An investigation of the possible extent of the Re-spending Rebound Effect in the sphere of consumer products

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A key method used to reduce the environmental impact of a product is to make it more energy efficient. Previous studies have found that the potential benefits from improved efficiency are often at least partially negated by increased use of the product. This is called the 'rebound effect'. The logical extension of this theory is to consider what happens when efficiency savings from one product lead to the purchase of, or greater use of, another. This paper considers this issue, called the 're-spending effect', and uses the illustration of the purchase of an energy-efficient fridge-freezer and the installation of a high-efficiency domestic boiler to demonstrate the loss of up to 27% of the potential environmental benefit when monetary savings are spent on other products and services. The paper concludes that the development of high value, long-lasting, low resource-use products should be encouraged as a way of counteracting the 're-spending' effect thus producing an overall reduction in energy use and its attendant environmental damage.

Introduction

The 'rebound effect' in an environmental context has been discussed by a number of authors, (Greene et al. 1999; Haas et al. 1998; Radermacher 1996). Radermacher defines it as '*the subsequent erosion of the positive potential of technological innovation by increases in overall activities, and the concomitant increase in consumption of material and energy.*' The effect can be seen particularly clearly in products that have been made 'greener' by reducing their energy consumption during use.

Due to the pollution caused by power production, energy consumption in the *use* phase is often the greatest part of the environmental impact of a product. For example, when the PA Consulting Group carried out life-cycle analysis (LCA) on washing machines during the development of the European eco-labelling scheme, it was found that over ninety percent of the energy consumption occurred during the consumer's use of the product, with correspondingly high percentages of the air pollution and production of solid waste also happening at that stage (PA Consulting Group).

Over the past thirty years, the energy use of household appliances has been steadily decreasing with greater awareness of the importance of energy efficiency and innovations in technology. Logically, this would bring a general decrease in energy use, but overall household energy consumption for this period has actually risen (Wilting and Biesiot 1998). The 'rebound effect' goes some way to explaining this in describing how the effect of reducing energy use, and thus the cost of using a product, is often increased use of the product. For example, it has been shown that up to 20% of potential energy savings from improved fuel economy in cars are lost in increased travel (Greene et al. 1998). However in a study of the impact on electricity consumption of household appliances in Austria, Haas et al (1998) found that efficiency improvements correlate exactly with savings in electricity consumption (1% increase in efficiency = 1% reduction in electricity use) and therefore concluded that in this particular area the 'rebound effect' is very low. Therefore, although it may be a factor, this 'rebound effect' cannot be the only explanation for the continued rise in power consumption.

The general principal behind the 'rebound effect' is that by reducing a product's energy consumption, pollution and use of natural resources are also reduced, but less energy use means lower running costs which encourages greater use of the product, limiting the benefits that the energy reduction should have brought. However, if a user reduces costs by using a more energy efficient product, it is likely that as well as, or even instead of, increasing their use of that product, they will spend the saved money on other products or services which themselves may be significant users of energy. Thus the overall net effect of the production of the more energy efficient product on the total consumption of energy is limited. Haas et al. (1998) approach this idea when they state that one of the reasons for the continuing rise in energy consumption is the acquisition of new types of appliances.

Although the primary 'rebound effect' within one product has been described, quantified and discussed by many researchers, less work has been done to investigate the secondary rebound effects where benefits gained by improvements to one product or service are, at least in part, negated by increased use of another. This effect is mentioned by several authors (Berkhout et al. 2000; Greening et al. 2000; Sanne 2000; Binswanger 2001) including Schipper and Grubb (2000) who name it the 'Re-spending Effect'. Although the existence of the 're-spending effect' is thus well documented, there seems to be little quantitative investigation of its possible significance. It is expected that re-spending effects will, like most primary 'rebound effects', produce a rebound of less than 100% (because it is difficult to purchase anything more environmentally damaging – measured by the usual indicators – than energy) and thus they will never completely cancel out the original saving. To find whether the effect does have a significant impact on overall energy savings, its likely magnitude must be calculated.

In this paper we consider two case studies which examine the possible extent of the respending effect in the sphere of consumer products.

Method

By reducing energy consumption, improved efficiency appliances also save consumers money. We have seen how this leads to the primary 'rebound effect', however the 're-spending' effect describes what happens when this extra money is spent on another product or service. To be able to quantify the effect, we need to know how large the saving will be and how the consumer is likely to use the surplus money.

The magnitude of monetary saving can be found by comparing the energy use of a very efficient, 'A' model energy classification of a particular appliance with a lower rated one of a similar size and specification. The cost of the energy saved over the product's expected lifespan can then be calculated. A fridgefreezer and a heating boiler are used as examples because they are both in use for much of the time anyway and so improved energy efficiency is unlikely to lead to a change in usage. This means that their primary 'rebound effect' will be very small and so does not have to be considered in these calculations.

The degree of environmental benefit from the energy efficient model can also be found from the energy use. The energy saved by using the more efficient appliance is used to calculate the associated saving in carbon dioxide (CO_2) pollution. CO_2 production is used as an indicator of environmental impact because it is produced during all forms of energy generation involving fossil fuels and so allows comparisons between different sorts of power use.

Changes in buying behaviour due to fluctuations in prices are often described in terms of substitute products, goods or services that are considered to be economically interchangeable by buyers (Pass et al. 1988). Since there would seem to be no direct substitute products for energy supplies, it is necessary to examine more general expenditure patterns to find possible 'supplementary' products. The Family Expenditure Survey (reported annually in Family Spending) shows that, although actual consumption has increased over the past twenty years, expenditure on fuels and power has decreased, both as a percentage of overall expenditure and in actual money terms. This is due to significant reductions in energy prices over this period. Although we cannot yet see an overall decrease in energy usage from improved energy efficiency, spending patterns for the reduction in energy expenditure due to lowered prices can be used to predict patterns for a reduction in expenditure due to decreased consumption.

The Family Expenditure Survey shows, as a percentage of overall expenditure, a general reduction in spending on meeting basic needs (e.g., housing, food, energy and fuels), and a rise in spending on less essential and luxury products and services (e.g., personal goods and services, leisure services, household goods) over the past twenty years. It also shows that higher income households spend a similar or lower percentage of their income on meeting basic needs compared with lower income groups. These two observations indicate that a reduction in the cost of meeting a basic need, and thus a little surplus money, would lead to greater expenditure on less essential items.

The Family Expenditure Survey was used to identify particular examples of products on which expenditure would increase with a rise in income. A comparison between pairs of consecutive income groups in the Survey was used to analyse the effects on spending behaviour associated with an increase in disposable income. The survey shows that for wealthier groups, an increase in income leads to a greater percentage expenditure on clothing and footwear, household goods, and motoring. For lower income groups the same expenditure categories plus leisure services show a percentage increase. From within the three common general categories, specific commodities showing significant expenditure increases for both high and low income sectors were selected. From these commodities, which included outerwear, furniture, gas and electrical appliances, motor vehicles, and motor fuels, the specific examples of a household appliance and petrol were chosen. These particular products were chosen with the knowledge that they would have a significant environmental impact, measured by CO_2 emissions. As the intention of this paper is to show the possible extent of the 're-spending' effect, it was important to select the most environmentally damaging items from those shown by the analysis of consumer spending behaviour to be likely supplementary products.

A particular example of a household appliance as a supplementary product was found by examining ownership levels of various household products by different income groups. Some products are found in a large percentage of both low and high-income homes, indicating that they are viewed as essentials. For example, washing machines are owned by 99% of households in the ninth decile income group and 84% of those in the second decile group. However, for some products, lower overall ownership levels and significant differences in ownership by high and low income households indicates that they are seen as luxury items. The dishwasher is selected as an illustrative example because it is owned by a very small percentage of lower income households (5%) but a significant number (42%) of wealthier homes.

The energy use of the two chosen supplementary products, petrol and the dishwasher, was also calculated, and from this the associated CO_2 release found. The degree of 're-spending rebound' is calculated by comparing the saving in CO_2 from the use of the energy efficient appliance, with the extra CO_2 generated by the use of the supplementary product.

Case studies

Energy efficient fridge-freezer

Refrigerators and freezers, or combination fridge-freezers, are found in most households. Although their energy usage is fairly low, they are running constantly and so over their lifespan will probably consume more energy than higher drain appliances which are used only for short periods. This means that over a period of years, an energy efficient model will give a significant saving. Comparing a high efficiency (A) fridge-freezer with a lower rated (C) one of similar capacity and function over a lifetime of ten years (Cooper 1994) will give the total saving of energy and thus of money.

Annual fuel use of A rated appliance = 308 kWh
Annual fuel use of C rated appliance = 544 kWh
Lifetime fuel use of A rated appliance = 3,080 kWh
Lifetime fuel use of C rated appliance = 5,440 kWh
Fuel saving over lifetime = 2,360 kWh
Current cost = 6.38p per kWh
Fuel cost saving over lifetime = £150.57

The fuel saving is then used to calculate the amount of CO_2 released during the appliances' use.

Fuel saving over lifetime = 2,360 kWh = 8,496 MJ (1kWh = 3.6 MJ)
Assuming a power station efficiency of 33%, the amount of energy needed to provide that amount of electricity is 22,032 MJ.

Using the energy mix for British electricity generation (data for 1996/97) and taking into account energy intensity and carbon content of the various fuels, using the energy efficient appliance has saved the release of 1,645 kg of CO_2.

Although this is not always the case, in the comparison made here the A-rated model is a little more expensive than the C-rated one. The price difference between the two models is £30. Therefore, deducting £30 from the fuel cost saving gives the overall monetary saving:

Total monetary saving from more efficient fridge-freezer = £120.57

Because this is a relatively small monetary saving spread over ten years, the consumer is unlikely to spend the money on a single product but use it gradually in their normal expenditure. To illustrate the possible extent of the 'respending effect' in this case, the CO_2 release if the money was used to buy petrol will be calculated.

Average price of petrol = 73p per litre (including UK tax, October 2001 prices)
Amount of petrol bought by saving of £120.57 = 165.16 l = 0.165 m^3 = 116 kg
Assuming the fuel is completely burnt, 1kg of petrol will produce 3.09kg of CO_2, CO_2 produced from petrol = 358 kg

Condensing boiler

Heating the home uses 26% of the total domestic energy use (Wilting and Biesiot 1998).

Therefore, a significant reduction in this area of energy use would show a correspondingly large reduction in fuel bills. By fitting a condensing boiler instead of the more common non-condensing type, a large increase in efficiency can be achieved, meaning that the same amount of heat can be produced from less fuel at a lower cost.

Using actual gas bills from a house before and after the standard boiler (seasonal efficiency of around 70%) was replaced by a condensing type (seasonal efficiency of 92%) it is possible to calculate the amount and cost of the fuel used by each type and thus the savings from the greater efficiency model.

Average annual fuel use with standard boiler = 24,631 kWh
Average annual fuel use with condensing boiler = 15,606 kWh

Assuming the boilers are in use for ten years, the total fuel use and costs for their lifetime can be calculated. The total fuel use is then used to calculate the amount of CO_2 released during the boilers' use.

Total lifetime fuel use for standard boiler = 246,310 kWh
Total lifetime fuel use for condensing boiler = 156,060 kWh
Fuel saving over lifetime- = 90,250 kWh
Current cost = 1.278p per kWh
Fuel cost saving over lifetime = £1153.40

Assuming that all the gas supplied is burnt, producing CO_2 and water, an energy saving of 90,250 kWh from the replacement of the standard boiler with a condensing model will save the release of 15,595 kg of CO_2 into the atmosphere.

On average the purchase price of a condensing boiler is £400 more than a traditional model. Therefore, deducting £400 from the fuel cost saving gives the overall monetary saving:

Total monetary saving from boiler replacement = £753.40

The consumer is likely to then spend this saved money on other goods or services. Using the example of the purchase of a new domestic appliance, the possible environmental cost of this extra purchase can be calculated.

Half of the saved money would buy a new dishwasher, and the remaining half would pay for the cost of the electricity used to run it.

A mid-range dishwasher uses 1.64kWh per cycle. If it is used once a day, every day over a lifetime of ten years, the total energy used is 5,986 kwh, or 21,549.6 MJ (1 kWh = 3.6 MJ). Assuming a power station efficiency of 33%, 64,648.8 MJ of energy would be needed to provide that amount of electricity. Using the energy mix for British electricity generation (data for 1996/97) and taking into account energy intensity and carbon content of the various fuels, this causes the release of 4,172 kg of CO_2. (Energy used in manufacturing the dishwasher was not included in the calculation because, using the figures available (PA Consulting Group 1992), it would be impossible to know what fraction of the total came from what source and thus how much CO_2 was released. The energy consumption for the production phase is also very small in comparison to that of the use phase so its omission makes almost no difference to the final result.)

Results

Description	A rated appliance	C rated appliance
Annual fuel use	308 kWh	544 kWh
Lifetime fuel use*	3,080 kWh	5,440 kWh
Lifetime fuel saving*	2,040 kWh	
CO_2 saving	1,645 kg	
Monetary saving **	£120.37	

Table 1: Comparison between A and C rated fridge-freezers. *Lifetime is ten years ** Higher cost of A-rated appliance taken into account

Description	Condensing boiler	Standard boiler
Fuel use for one year	15,606 kWh	24,631 kWh
Lifetime fuel use*	156,060 kWh	246,310 kWh
Lifetime fuel saving*	90,250 kWh	
CO_2 saving	15,595 kg	
Monetary saving **	£703.76	

Table 2: Comparison between condensing and standard boiler. *Lifetime is ten years ** Higher cost of condensing boiler taken into account

CO_2 saved by use of 'A' rated fridgefreezer	CO_2 released by petrol	Rebound
1,645 kg	358 kg	22%
CO_2 saved by use of condensing boiler	**CO_2 released by use of dishwasher**	**Rebound**
15,595 kg	4,172 kg	27%

Table 3: Balance of CO_2 emissions

Conclusions

The calculations show that the purchase of a highly energy efficient fridge-freezer, 'A' energy rating, rather than a less efficient model, 'C' energy rating, can lead to a small but significant monetary saving from reduced electricity consumption over the product's lifetime. There is also a reduction in environmental impact, measured by the decrease in the CO_2 released.

It can also be seen that the replacement of a standard design boiler with a condensing model leads to considerable monetary savings and a sizeable reduction in CO_2 released. In this particular case, more than fifteen tonnes of CO_2 were saved from release into the atmosphere.

The two possible ways of spending the saved money considered here are shown to cause significant environmental impact, particularly the use of the dishwasher which in this example released four tonnes of CO_2. The use of savings from the more efficient fridge-freezer to buy petrol, and savings from the efficient boiler to purchase and run a dishwasher gave a re-spending rebound of 22% and 27%, respectively. As these two products were selected from the list of likely supplementary products for their relatively high environmental impact, this figure represents the upper end of the range of 're-spending rebound' that could be expected for domestic products. Since the choice of some supplementary products (for example insurance) would give a rebound of practically zero, a reasonable estimate of the possible range for the 'respending effect' in the domestic appliance sector would be 0–30% (with some exceptions exceeding that, for example spending all the savings from a reduction in consumption of one sort of energy on a cheaper energy type). These figures indicate that the 'respending effect' is significant and should be considered as a factor when evaluating energy efficiency.

Energy consumption during *use* is being reduced in many domestic appliances (Wilting and Biesiot 1998). As more energy-efficient products are bought to replace existing less efficient ones, the 're-spending effect' will become more widespread, partially negating the environmental benefits achieved by the reduction in energy use. If more efficient appliances are to lead to a reduction in overall energy use and the environmental damage associated with it, the 're-spending effect' must be countered. Although the most effective strategy for achieving this would also involve changes in legislation and in consumer thinking, the way products are designed, manufactured, and marketed also has a large part to play.

The degree of rebound caused by the 'respending effect' depends on how environmentally damaging the supplementary product or service is compared with the energy. This can be measured by environmental value (equal to cost/environmental impact). To minimise the 're-spending rebound', the money saved by the reduction in energy consumption must be spent on something with a higher environmental value than the energy. For the 're- spending effect' the cost component is constant, £x of energy replaced by £x of another commodity, so a higher environmental value must be achieved by reducing the ecoimpact. The lower the environmental impact, the higher the environmental value and the lower the respending rebound.

A very high environmental value can be achieved by *absorbing* the extra money without creating extra products or services. Where the monetary savings are fairly small, as with the fridge-freezer, it may be possible to add at least some of the estimated saving onto the price. This may mean 'adding (perceived) value' through the design of the product and its promotion to make the higher cost acceptable to consumers. The option to pay in instalments could be used to both obscure the higher price and encourage lower income groups to purchase the more energy efficient appliances. However, one important consideration for the 'increased-price' approach is whether it would be fair to penalise consumers who make environmentally friendly choices.

A higher purchase price would perhaps be more justifiable if it also included a service contract. This would mean that the manufacturer or supplier would have to have the infrastructure in place to deliver this, and that the product would have to be designed to facilitate repair. This option also has other environmental benefits in that it extends useful life, reducing waste and resource use.

If the savings from energy efficiency cannot be negated by an increase in price, other ways of using the money in an environmentally benign fashion must be considered. A move away from products and towards services is often environmentally beneficial as services generally, but not always, have a significantly lower environmental impact, and thus a higher environmental value, than the manufacture and use of products. The Family Expenditure Survey shows that percentage expenditure on 'leisure services' in particular increases with income. From an environmental perspective this is a positive trend as the services listed under this heading have, with the exception of 'holiday abroad' (due to associations with air travel), low environmental impacts. As there are services, particularly those related to travel and transport, which do have significant environmental effects, the best strategy is not to recommend expenditure on any service but to direct it to particular areas. For manufacturers this could take the form of the inclusion of a guarantee or service contract with a product.

Despite the increasing popularity of services, the consumer's impulse is often to spend extra money on a product. To minimise the 'respending rebound' from this tendency, consumers should be encouraged to buy products with as high an environmental value as possible. This requires manufacturers to produce goods with a high purchase price relative to the environmental impact caused by their production, use, and disposal. Some examples of this type of approach would be information-based products where little material is used, and thus few natural resources, and the value comes from the knowledge contained or the experience undergone; designer goods where a price far higher than the value of the materials is justified by the name and styling; long-life products (such as those referred to as 'tomorrow's antiques'), where a high price is acceptable because the item will last a long time and increase in value, and the environmental impact is less than for a similar 'ordinary' product because disposal is not a consideration. The concept of low cost, low material content, high perceived value products is well known to product designers, but they should be made aware of this as an environmental as well as economic strategy.

It has been shown that the 're-spending rebound effect' can be a significant factor in determining the overall environmental benefit achieved by improvements in the energy efficiency of household appliances. If the potential environmental savings from these improvements are to be fully realised, this and the other associated 'rebound effects' must be countered. The part that product designers and manufacturers could play in this has been discussed, with product/service packages and high environmental value products highlighted as particular strategies which would address the re-spending effect.

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