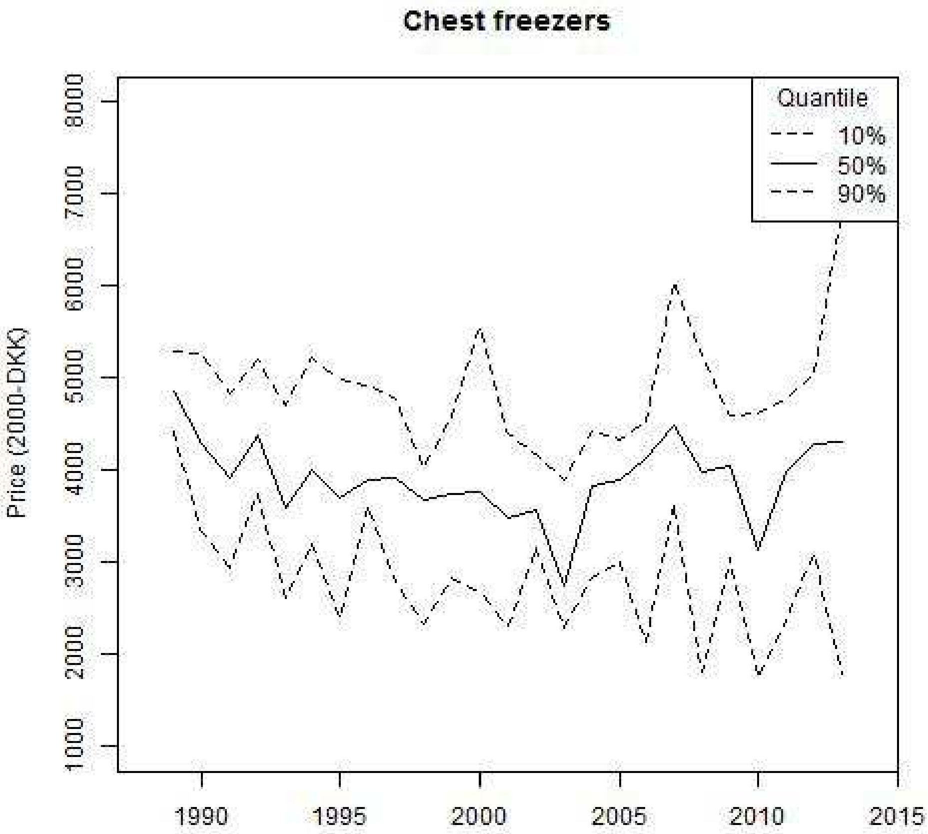
Introduced appliances by energy label, number 1989-2013

	A+++	A++	A+	A	B	C	D	E	F	G
1989									1	1
1990			1	2	13	1	4	7	12	8
1991			3		4	8	2	5	4	4
1992			1		15	1		1	3	1
1993			3	4	13	3	2	5	7	3
1994			8	3	21	8	3	12		
1995			5	5	15	4	1	8	3	3
1996		1	3	4	2					
1997					5	5	1			
1998			1	1					1	
1999		1	6	4	13	4	1	2	1	
2000			5	5	7	1	2			
2001		1	9	4	1	3		1		
2002			16	2						
2003		4	2		5	2				
2004		23	47		9	1				
2005		21	4		1					
2006			6		1					
2007		4	14						1	
2008		9	39		5	1				
2009		1	27							
2010		3	17							
2011		11	37	6		1				
2012		9	30	1						
2013	3	4	8	3						


Chest freezers
Quantile
10%
50%
90%
Energy Efficiency Index
20
40
60
80
100
120
1990
1995
2000
2005
2010
2015


Chest freezers
Index*5
kWh/year
800
600
400
200
1990
1995
2000
2005
2010
2015

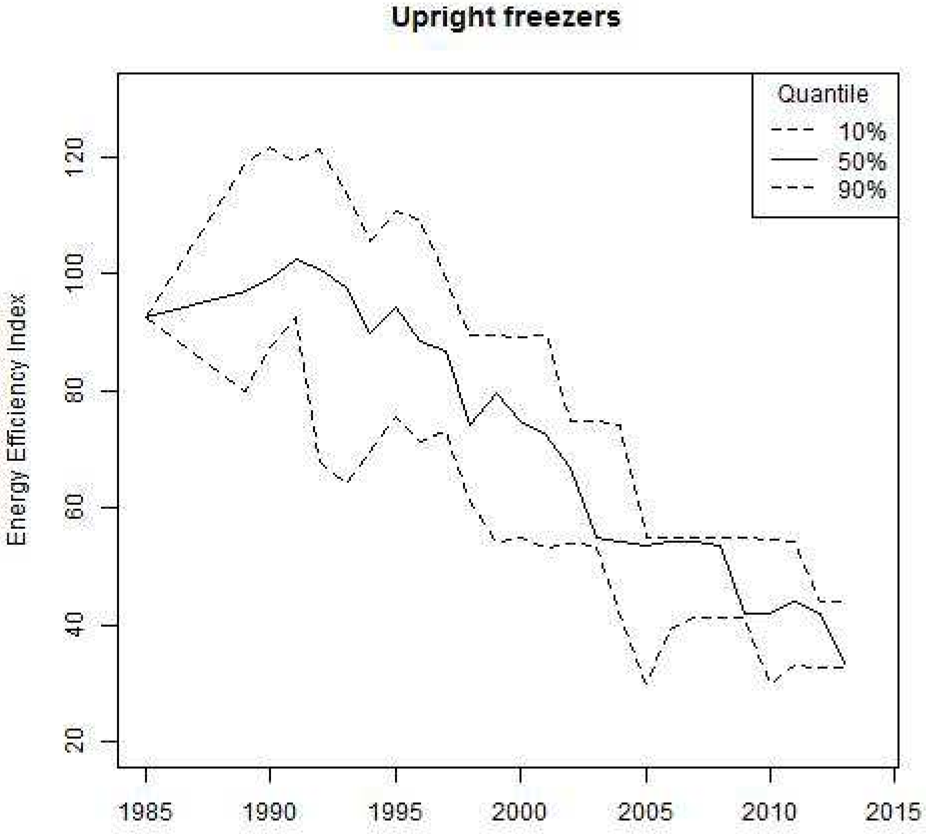

Chest freezers
Size, litre
200
250
300
350
400
1990
1995
2000
2005
2010


Chest freezers
Quantile
10%
50%
90%
Price (2000-DKK)
1000
2000
3000
4000
5000
6000
7000
8000
1990
1995
2000
2005
2010
2015

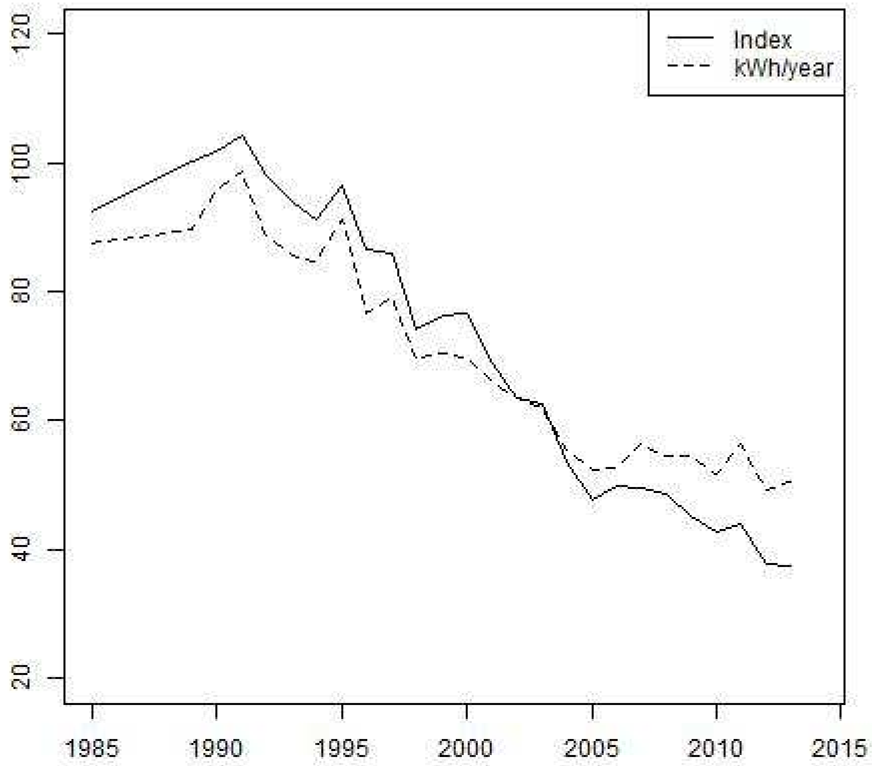
6. Upright freezers

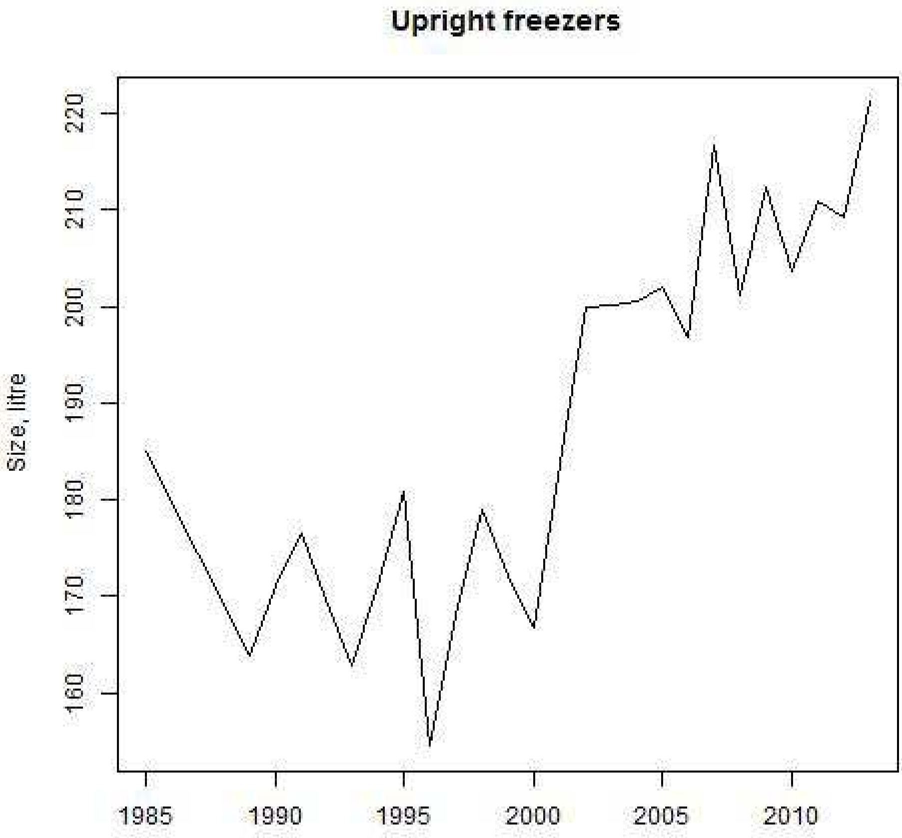
Introduced appliances by energy label, number 1985-2013

	A+++	A++	A+	A	B	C	D	E	F	G
1985							1			
1989						2	6	2	2	1
1990					4	11	24	15	13	4
1991						1	4	7	2	1
1992					3	2	3	2	6	
1993			1		3	6	10	8	4	
1994					12	28	23	12		4
1995					4	10	15	4	1	3
1996				1	8	4	4	3	1	
1997					21	22	11	3	2	
1998			1	2	19	7	2	1		
1999			1	9	16	22	3	1		
2000				4	12	12				
2001			2	18	27	15				
2002			3	25	32	2				
2003			4	42	41	4				
2004		1	31	43	19					
2005		13	36	45	7					
2006		7	17	42	7					
2007		3	33	53	4					
2008		3	43	58	3					
2009		6	66	34	2					
2010		13	81	22	1					
2011	3	21	158	43	1					
2012	11	47	77	2						
2013	2	42	45	1						

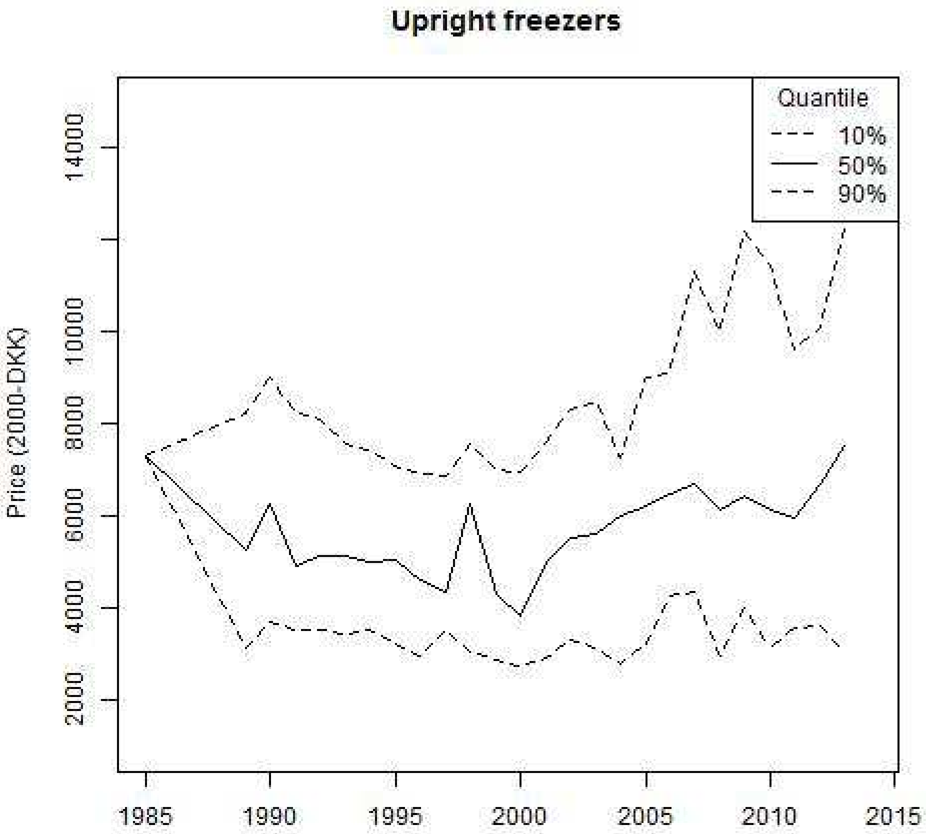

Upright freezers
Quantile
10%
50%
90%
Energy Efficiency Index
20
40
60
80
100
120
1985
1990
1995
2000
2005
2010
2015

Upright freezers





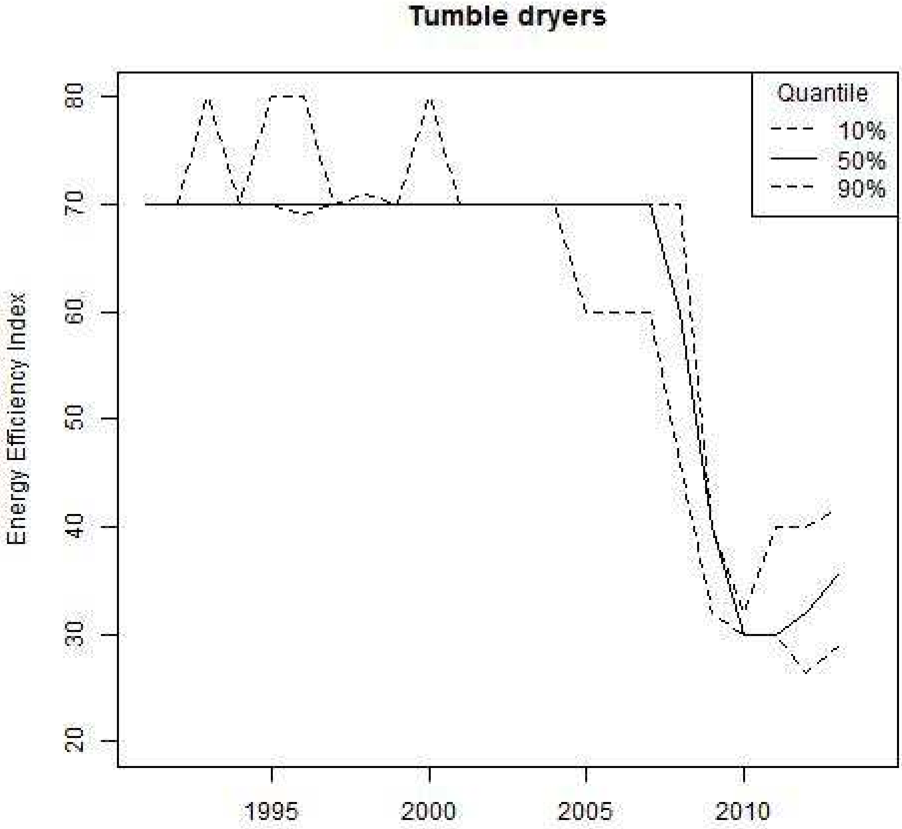
Upright freezers
Size, litre
220
210
200
190
180
170
160
1985
1990
1995
2000
2005
2010


Upright freezers
Quantile
10%
50%
90%
Price (2000-DKK)
2000
4000
6000
8000
10000
14000
1985
1990
1995
2000
2005
2010
2015

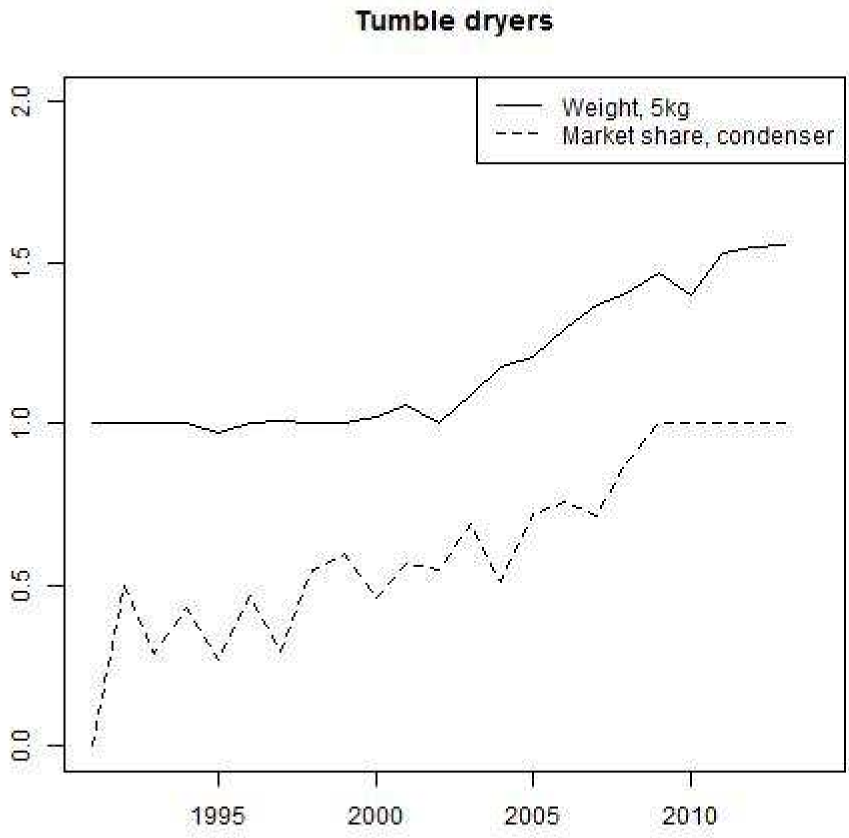
7. Tumble dryers

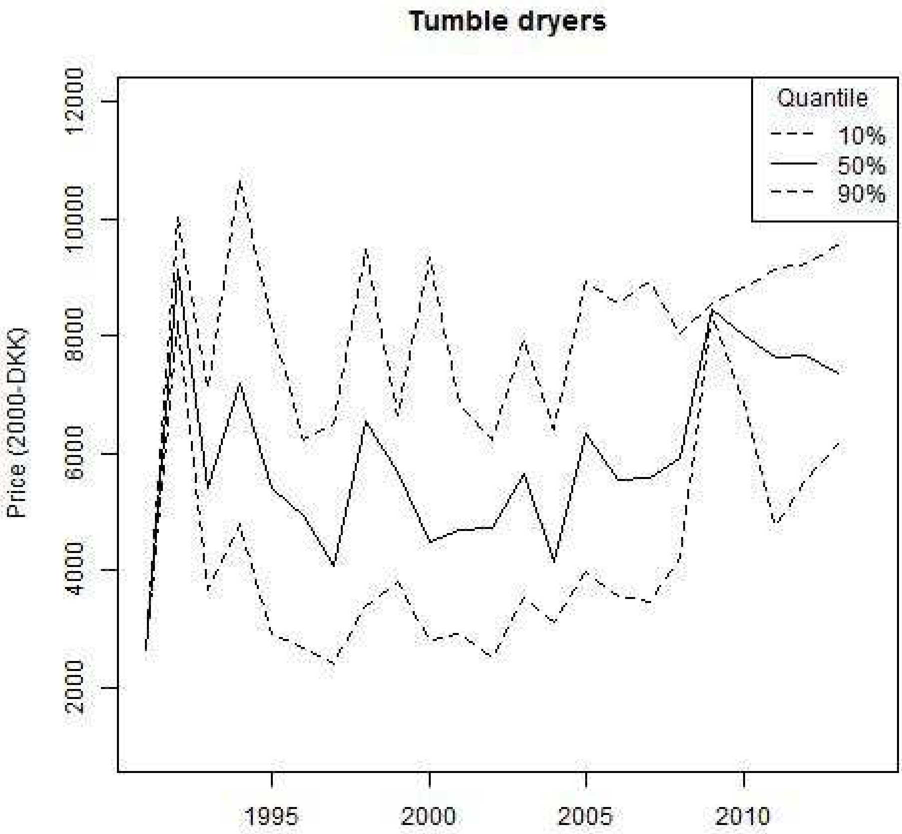
Introduced appliances by energy label, number 1991-2013

	A+++	A++	A+	A	B	C	D	E	F
1991						1			
1992						4			
1993							7		
1994						8	6		
1995						13	12	3	2
1996						17	13		
1997						22	12		
1998						15	5		
1999				1		32	2		
2000				1		18	4	1	
2001						50	3		
2002						41		1	
2003						57	1		
2004						43			
2005				3	4	43			
2006					21	37			
2007				3	27	32	2		
2008				5	27	12			
2009				3					
2010				19					
2011		3	1	27					
2012	1	11	20	24					
2013	4	28	43	2					



Tumble dryers
Quantile
10%
50%
90%
Energy Efficiency Index
20
30
40
50
60
70
80
1995
2000
2005
2010

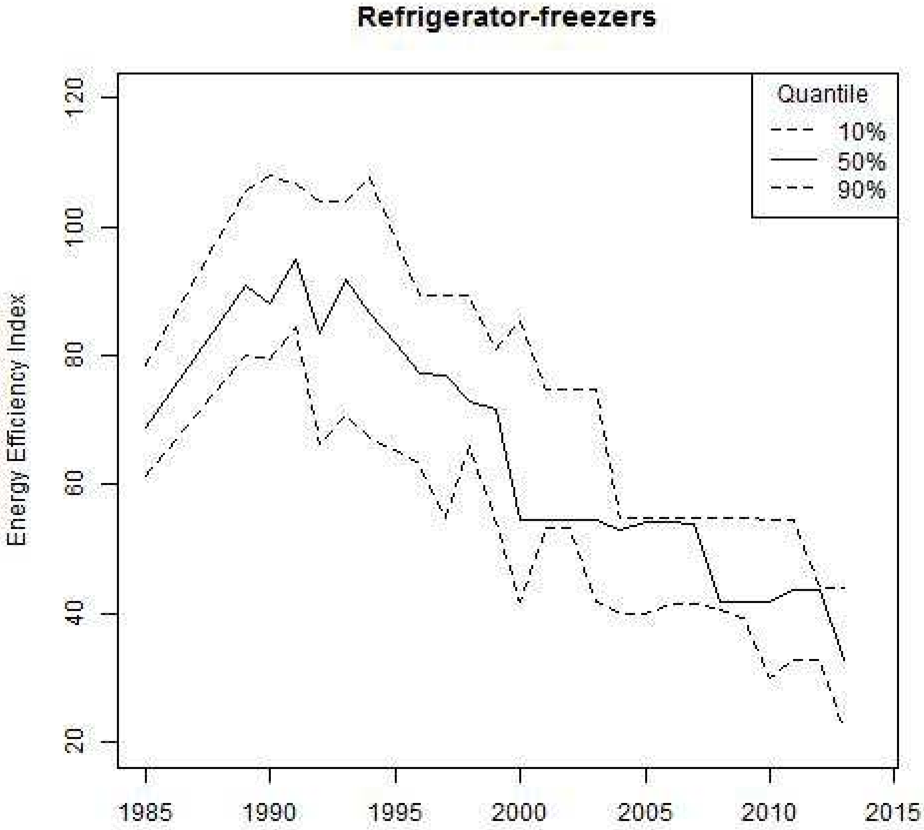

Tumble dryers
Weight, 5kg
Market share, condenser
0.0
0.5
1.0
1.5
2.0
1995
2000
2005
2010


Tumble dryers
Quantile
10%
50%
90%
Price (2000-DKK)
2000
4000
6000
8000
10000
12000
1995
2000
2005
2010

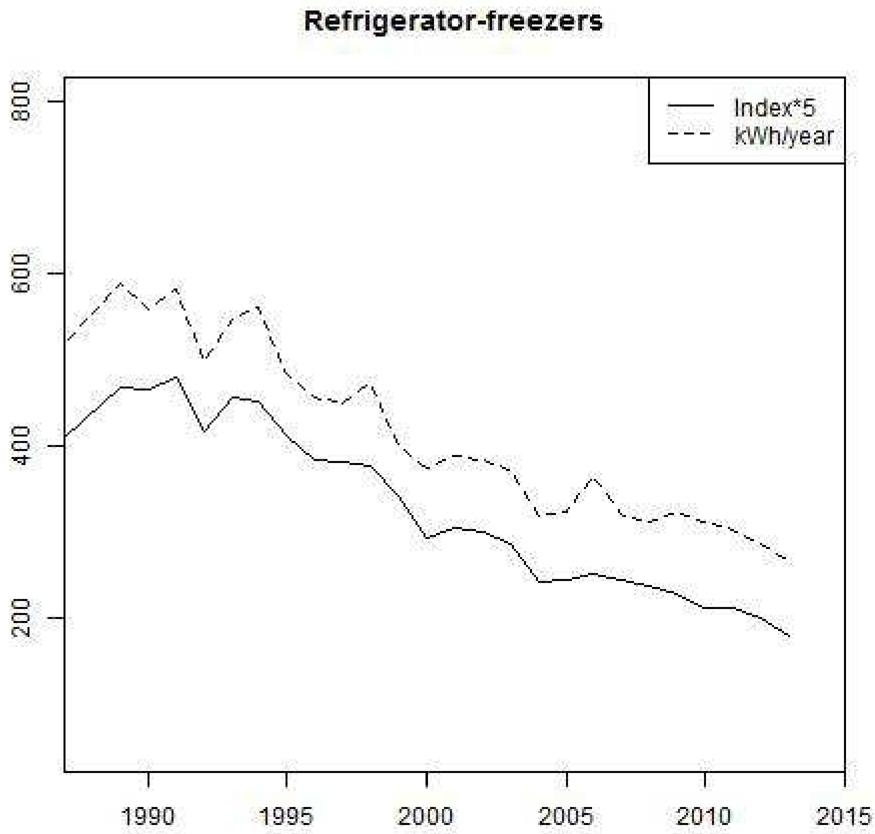
8. Refrigerator-freezers

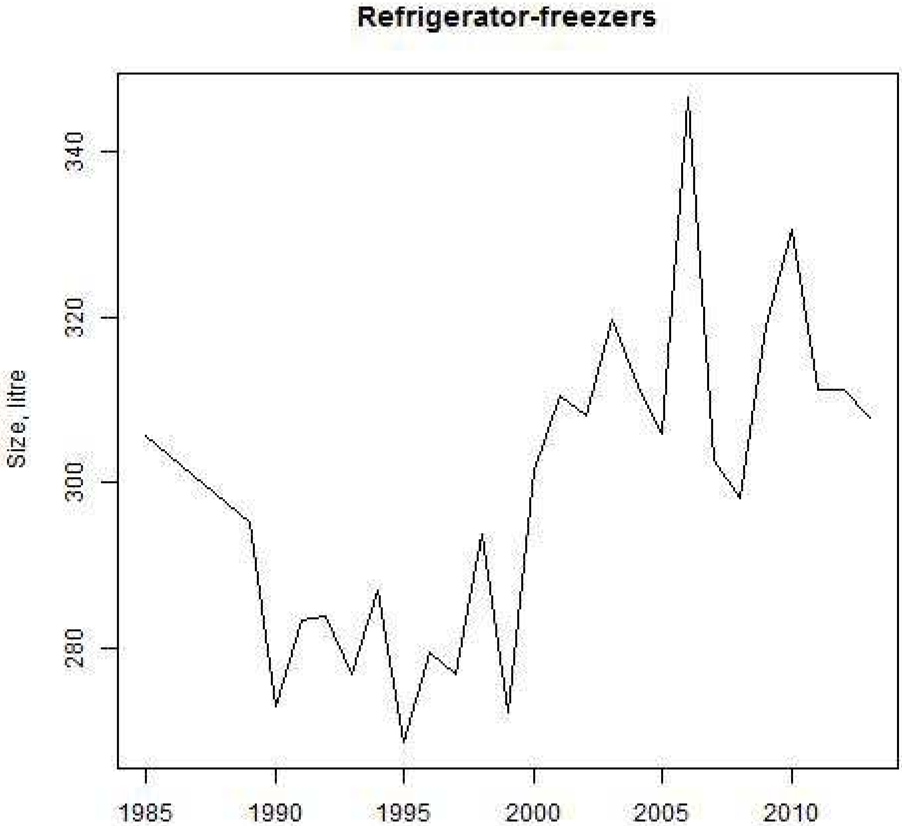
Introduced appliances by energy label, number 1989-2013

	A+++	A++	A+	A	B	C	D	E	F	G
1989					2	36	25	9	3	3
1990					1	13	3	6		1
1991					1	15	12	11	2	2
1992				1	9	11	4	4	1	
1993					8	18	17	12		2
1994				1	18	40	20	12	2	5
1995				1	21	31	13	4		1
1996			1	4	30	37	3	1		
1997			1	8	31	35	5	1		
1998				4	57	16	3		1	1
1999				29	64	19	0			
2000			40	40	25	11	4	2		
2001			6	92	49	11	2			
2002			6	105	45	16				
2003		2	18	119	26	13				
2004		1	110	120	9	1				
2005		12	51	108	6					
2006			70	138	10	1				
2007			76	92	1					
2008		2	132	120	6					
2009		15	148	99	5					
2010		30	159	45	2					
2011	16	88	319	77	4					
2012	11	59	172	14						
2013	11	37	36	4						

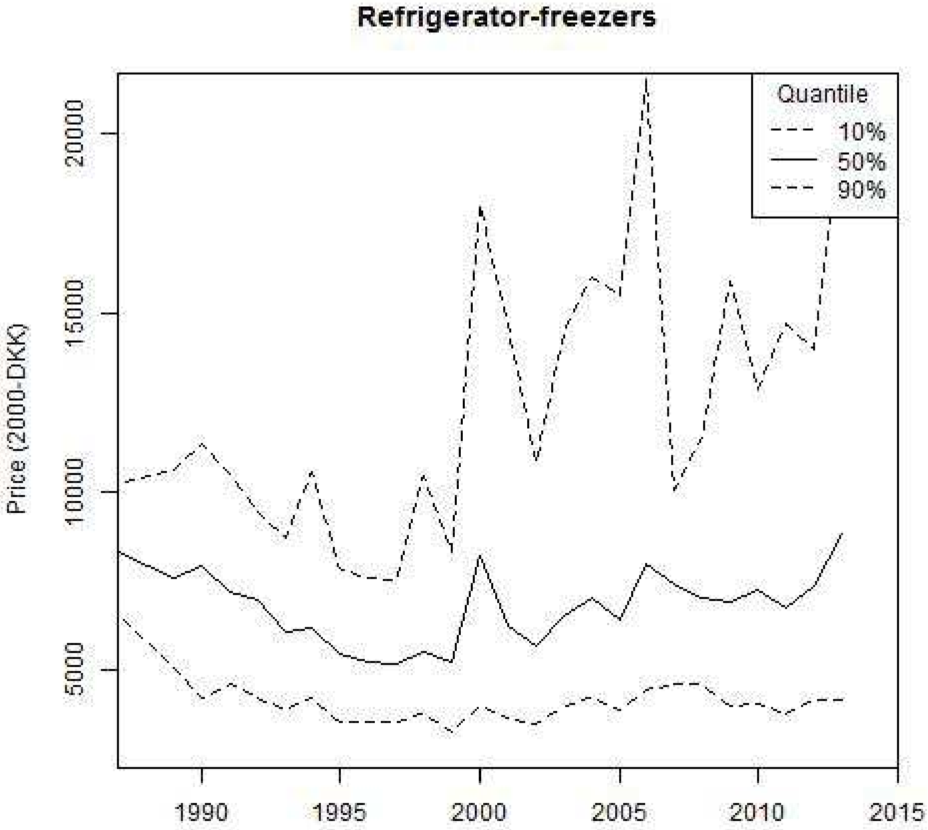


Refrigerator-freezers
Quantile
10%
50%
90%
Energy Efficiency Index
20
40
60
80
100
120
1985
1990
1995
2000
2005
2010
2015


Refrigerator-freezers
Index*5
kWh/year
800
600
400
200
1990
1995
2000
2005
2010
2015



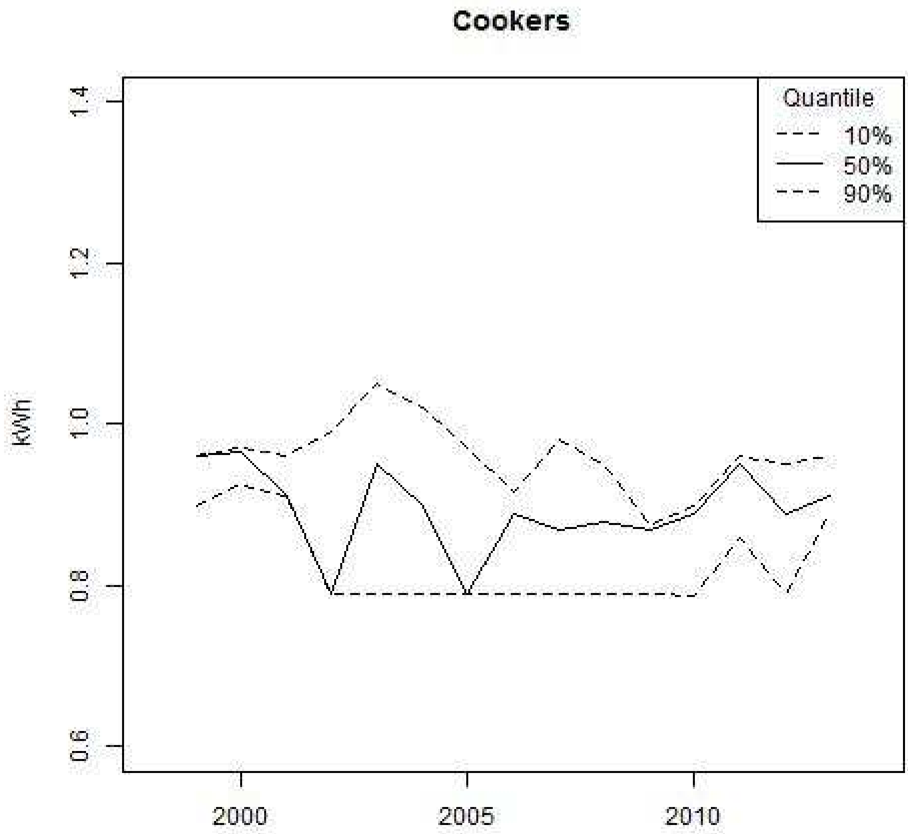
Refrigerator-freezers
Size, litre
340
320
300
280
1985
1990
1995
2000
2005
2010


Refrigerator-freezers
Quantile
10%
50%
90%
Price (2000-DKK)
20000
15000
10000
5000
1990
1995
2000
2005
2010
2015

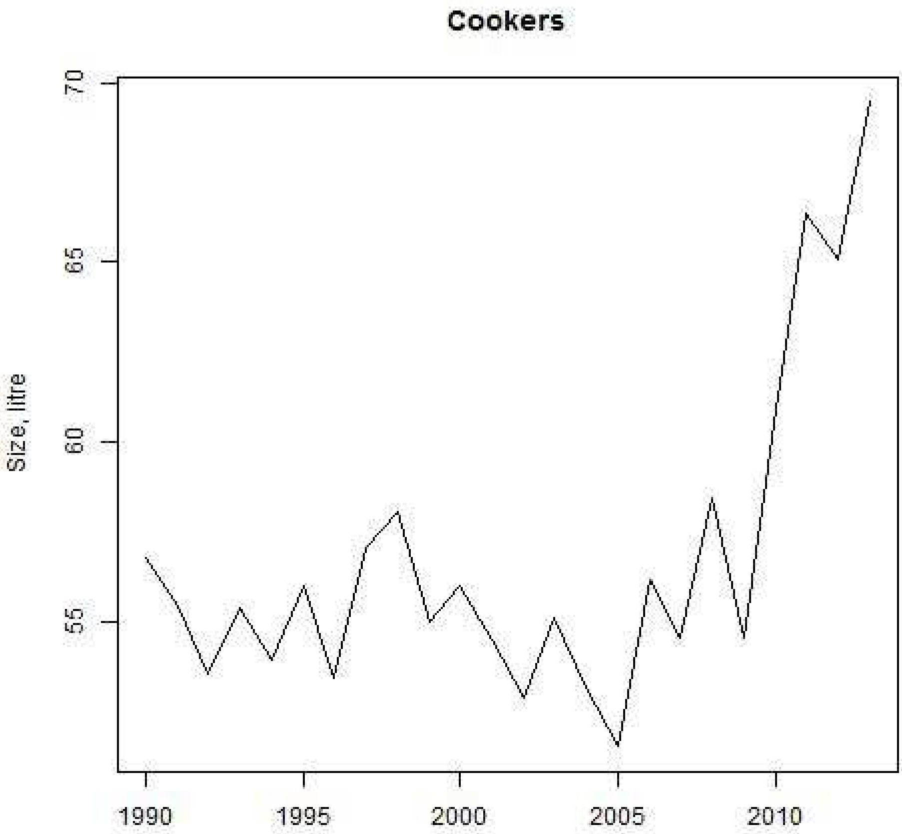
9. Cookers

Introduced appliances by energy label, number 1989-2013

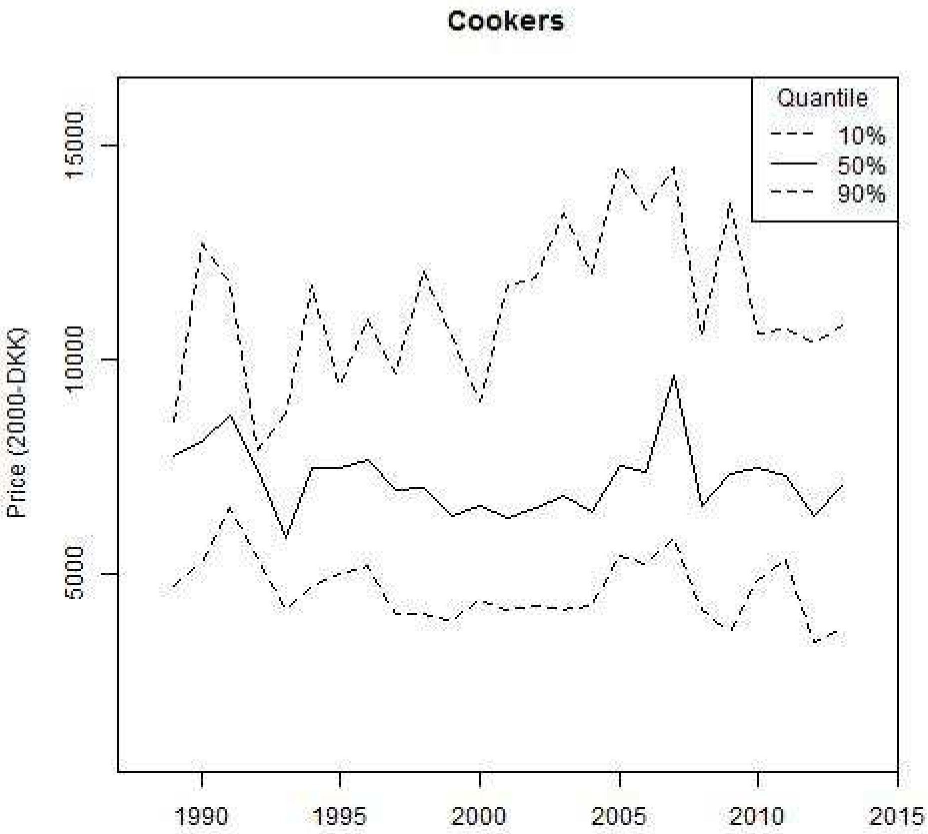
	A	B	C	D	Not labelled
1989					5
1990					88
1991					14
1992					7
1993					15
1994					27
1995					42
1996					23
1997					76
1998					59
1999		5			42
2000	1	3			30
2001	15	6		1	31
2002	23	11	1		28
2003	31	21	3	1	7
2004	41	13	1		
2005	54	6			
2006	71	5			
2007	81	2	6		
2008	61	3	2		1
2009	28				
2010	49				
2011	104				
2012	60	1	2		
2013	60				2



Cookers
Quantile
10%
50%
90%
kWh
1.4
1.2
1.0
0.8
0.6
2000
2005
2010



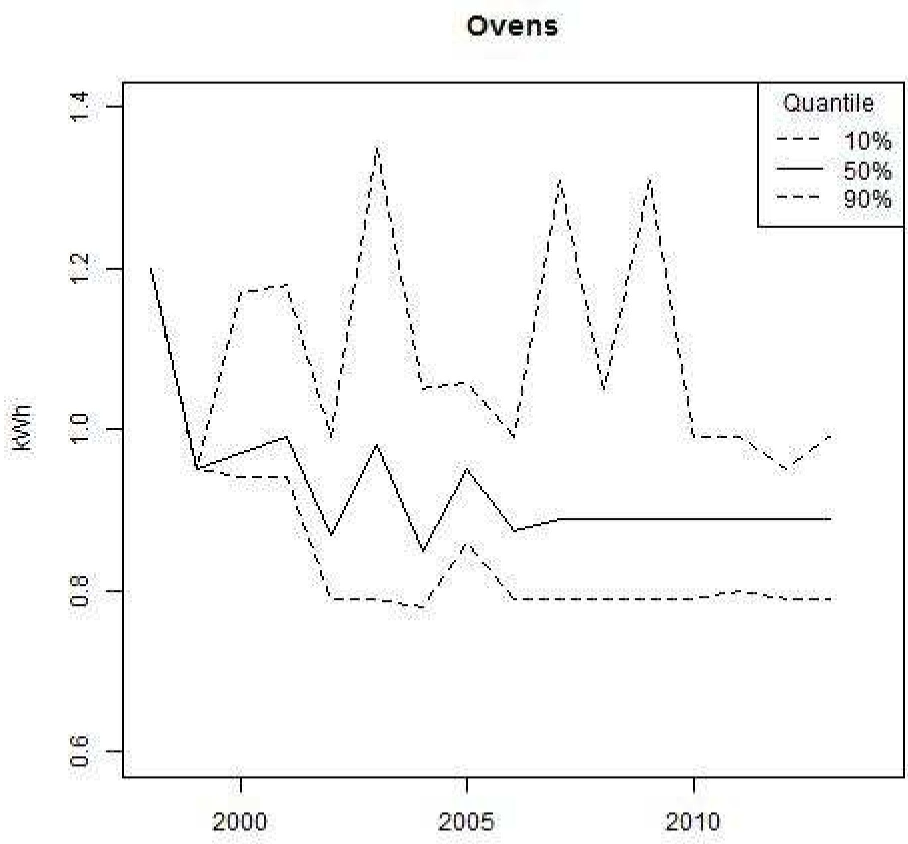
Cookers
Size, litre
70
65
60
55
1990
1995
2000
2005
2010

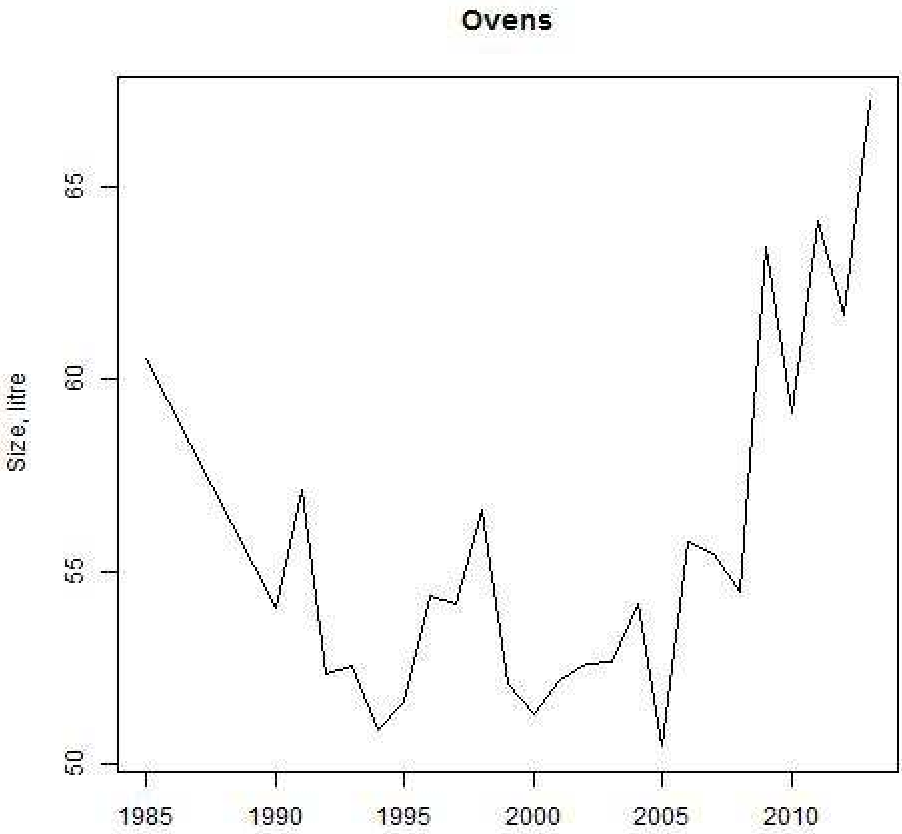

Cookers
Quantile
10%
50%
90%
Price (2000-DKK)
15000
10000
5000
1990
1995
2000
2005
2010
2015

10. Ovens

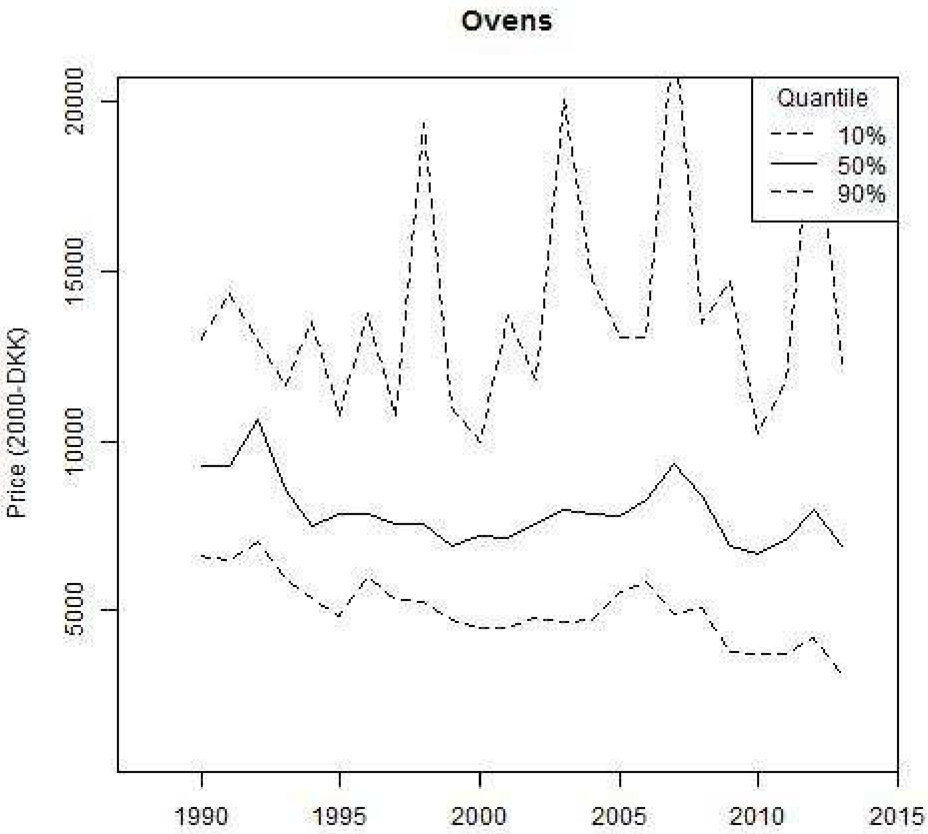
Introduced appliances by energy label, number 1985-2013

	A	B	C	Not labelled
1985				7
1990				113
1991				32
1992				9
1993				38
1994				30
1995				43
1996				61
1997				69
1998		1		83
1999		1		44
2000	1	8	4	89
2001	9	11	2	28
2002	58	16	1	23
2003	67	35		29
2004	137	17	2	7
2005	110	11	1	6
2006	53	1		2
2007	141	12	1	10
2008	159	2		12
2009	177	1		
2010	78	6		
2011	111	4		1
2012	132			2
2013	154			


Ovens
Quantile
10%
50%
90%
kWh
1.4
1.2
1.0
0.8
0.6
2000
2005
2010



Ovens
Size, litre
65
60
55
50
1985
1990
1995
2000
2005
2010


Ovens
Quantile
10%
50%
90%
Price (2000-DKK)
20000
15000
10000
5000
1990
1995
2000
2005
2010
2015

Appendix 2. Estimation results for 10 types of appliances

Washing machines

Table B2.1. Estimation of the effect of energy efficiency on the price of the appliance, washing machines

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.278	0.032	<0.001
log(Energy efficiency on the market)	-0.146	0.038	<0.001
R^2=0.79, df=2147 Explanatory variables: Year, size (kg clothes), name of producer, spin-drying efficiency			

Tørretumblere

Table B2.2. Estimation of the effect of energy efficiency on the price of the appliance, tumble dryers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.464	0.051	<0.001
log(Energy efficiency on the market)	-0.185	0.063	<0.01
R^2=0.84, df=638 Explanatory variables: Year, capacity, name of producer, drying efficiency			

Dishwashers

Table B2.3. Estimation of the effect of energy efficiency on the price of the appliance, dishwashers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.474	0.051	<0.001
log(Energy efficiency on the market)	-0.049	0.031	<0.109
R^2=0.71, df=2302 Explanatory variables: Year, built-in, name of producer, drying efficiency, capacity			

Refrigerator-freezers

Table B2.4. Estimation of the effect of energy efficiency on the price of the appliance, refrigerator-freezers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.242	0.024	<0.001
R^2=0.69, df=2958 Explanatory variables: Year, volumes, built-in, name of producer, no-frost-function, climate class, cellar compartment			

Refrigerators (without freezer compartment)

Table B2.5. Estimation of the effect of energy efficiency on the price of the appliance, refrigerators

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.233	0.034	<0.001
log(Energy efficiency on the market)	-0.231	0.079	0.003
R^2=0.67, df=1964 Explanatory variables: Year, volume, built-in, name of producer, climate class			

Refrigerators with freezer compartment

Table B2.6. Estimation of the effect of energy efficiency on the price of the appliance, refrigerators with freezer compartment

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.335	0.062	<0.001
R^2=0.80, df=795 Explanatory variables: Year, volume, built-in, name of producer, type of freezer compartment, climate class			

Upright freezers

Table B2.7. Estimation of the effect of energy efficiency on the price of the appliance, upright freezers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.224	0.029	<0.001
R^2=0.83, df=1534 Explanatory variables: Year, volume, built-in, name of producer, no-frost system, climate class			

Chest freezers

Table B2.8. Estimation of the effect of energy efficiency on the price of the appliance, chest freezers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.274	0.019	<0.001
log(Energy efficiency on the market)	-0.105	0.029	0.0004
R^2=0.90, df=528 Explanatory variables: Year, volume, built-in, name of producer, no-frost system, climate class			

Cookers

Table B2.9. Estimation of the effect of energy efficiency on the price of the appliance, cookers

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.211	0.090	<0.05
R^2=0.90, df=528 Explanatory variables: Year, volume, name of producer, noise, grill motor, type of oven, type of hub, colour, cleaning system, clock, thermometers, induction heating, number of zones, frying zone			

Ovens

Table B2.10. Estimation of the effect of energy efficiency on the price of the appliance, ovens

	Dependent variable: log(p)		
	Parameter estimat	Std.dev.	p
log(Energy efficiency)	0.344	0.065	<0.001
R^2=0.77, df=942 Explanatory variables: Year, volume, name of producer, noise, grill motor, type of oven, colour, cleaning system, clock, thermometers			

Appendix 3. Payback periods for 10 types of appliances

Washings machines

Table B3.1. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, washing machines introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumption (kWh per wash)
A+	4740		7.07	1.01
A++	=4740*(1+0.34*0.278) = 5188	=4740*(1+0.34*(0.278 -0.146)) = 4953	9.49	=1.01/1.34 = 0.75
Increase from A+ to A++	= 448 DKK	= 213 kr.	= 34 %	= -0.26 kWh
Energy savings DKK/year (3 washings/week, price of electricity=2 DKK/kWh)	84 DKK			
Payback period Years	5.3	2.5		

Tumble dryers

Table B3.2. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, tumble dryers introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	7210		0.0269	2.11
A++	=7210*(1+0.19*0.464) = 7846	=7210*(1+0.19*(0.464 -0.185)) = 7592	0.0321	=2.11/1.19 = 0.75
Increase from A+ to A++	= 636 DKK	= 381 kr.	= 19 %	= -0.34 kWh
Energy savings DKK/year (2 uses/week, price of electricity=2 DKK/kWh)	71 DKK			
Payback period Years	9.0	5.4		

Dishwashers

Table B3.3. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, dishwashers introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	5790		12.0	0.97
A++	=5790*(1+0.19*0.474) = 6311	=5790*(1+0.19*(0.474 -0.049)) = 6258	14.3	=0.97/1.19 = 0.82
Increase from A+ to A++	= 521 DKK	= 468 kr.	= 19 %	= -0.15 kWh
Energy savings DKK/year (1 use /day, price of electricity=2 DKK/kWh)	110 DKK			
Payback period Years	4.7	4.3		

Refrigerator-freezers

Table B3.4. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, refrigerator-freezers introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	8468		0.0233	311
A++	=8468*(1+0.32*0.242) = 9124		0.0307	=311/1.32 = 235
Increase from A+ to A++	= 656 DKK		= 32 %	= 75 kWh
Energy savings DKK/year (electricity price=2 DKK/kWh)	150 DKK			
Payback period Years	4.4			

Refrigerators

Table B3.5. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, refrigerators introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	5855		0.0232	143
A++	=5855*(1+0.32*0.233) = 6292	=5855*(1+0.32*(0.233 -0.231)) = 5857	0.0306	=143/1.32 = 108
Increase from A+ to A++	= 437 DKK	= 2 kr.	= 32 %	= -35 kWh
Energy savings DKK/year (2 DKK/kWh)	70 DKK			
Payback period Years	6.2	0.0		

Refrigerators with freezer compartment

Table B3.6. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, refrigerators with freezer compartment introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	4383		0.0234	216
A++	=4383*(1+0.32*0.335) = 4853		0.0308	=216/1.32 = 164
Increase from A+ to A++	= 470 DKK		= 32 %	= -52 kWh
Energy savings DKK/year (2 DKK/kWh)	104 DKK			
Payback period Years	4.5			

Upright freezers

Table B3.7. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, upright freezers introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	6823		0.0232	279
A++	=6823*(1+0.31*0.224) = 7279		0.0305	=279/1.31 = 213
Increase from A+ to A++	= 474 DKK		= 31 %	= -66 kWh
Energy savings DKK/year (2 DKK/kWh)	132 DKK			
Payback period Years	3.6			

Chest freezers

Table B3.8. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, chest freezers introduced 2011-2013 labelled A++ compared to A+

	Average price and price calculated with few A++ on the market	Average price and price calculated with many A++ on the market	Energy efficiency index	Absolute energy consumptio n (kWh per wash)
A+	3843		0.0236	268
A++	=3843*(1+0.32*0.274) = 4180	=3843*(1+0.32*(0.274 -0.105)) = 4051	0.0312	=268/1.32 = 203
Increase from A+ to A++	= 337 DKK	= 209 kr.	= 32 %	= -65 kWh
Energy savings DKK/year (2 DKK/kWh)	130 DKK			
Payback period Years	2.6	1.6		

Cookers

Table B3.9. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, cookers introduced 2001-2004 labelled B compared to A

	Average price and price calculated with few A on the market	Average price and price calculated with many A on the market	Energy efficiency index	Absolute energy consumption (kWh per wash)
A+	6137		1.0098	0.993
A++	=6137*(1+0.18*0.211) = 6370		1.1875	=0.993/1.18 = 0.842
Increase from A+ to A++	= 233 DKK		= 18 %	= -0.15 kWh
Energy savings DKK/year (2 DKK/kWh)	110 DKK			
Payback period Years	2.1			

* The oven is assumed to be used at 200°C once a day.

Ovens

Table B3.10. Average and calculated price, energy efficiency index and absolute energy consumption, payback period, ovens introduced 2001-2007 labelled B compared to A

	Average price and price calculated with few A on the market	Average price and price calculated with many A on the market	Energy efficiency index	Absolute energy consumption (kWh per wash)
A+	11978**		0.9421	1.207
A++	=11978*(1+0.19*0.344) = 12761		1.1189	=1.207/1.19 = 1.014
Increase from A+ to A++	= 783 DKK		= 19 %	= -0.19 kWh
Energy savings DKK/year (2 DKK/kWh)	139 DKK			
Payback period Years	5.6			

* * The oven is assumed to be used at 200°C once a day.

** The price of appliances labelled B is exceptionally high. The average price across labels is 8978 DKK.