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Household appliances penetration and ownership trends in residential buildings

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Abstract

Understanding the development of the trends in the ownership of different appliances in a historic context in various countries of the world can not only provide important insights for understanding the dynamics of adoption of different appliances, but can also help with foresight: how the future may develop for these or other, new appliances on the market. Although available literature in household appliances energy consumption, energy management and energy efficiency has seen some advances, there is a clear lack in the literature on household appliance ownership. In this paper, historic data is gathered and analysed for several groups of appliance types (white appliances, brown appliances and small appliances) for 12 countries representing four continents, when available since 1970 to date. Countries representing different parts of the world were selected to present an overview on household appliances ownership and energy consumption. One of the first conclusions of the study is that there is little or no information in many countries from South America, Africa or South Asia. Refrigerators, freezers and washing machines ownership are an example of most other white goods. Brown goods appeared in the market at very different time, depending on each one (from the 70s to the late 90s) and their ownership growth is much higher than for the previous ones. Most of small line appliances ownership has not reached saturation yet.

Keywords: household appliances; penetration; ownership; trends; use.

1. Introduction

Household appliances are key contributors to residential energy consumption [1] and at the same time there is limited understanding about their ownership and use. While there is growing literature on their energy consumption, energy management and energy efficiency and many of these papers recognise that the number of appliances is growing, there is a clear gap in publicly available, consistent, and comparable knowledge on their ownership and the historic trends of these. A short summary of such literature found in 2015 is given below as example.

A precise factual and numeric understanding of appliance ownership, and its historic trends, in an international context can help answer many research questions. First, it is important to understand how the ownership and use of these appliances compare throughout different countries, cultures, geographic, and economic contexts. Second, understanding the historic dynamics of the penetration and ownership of household appliances can help in advancing many other research questions, such as predicting future adoption of existing and new appliances, can help in modelling future building energy use, etc. The dynamics of adoption of different equipment in different cultures and geographies can help in understanding and projecting the use and adoption of other appliances and equipment for other uses.

In the following, we provide a brief review of the literature on energy consumption and management of household appliances to direct the reader to the primary sources of information in the subject. On energy consumption, Desroches et al. [2] stated that while the share of electricity consumed by consumer electronics in US households has increased in the last decade, many devices lack robust energy use data, making energy consumption estimates difficult and uncertain; therefore they present the results of a survey collecting data from 880 households. Belman-Flores et al. [3] identified refrigerators among the home appliances that use most energy; but the only ownership data presented is from Mexico (authors state that in the period 2011-2014 Mexico made an annual average number of refrigerators of 1,4430,483 units per year for volumetric capacities of up to 0.3 m³, and approximately double for units with bigger capacities). On the other hand, on energy management, Abushnag et al. [4] identified home energy management systems technology as a way of optimizing energy use in residential buildings since they can contribute in reducing energy use and energy wastage by monitoring and controlling household appliances, since the number of electrical home appliances is increasing in the average household. Moreover, on energy efficiency, Datta and Filippini [5] estimated the impact of rebate policies in USA on the sales of share of highly efficient household appliances. Hosgor and Fischbeck [6] examined the energy efficiency profile of 7091 individual single-family houses from USA. Jridi et al. [7] showed that in Tunisia gains in energy

efficiency is one of the reasons for acceptance of changes in refrigerators prices. Finally, on energy usage, Lu et al. [8] conducted a field study on off-shore islands in Taiwan to investigate the energy usage of local residents comparing household appliance usage in mainland Taiwan. Interestingly, the authors present penetration percentages of appliances such as refrigerators and freezers, but no absolute ownership data is presented. Mills and Mills [9] identified gaming as the most energy-intensive use of personal computers and present peak demand data on the topic, highlighting the need to collect more market data and raise the issue to the consumer.

Therefore the authors of this paper identified a gap on presenting data on ownership of household appliances to be able to assess the trends in appliances for residential buildings considering the different appliances types. The data gathered is presented with appliances grouped by appliance type and the countries chosen represent different areas of the world and different level of gross domestic product (GDP), although no data on some interesting and potentially important countries was found.

Moreover, an overview regarding appliances ownership and energy consumption was performed and several countries have been included in this study because they are representative for several parts of the world:

- South and North Europe areas are represented by Spain, France, Austria, Denmark, and UK, respectively.
- Eastern Europe is represented by Hungary.
- USA is the country where households consume high amounts of energy and one reason is because of high appliances ownership.
- Japan and China are clearly good representation of Asia because Japan is considered high-tech since decades while China is an emergent country where the situation regarding everything including appliances ownership has change a lot during the last decades. Therefore, Asia countries that have not emerged yet may be considered as China 20 years ago. India is also very important because it is in an extremely dynamic development phase in terms of household appliance ownership and use; but unfortunately very limited information was found that was publicly available.
- Australia is a single case because they have low population density in a huge country within a very different climate zone but the economy is considered inside the OCDE and these are the reasons why Australia is included in this study.

However, unfortunately little to no information is available about countries of other world areas as South America, Africa, or South Asia, etc.

2. Methodology

2.1. Appliances considered

Information regarding appliances is available in several different ways, such as those used by the National Centre of Statistics Denmark [10], Statistic Austria [11], Australian Government department of industry [12], National Bureau of Statistics of China [13], etc. Therefore, the data information must be classified and organized in order to evaluate the overview regarding the appliance ownership trends and usage energy consumption in residential buildings.

In general, the appliances are divided in three categories: white goods, brown goods, and small appliances [14], which are defined as follows:

- White goods are considered those that historically present a white cover like washing machine, refrigerator or freezer, cloth dryer, dishwasher, etc. These appliances are those that comprise the basics needs of society. Moreover, the appliances included in this category are the ones with highest energy consumption due to their continuous usage.
- Brown goods are intended for used in leisure time as well as secondary needs, such as TV, computers, DVD, cameras, videogames, etc. In last years, this category has been expanded by the proliferation of new appliances based on the personal communication in a very different way. Therefore, smartphones, music player, and tablets are included in this group because they have become a very important need for the new XXI century generations. Brown goods usage consists of part time use related with the connection between the technology and the society and they have background energy consumption since they are in standby during their time of no use.
- Small line appliances are described as those one that are needed domestically to make small works, such as griddle, coffee maker, microwave, beater, hair dryer, fans, etc. The energy consumption of these appliances is high but the short time of use compensates this fact becoming a low contribution of the final energy consumed by appliances.

Table 1 summarizes the appliances considered in this paper classified in each category here described.

Table 1. Appliances included in this study classified in each category

White goods	Brown goods	Small appliances
Refrigerator	Television	Microwave
Freezer	Video recorder	
Washing machine	Computer	
Clothes dryer	Mobile phone	
Dishwasher	DVD player	

2.2. Data sources

Data from the different countries considered was obtained from the following sources:

- Spain: *Intituto Nacional de Estadística* [15]
- France: *Institute National de la Statistique et des Études Économiques* [16]
- Austria: *Statistik Austria* [11] and Hass et al. [17]
- Denmark: *Statistics Denmark* [10]
- UK: *Department of Energy & Climate Change* [18]
- USA: *U.S. Energy Information Administration (EIA)* [19]
- Japan: *The Institute of Energy Economics* [20]
- China: *Chinese Statistical yearbook* [13],[21] [27]
- Australia: *Australian Bureau of Statistics* [28] and *Department of Industry and Science* [12].
- Hungary: *Statistical Yearbook of Hungary* [29][32]
- India: *United States Agency International Development* [33]

3. Trends in appliance ownership

3.1. White goods

White goods, i.e. cold appliances and those used for basic hygiene such as clothes and dish washing, are among the most fundamental appliances (after cooking) – they are used for meeting basic household hygiene and food safety needs. Electric refrigeration, for instance, is typically adopted as second or third electricity service as households gain increasing access to power.

Figure 1 shows the refrigerators ownership in households between 1970 and 2010 for seven different countries from five key regions of the world. European countries such as France, Spain and Austria show an average of 100% ownership already since 1970; moreover, these countries show established stagnation, but all developed countries also have a close to full penetration already in the 80s. On the other hand, developed countries such as Japan, Australia, and USA show still growing trends, higher than 110% ownership. Australian data show an interesting trend, around 40% ownership in refrigerators from 1995 to 2005. China shows accordance between refrigerator ownership trend and GDP growth [28]; Chinese households went from mostly not having refrigerators in 1980 to 95% ownership in 30 years. India shows a seemingly bizarre trend, but it is actually likely to be representative of former communist countries in Eastern Europe. As the supply of different food types in communist countries were constrained, households reacted by stocking up food when it was available. This resulted in refrigerators and freezers gaining special significance in communist country households. After the fall of communism in 1990 this special rationale was removed. While households still used the cold appliances they had, there was an abrupt discontinuation in the growing trend in ownership, and once these equipment started to retire, they are only partially replaced, and thus there is a declining trend today in refrigerator ownership.

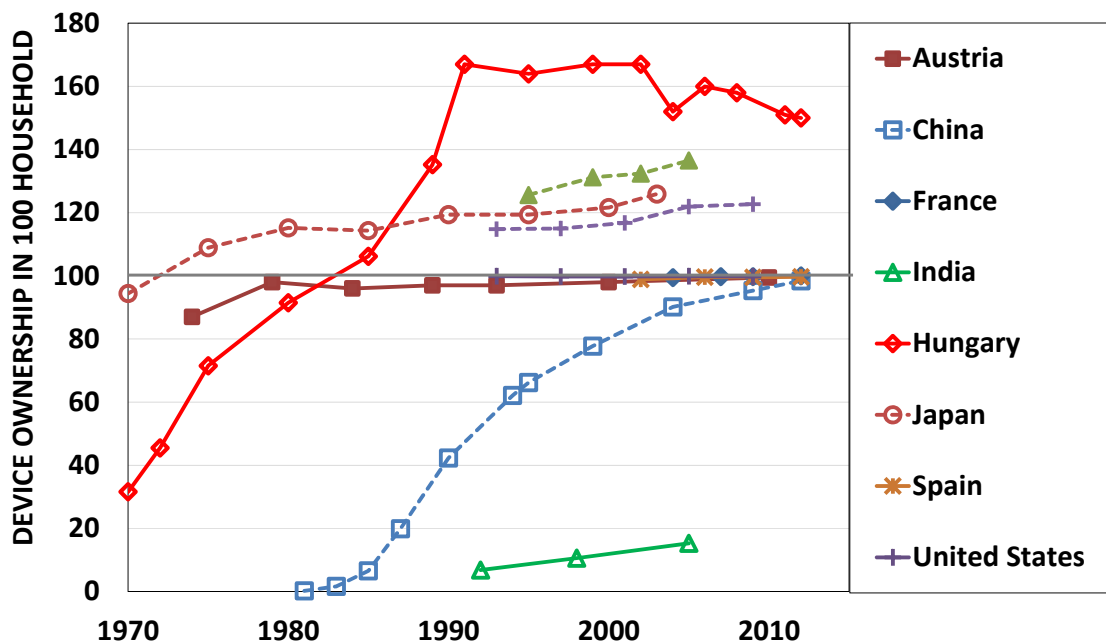


Figure 1. Refrigerator overview by country

Freezers (Figure 2), also considered white goods, show much lower ownership than refrigerators (Figure 1). Austria is the country where freezers ownership deployed first in the countries present in this study, already in 1974 having 32% ownership and reaching 80% in 2010. On the other hand, Spain shows moderate ownership but still experiences growth, going from 22.5% in 2002 to 28.1% in 2009. While Australia and USA also has relatively low ownership between 30-40%, they are actually showing a slightly declining trend for decades. Denmark shows a quite rapid growth in freezers ownership as was seen for refrigerators, trend also followed by France for this appliance. More research is needed for better understanding these stark differences in freezer ownership in OECD countries, some with by and large similar climates and levels of economic development (e.g. US and France; Austria and Denmark). Differences in statistical data collection and category definitions (e.g. the inclusion of combined freezer-refrigerators) may also play important roles.

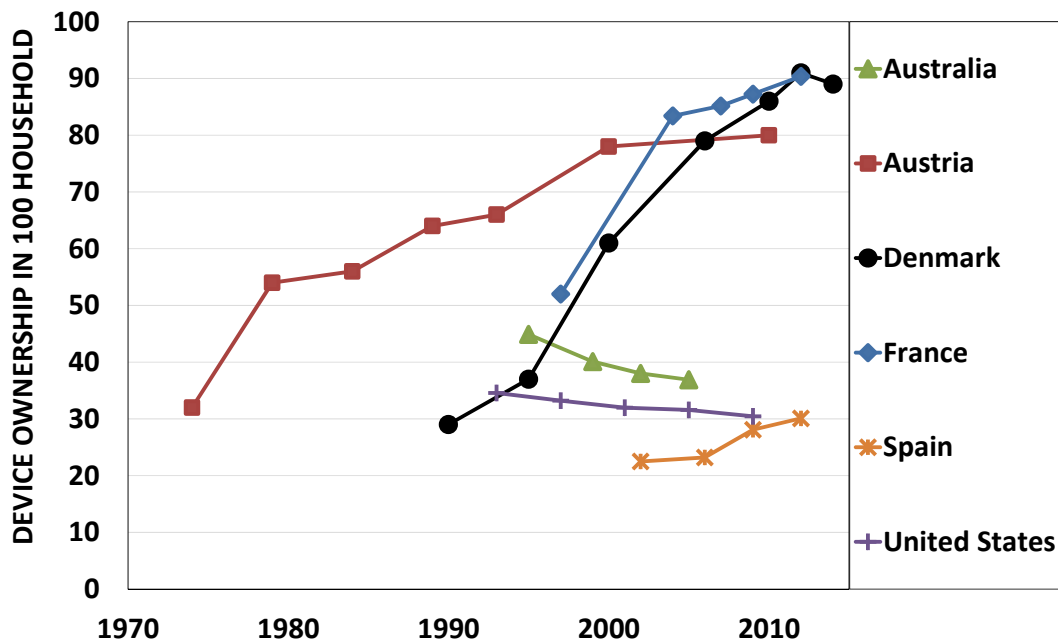


Figure 2. Freezer overview by country

The next category of appliances analysed are those related to clothes and dish washing. Clothes washers are by far the most widely adopted. For instance, the common trend in European countries and USA is a stagnation around 80-95% ownership reached around year 2000, as is shown in Figure 3. The data indicate that virtually all households in most developed countries tend to own at least one washing machine, except for Denmark and USA where ownership is around 80%, probably indicating a more prevalent use of laundrettes. Similarly as shown before for cold appliances, China experienced unprecedented growth in the ownership of washing machines as well: it increased from 2% to 100% ownership very rapidly, in this case

the full deployment was reached in 20 years, and a close to 80% explosion in ownership was seen in just one decade, the 80s.

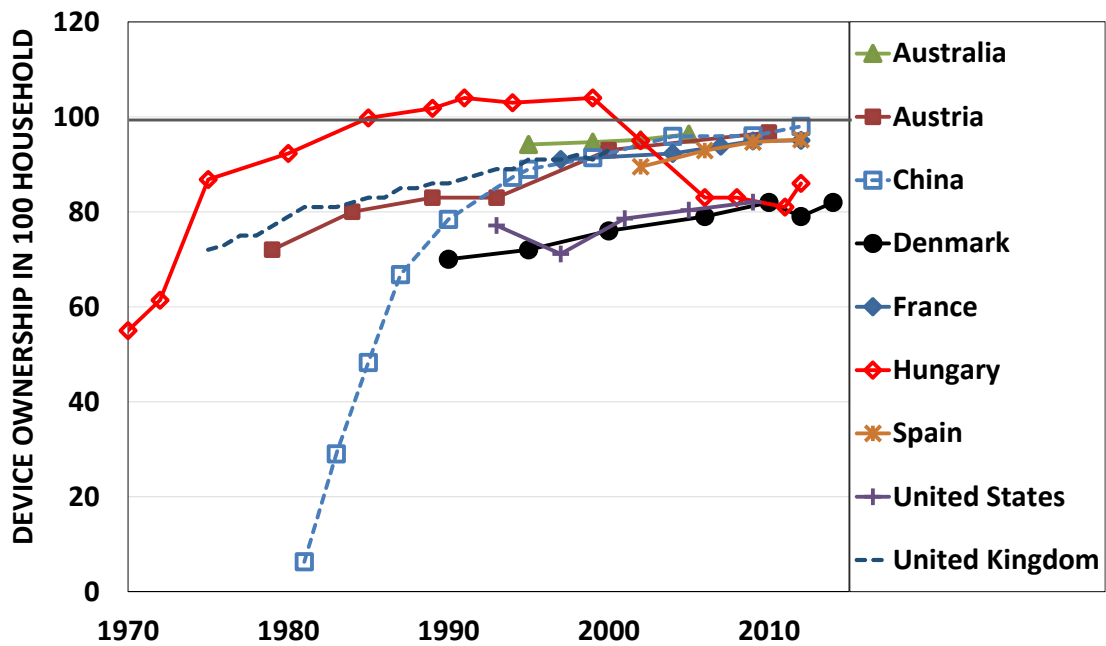


Figure 3. Washing machine ownership overview by country

It is interesting to see that the ownership trend followed by a not overriding appliance such as cloth dryer is completely different than for more necessary ones, especially compared to washing machines in this case (Figure 4). First of all, no stagnation has been reached by any country, in fact the growth is quite sharp in all countries except Spain (this can be explained by its warm weather).

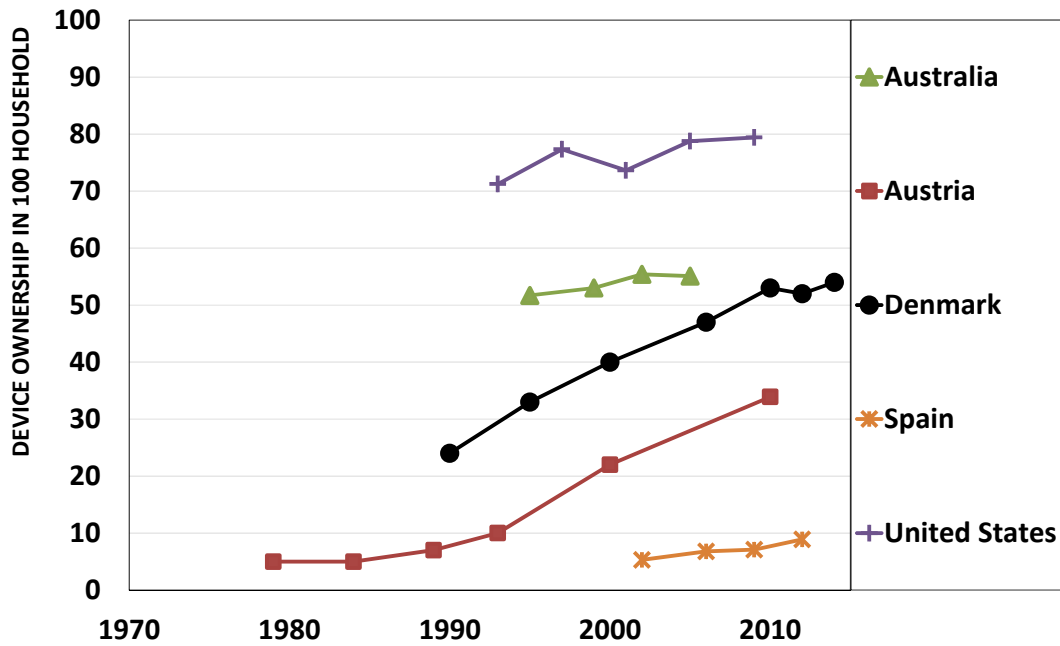


Figure 4. Clothes dryer ownership overview by country

Dishwashers are also becoming increasingly common in the households of developed countries. By today more than every second household in each developed country studied owns one. All studied countries show the same growing trend in dishwasher ownership as in dryers ownership, around 1-2%/year (Figure 5). As in other appliances shown before, dishwashers have not reached fully ownership in households although UK's is higher than any other country.

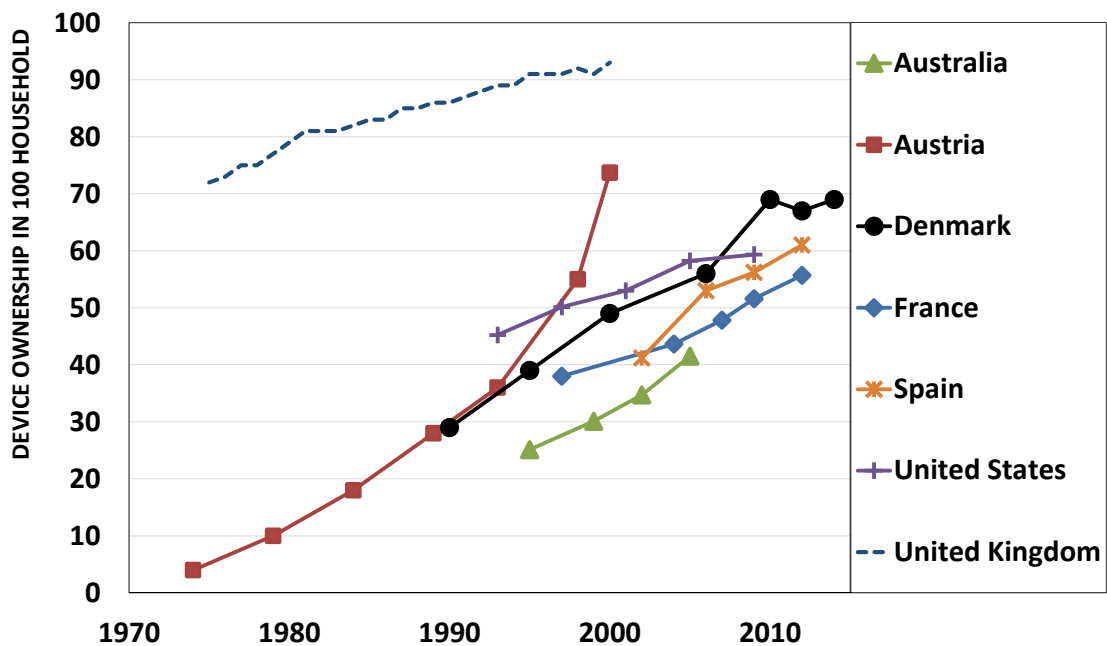


Figure 5. Dishwasher ownership overview by country

3.2. Brown goods

Brown goods presented here are televisions, video recorders, computers, and mobile phones, following chronological order of emergence in the market. This category is especially interesting to study because these types of equipment are not necessary for meeting fundamental household needs, however, they are very highly wanted by residents, as the data indicate. In fact, information/entertainment services were found to be the second, recently increasingly the first, energy service households choose to spend their increasing access to power resources in developing countries in the most recent decades.

For television (Figure 6) Austria, France and Spain show clear stagnation at 100% ownership, and reached this value around 1990. China and Japan trends show higher ownership probably due to cultural technology appeal. Japan highlights with values of 230% television ownership in households in 2000, similar to those in USA.

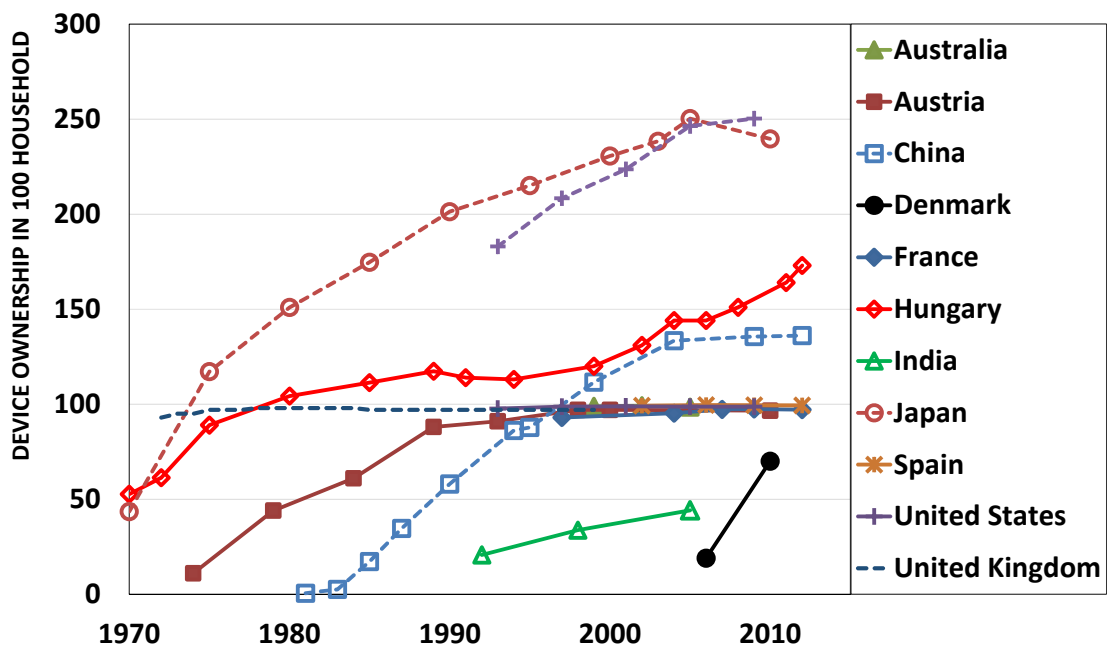


Figure 6. Television ownership overview by country

Figure 7 shows that video recorders appeared in the market in the 80s and are already disappearing, probably due to the emergence of compact cameras and smart phones. Most countries reached stagnation at about 80% ownerships in 2000, except USA that reached nearly 100% ownership in the early 90s.

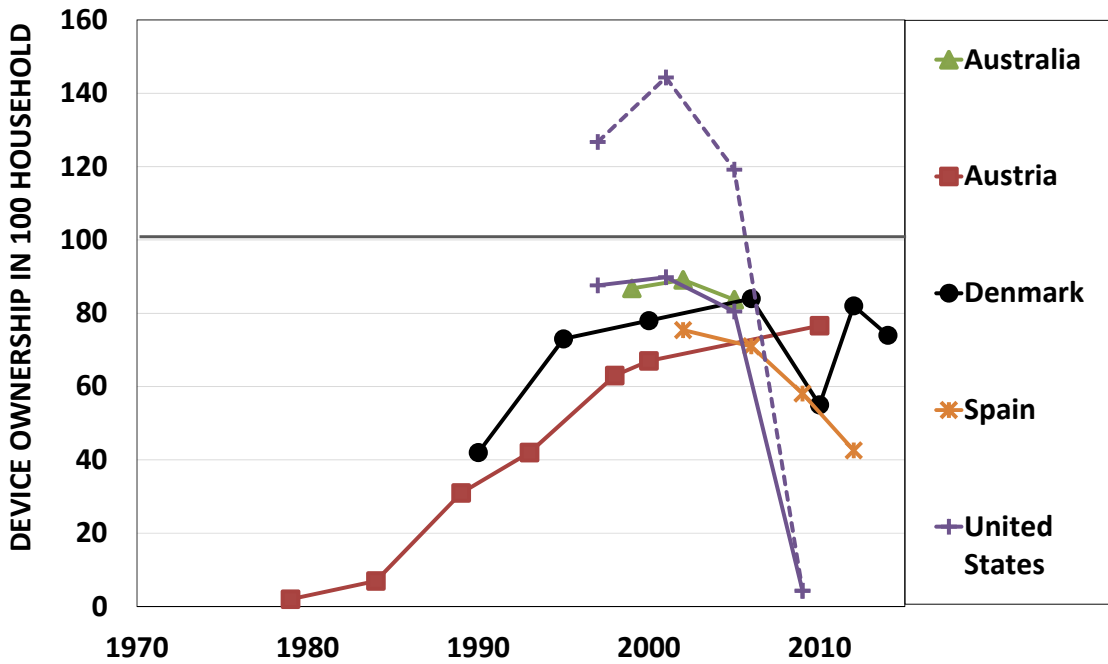


Figure 7. Video recorder ownership overview by country

Computer ownership represents the sharp increment in deployment of the new technology devices (Figure 9). Most countries show growths between 6-8% per year, being for Austria and Japan in the 80s and for USA, Austria and Denmark in the 90s. An exception is the case of Spain, which shows stagnation of 50% already reached in 2000.

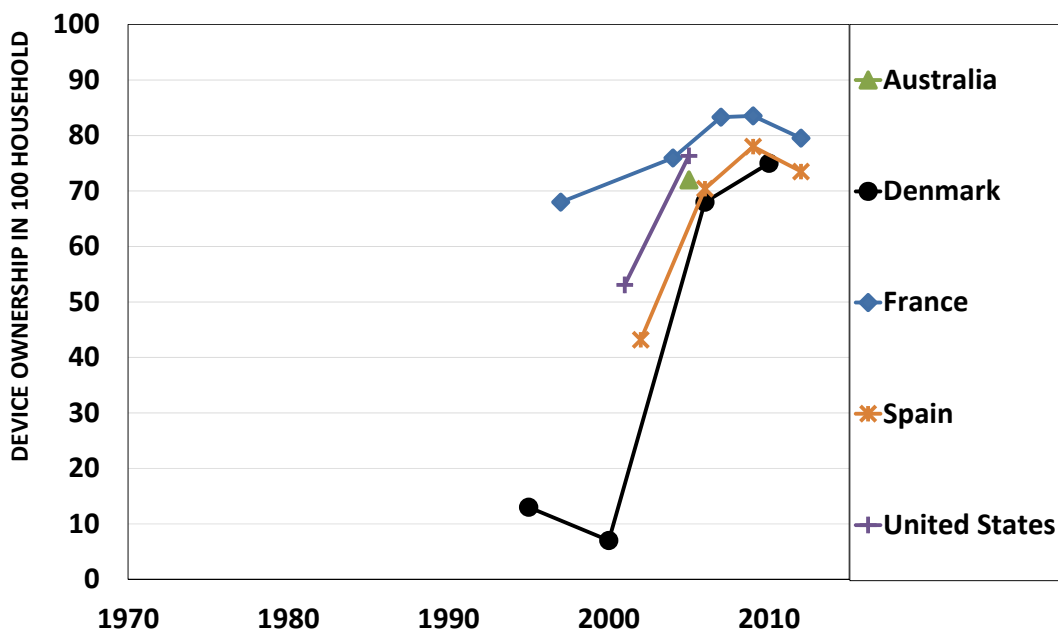


Figure 8. DVD Player ownership overview by country

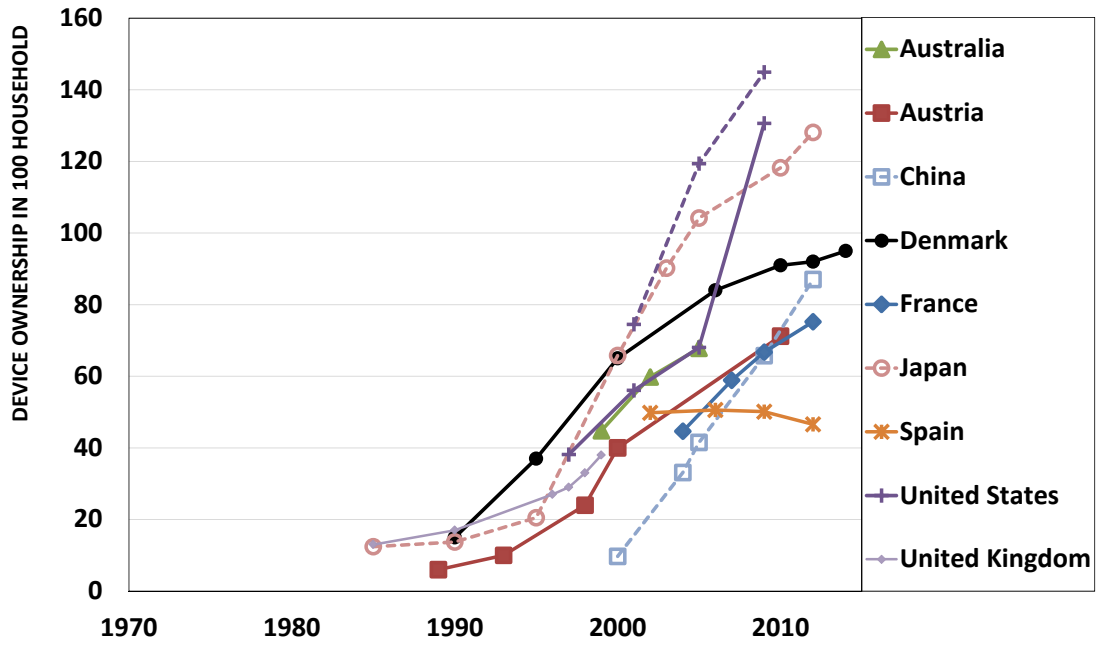


Figure 9. Computer ownership overview by country

Mobile phones substantiate this trend, showing growths up to 8% per year and with stagnations close to 96% for nearly all countries (Figure 10). As for computers, in Austria and Denmark the deployment was in the 90s.

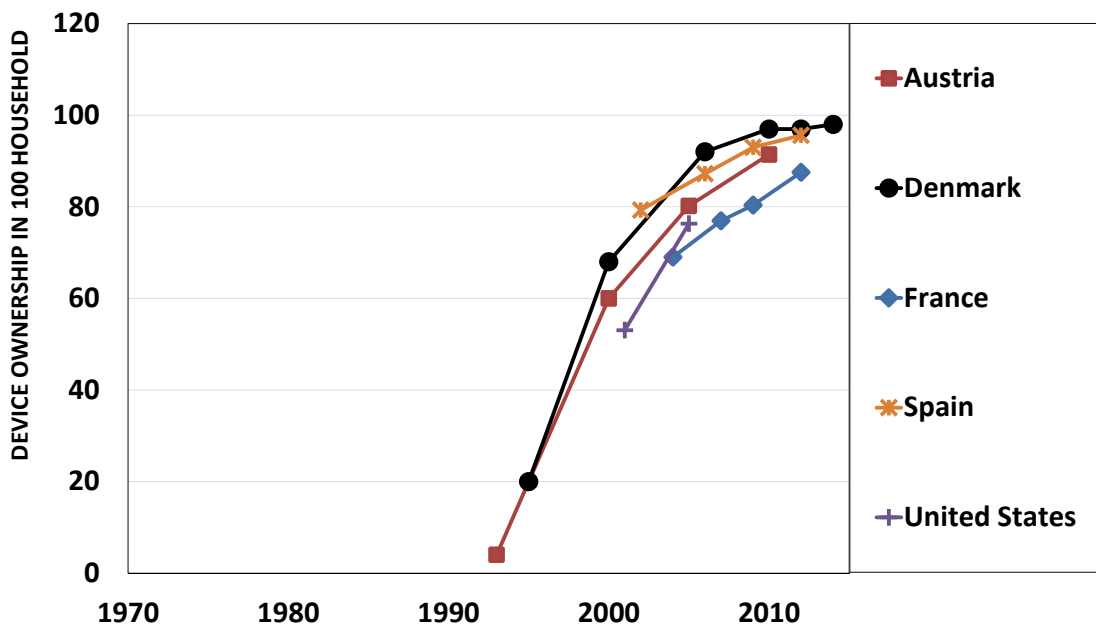


Figure 10. Mobile phone ownership overview by country

3.3. Small appliances

Figure 11 presents that microwaves emerged in the market in the early 90s and already before 1995 Australia and USA have nearly 100% ownership, showing the big market acceptance reached by these appliances. The European countries France, Denmark and United Kingdom also show rapid growth, about 3.5% per year.

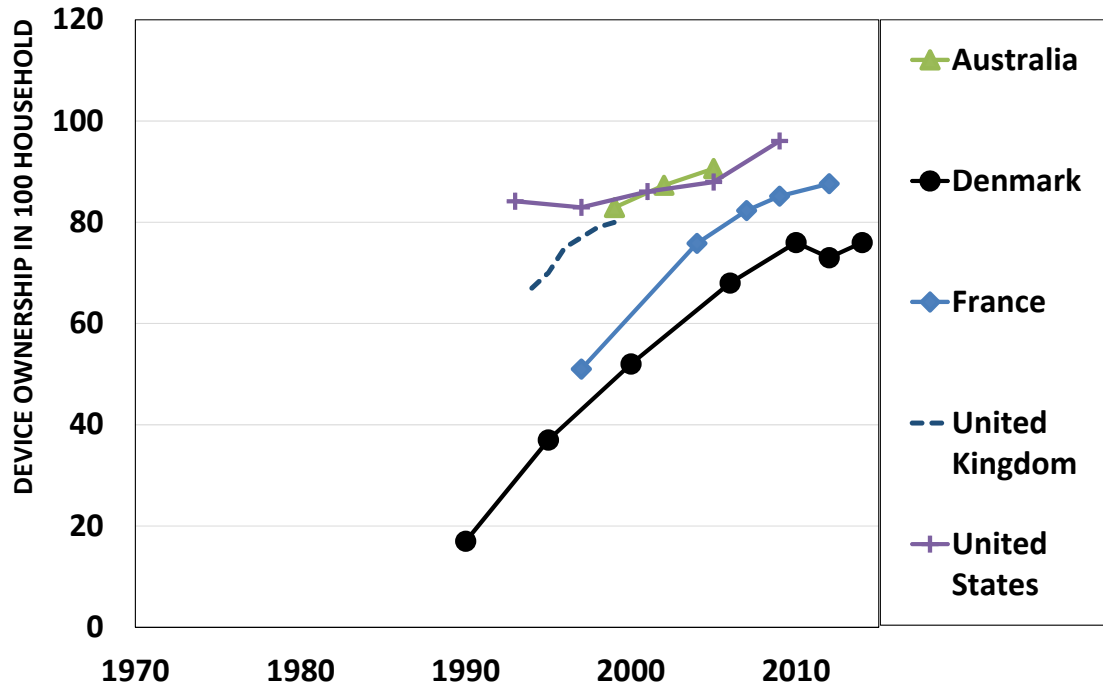


Figure 11. Microwave oven ownership overview by country

4. Conclusions

Studying ownership trends of appliances grouped them following the classification of white goods, brown goods and small appliances allow good comparison of the historic data obtained. Nevertheless, differences in statistical data collection and category definitions may have had importance on the comparison (for example, classification of combined freezer-refrigerators in different categories).

Refrigerators, freezers and washing machines ownership are an example of most other white goods. As expected, refrigerators ownership in Europe had reached saturation already in the 70s, and today show stagnation, similarly to washing machines (in stagnation since 2000); freezers show lower ownership. Other developed countries from other areas of the world (such as Japan and USA) show increasing ownership in refrigerators still today, and have ownerships higher

than 100% households. Interesting is that Australia refrigerators ownership is considerably lower than expected, in stagnation at about 40% since 1995. China's refrigerators ownership is also as expected, growing at the same rate as its GDP growth, and achieved full development of washing machines ownership in 20 years (1980-2000). Hungary ownership reflected the behaviour in food storage within communists countries. Finally, Spain, Australia and USA show little growth and low freezer ownership (maybe because refrigerators already have freezer).

Cloth dryers show a very different trend to other white goods, with no stagnation in any country, and with growth in all studied countries except Spain (probably due to the warm dry weather in most of the country). Finally, all countries have the same trend in dish washers ownership growth, around 1-2% per year; they all have very similar ownership values, except UK that is higher; none of them has achieved saturation.

Brown goods has an appearance in the market at very different time, in chronological order the considered ones are television (appearance 70-80s), Video recorders (appeared in 1980 and are already disappearing), computers (late 80s), and mobile phones (90s). Ownership growth is very different for each appliance in this group. Television and video recorders have already reached stagnation in many developed countries. Interesting is the growing ownership trends of television in China and Japan, being much higher than the European countries and USA, and the values of television ownership of Japan in 2000 (230%). On the other hand, new appliances such as computers and mobile phones show very good acceptance in the market, with very sharp slopes in ownership increase (around 6-8% per year).

Microwaves is a small line appliance that appeared in the market in early 90s and reached saturation in five years in Australia and USA, while European countries do not show saturation yet but show a rapid growth of about 3.5% per year.

The appliance trends penetration and/or ownership remarks the development stage of the countries and the time they expend to achieve appliances deployment and stagnation. This paper compiles for the first time all the information about appliance penetration and/or ownership in countries from around the world and presents an exhaustive analysis of its trends over time. Moreover, assessed data evidences the relation with the country economic development and cultural differences.

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