# Rebound effects from climate policies

***DRAFT***

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# Abstract

This paper examines the neglected area of rebound effects from government policies to reduce greenhouse gas emissions. A series of case studies including environmental taxes, subsidies, household adoption of photovoltaic electricity generation, and the role of general government taxation and transfers, are presented to demonstrate how rebound effects occur in the policy context. The results suggest that rebound effects can be significant and should be anticipated by policy makers. For example, the estimated greenhouse gas rebound for carbon taxes is between 11 and 32%. The results also suggest the possibility of negative rebound effects, which may amplify the expected environmental benefits, in cases where significant costs are incurred to reduce greenhouse gas emissions.

# Keywords

Rebound effect, greenhouse gas emissions, climate policy, environmental policy.

**JEL Classification:** D11, D12, Q31, Q38, Q48, Q40

# Introduction

Environmental disamenity, whether in the form of climate change or land degradation, is a concern for individuals and governments worldwide (cite Kyoto, Rio, EU, Copenhagen). Determining an appropriate policy response to environmental externalities requires an understanding of the economic flow-on effects, or rebound effects, to estimate the economy-wide net environmental benefits. Such effects are often ignored. This paper estimates the rebound effect from a number of proposed policies targeting reductions in greenhouse gas emissions.

If the economy is suitably defined as a system producing final goods and services consumed by households, each consumption item will have embodied in its production, a multitude of resource inputs and some environmental externalities. This is the approach of life cycle analysis (LCA) (insert reference), which estimates the embodied resources and externalities of consumer goods.

Rebound effects occur from environmental policy, such as taxes and subsidies, when purchasing power is transferred between government and households or vice-versa, to be subsequently spent on final goods produced in the economy. For example, a carbon tax on greenhouse gas emissions will shift purchasing power from households to government. If the government maintains a revenue neutral position and reduces other taxes, this further increases household purchasing power, offsetting some of the environmental benefits of the carbon tax.

These approaches to environmental policy are characterised as demand side measures, which rely on consumer (and producer) responses to prices, or simply moral suasion, in the hope of shift in the composition of consumption patterns activity away from polluting consumables. Alternatively, supply side measures include regulations such as minimum environmental standards, cap and trade schemes, or hypothetically, limitations on fossil fuel extraction.

There are many examples of the push to change consumption patterns (OECD 1992 and 2002). The ‘reduce, reuse, recycle’ mantra encapsulates the moral suasion efforts of governments and environmental groups to promote consumption pattern changes (2007a; 2007b; 2007; 2008c; 2008b). Underlying these messages is the principle that if every person just took a few small actions, they would add to very large environmental benefits. Such thinking ignores rebound effects.

Examples of the more blunt economic instruments include the Australian government’s current subsidises for domestic photovoltaic (PV) panels (2008d), and the introduction of carbon taxes in Sweden, Netherlands and France (insert reference). Often mistaken as a supply side measure, the installation of domestic PV panels is simply a change in consumption patterns away from coal-fired electricity, and towards other final goods. Additionally, the subsidy scheme results in a substitution of government consumption for household consumption. Considering the impact of these effects may greatly change the estimated environmental benefits.

Many authors postulate that recycling environmental tax revenues to reduce distortionary taxes, such as income taxes, enables the realisation of a ‘double dividend’ due to improved efficiency from environmental taxes (Bovenberg and de Mooij, 1994; Ekins, 2000; Manresa and Sancho, 2005; Bento and Jacobsen, 2007; Lawn, 2007). Incorporating the government sector into rebound effect analysis will provide insights into the potential for this second efficiency dividend.

From an international perspective, both supply and demand side environmental policy measures face significant political challenges when dealing with global environmental issues. Supply side approaches that restrict resource use may raise prices in international markets and encourage the exploitation of marginal resource deposits abroad, provided substitute resources remain more expensive (Alcott, 2008). One could imagine such a situation if Australia regulated the production volume of coal. Demand side approaches on the other hand will provide incentives for producers to seek customers abroad, unless bound be trade restrictions or treaties (Alcott, 2008). The net effect of single country’s actions cannot be known.

Even the measurement of the greenhouse emissions of a single country is debatable. Ghertner and Fripp (2007) calculated the displaced emissions of US consumption patterns by adopting a consumption side approach rather than a production side approach. They show that in 2004, under an assumption of equivalent emissions per unit of production of imports, there is an 8% increase in CO2, a 7.2% increase in energy, an 8.8% increase in sulphur dioxide, and a 29% increase in lead pollutants, compared with a production based approach. This highlights the importance of taking a consumption side approach to first determining responsibility, and second, evaluating environmental policies.

Given these issues, this paper explores the possible rebound effects and subsequently, the net environmental benefit, of a number of demand side policies using Australian LCA data.

# The rebound effect from expenditure reallocation

Data on household and government expenditure, along with the corresponding LCA data of the resource intensity of the resource of concern can be used to estimate the magnitude of this rebound effect.

The household consumption data used in this study is the 2003-4 Australian Bureau of Statistics (ABS) Household Expenditure Survey (HES), aggregated into 36 commodity groups (ABS, 2004). The corresponding embodied greenhouse gas emissions for each commodity group, calculated using an input-output based hybrid method, was sourced from the Centre for Integrated Sustainability Analysis, Sydney, and is shown in Appendix B (Dey, 2008).

Also data from Lenzen and Dey (2002) on government consumption.

Computing LCA data requires accounting for resources embodied in imports and exports, and provides adjustment for this, eliminating a trade explanation for any observed trends in resource intensity.

Combining the two data sets clearly shows decreasing emissions intensity, but increasing quantity of emissions, with increasing household expenditure (Figure 2). This corresponds well with the macroeconomic relationship between energy and greenhouse emissions and gross domestic product (GDP) commonly observed, and also other household emissions studies (Holtz-Eakin and Selden, 1995; Schipper and Grubb, 2000; Greening, 2001; Lenzen et al., 2004). This data provides no evidence to suggest an EKC for household greenhouse gas emissions within Australia using a consumption side approach.

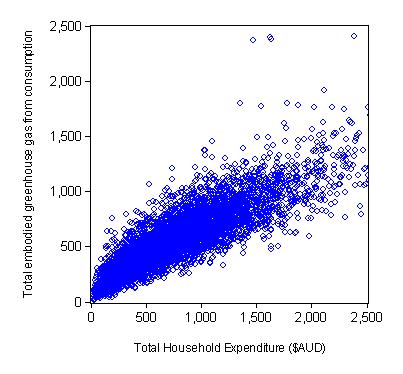


Figure 1. Total household greenhouse gas emissions embodied in consumption.

Modelling the rebound effect is based on a system household demand equations where expenditure on each of the commodity groups in the data is dependent on household income level.[[1]](#footnote-1) Housing expenditure is removed from this system, and it is assumed that changes to consumption patterns do not affect the savings rate.[[2]](#footnote-2)

Selection of a functional form of the household demand system requires the ability to assess the potential variation in the rebound effect at different income levels, and as such, the system should comply with the following criteria;

* the possibility of threshold or saturation levels,[[3]](#footnote-3)
* the adding up criterion,[[4]](#footnote-4) and
* the best representation of the data.

Two variations of the double semi-log (DSL) functional form[[5]](#footnote-5) are used in this study. One of these regressions contains dummy variables of age of household reference person, *A*, number of persons in the household, *N*, state, S, degree of urbanity, *U*, and dwelling type, *D*, each of which have been previously shown to have an impact on household emissions (Lenzen et al., 2004; Vringer et al., 2007). For completeness a linear and Working-Leser functional form are also used. By estimating the rebound effect based on these four functional forms of the household demand system enables the sensitivity of rebound effect estimation to the choice of functional form to be examined.

The first version of the DSL form retains only total expenditure, *X*, and the log of total expenditure as the independent variables, so that the functional form for expenditure on each *i* commodity is:

(2)

The second DSL model (DSL2) has the functional form

The linear form is the simplest, but does not allow for threshold or saturation levels. The functional form is:

(3)

At all levels of total expenditure the linear and both DSL models satisfies the adding-up criterion when

Finally, the Working-Leser (WL) model relates budget shares, rather than expenditure, linearly with the logarithm of total expenditure. The budget share, *w,* of each *i* commodity is calculated by

(4)

Then the relationship

(5)

is estimated. This model also satisfies the adding up criterion automatically using least squares estimation equation by equation, and is true when

The functional from of the Engel curve from the WL model is then determined by substituting equation (4) into (5) as follows.

(6)

Appendices C through F shows the results of the regressions for each demand equation of the four demand models used in this study. In both DSL models, Whites heteroskedasticity consistent method of calculating standard errors and covariance is used. For the linear and WL model, ordinary least squares are used with no further statistical adjustment. The standard errors and significance levels for some of the independent variables in each DSL model are often quite high. It is expected that not every commodity group is significantly determined by each of the variables, but it is important to note that total expenditure is significant for every commodity group. This validates to some degree the income determinism assumption underpinning these models. The significance levels observed for the extra explanatory variables in most the DSL2 model also provides evidence that these factors determine expenditure patterns to a fair degree. In the domestic fuel and power and vehicle fuel commodity groups, all of these variables are significant in explaining the expenditure levels, apart from degree of urbanity for domestic fuel and power.

Most other results follow intuitive logic. For meals out, intuition would suggest that urbanity would be a significant factor, as rural household have less option for take away foods. Dwelling type is also significant, and may also partly reflect urbanity, with apartment dwellers more likely to dine out, due to both location factors, and factors such as kitchen size and facilities.

Because the cost savings from consumption pattern changes will be re-spent at the margins rather than at the average expenditure pattern of the household, the rebound model is based on the marginal budget share (MBS) of each commodity. The MBS is the derivative of the demand function for each commodity with respect to the total expenditure. If the system of demand equations satisfies the adding-up criterion, then for all *i* commodity groups,

The interpretation of the MBS is that it is the amount of extra expenditure on commodity *i* for an increase in total expenditure of one dollar.

For each of the functional forms used in this study, the MBS for each commodity is as follows:

DSL/2 - (7)

Linear - (8)

WL - (9)

The rebound model developed from these results ensures there is no increase in expenditure on the commodity from which savings have been made. A model of this type has not been assessed in the literature. This type of model is labelled as ‘conservation’ and can be described as a shift in utility away from consumption a good with high embodied environmental costs. In this case savings are treated as an increase in income, and are allocated amongst all other commodities in the household consumption basked based on their estimated income elasticity.

*Efficiency case Conservation case*

Other consumption

Utility2

Passenger kilometres

Utility1

Other consumption

Utility2`

Passenger kilometres

Utility2

Utility1`

Utility1

Figure 2. Theoretical contrast between ‘efficient’ and ‘conservation’ consumption patterns.

In the conservation model, if the cost savings are denoted *Y*, then for the commodity *S* from which the savings are made, the new expenditure level is

(10)

but for all other *i* commodities the new expenditure level must account for the fact that no re-spending takes place on commodity *s*, and therefore is calculated by,

(11)

To estimate the change in greenhouse gas emissions from the change in consumption patterns, the expenditure in each commodity group is multiplied by the greenhouse gas intensity of that commodity. Since there are no technology changed applicable to production stages of the economy, the same embodied emissions data may be used in both the before and after scenario.

If the overall embodiment of resource *f,* for category *i*, is *Rf, i*, then the total embodiment of *f* for all consumption is

(14)

The potential savings are calculated as *Y* multiplied by the embodied factor *Rf* for commodity *s.* The rebound effect for resource *f* can then be expressed as a percentage of the potential resource savings, as

(15)

which can be simplified to

(16)

Importantly, in this model the rebound effect is simply a function of the total expenditure level. Comparing the scale of the rebound effect at different levels of total household expenditure will provide insights into the effectiveness of conservation measures at different income levels.

# Cases

#### 4.1 Win-lose photovoltaic panel case

Rebound effect theory can be applied to any case of consumption pattern changes. Of particular interest is domestic electricity generation with photovoltaic (PV) panels. This interest is due to the common perception that this type of energy generation is a supply side solution. In reality however, an increase in the adoption of PV panels by household will not change any production techniques upstream of the household and is best modelled as a household consumption pattern change.

There are a number of assumptions required to calculate the rebound effect from domestic photovoltaic panels. These include the greenhouse emissions intensity of the device (including installation and accessories), the energy output of the device, and the cost of the panels.

Without existing LCA data for the purchase of domestic scale photovoltaic panels in terms of CO2-e/$, it is necessary to establish the energy intensity of the device by other means. Much of the literature on the emissions intensity is calculated on a per kilowatt-hour (kWh) basis, rather than a per-dollar of cost basis, simply because of the variation in price across countries and regions. By starting with this information, and coupling it with local costs and expected output, one can achieve an estimate of the greenhouse gas emissions intensity on a per-dollar basis.

For mono-silicon crystal photovoltaic panels, Lenzen et al. (2006) summarise much of the existing literature, and find that estimates of the greenhouse emissions intensity for domestic scale PV panels range from 50-200g CO2-e/kWh. Sharp NU-R5E3Z panels retail for $33,400, and have an estimated annual output of 5,830kWh and a 25 year expected lifetime (Clifford, 2008). Table 2 shows how combining the estimates of greenhouse emissions intensity[[6]](#footnote-6) for domestic scale PV panels with the output and cost estimates, gives an estimate of the emissions intensity of domestic solar electricity of between 0.211 and 0.873kg CO2-e/$. While the variation in the resulting estimates of emissions intensity for PV panels is substantial, the data remains useful for demonstrating the indirect rebound effect in this case.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Emissions intensity of output (kg CO2-e/kWh) | Lifetime energy output (kWh) | Total emissions for device (kg CO2-e) | Price ($) | Emissions intensity (kg CO2-e/$) |
| 0.05 | 145,750 | 7,388 | 33,400 | 0.221 |
| 0.15 | 145,750 | 21,860 | 33,400 | 0.655 |
| 0.20 | 145,750 | 29,150 | 33,400 | 0.873 |

Table 1. Greenhouse gas emissions intensity calculation for domestic photovoltaic panels.

A low income household is unlikely to purchase PV panels at this price regardless of their environmental concern. It is assumed for this case that a household with $1500 per week non-housing expenditure will purchase the panels. Additionally, it is assumed that it takes the household two years to save the money to buy the panels, and the electricity price is $0.17/kWh over the whole life of the panels. The use of static LCA data requires static prices and technology over the period of the case study. [[7]](#footnote-7) This leaves the situation where for the two year saving period the household consumption pattern is equivalent to that of a household with total expenditure of $1,180 per week plus the panel purchase. After this saving period their consumption pattern is reflective of a rebound from a $19 per week reduction in electricity consumption at the same total expenditure level of $1500 per week.

The theoretically appropriate baseline potential emissions reductions are calculated net of the embodied emissions of the panel itself. Using this baseline, the indirect rebound effect due for this case with each assumption of panel emissions intensity is presented in Table 3*.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GHG intensity (kgCO2-e/$) | DSL | DSL2 | WL | Linear |
| *(0.221)* | -18.1% | -9.3% | 0.8% | -3.6% |
| *(0.655)* | -19.7% | -10.2% | 0.9% | -4.0% |
| *(0.873)* | -20.6% | -10.7% | 0.9% | -4.2% |

Table 2. Rebound effects from domestic photovoltaic electricity generation

Interestingly, in this win-lose case there is strong evidence for negative rebound effects. In such consumption pattern changes, the capital cost of the PV panels themselves outweighs the $19 per week gain from avoided electricity costs. In fact, around $10,000 more than the expected cost reductions are spent on the panel over the 27year period. That means that $10,000 of consumption elsewhere has to be sacrificed. If the greenhouse intensity of this consumption is more than that of the panels themselves, the rebound is negative. Following this logic, the cheaper PV panels become compared to existing fossil fuelled electricity sources, due to improvements in technology and production processes, the less effective they will be at reducing emissions due to higher indirect rebound effects.

The variation between model results is due to the marginal budget share of electricity and other commodities. For example, in the WL model, domestic fuel and power is an inferior good at a household expenditure level of $1500 per week. This means the marginal budget share of greenhouse gas emissions is very low, since the there is a negative contribution by the highest intensity commodity, electricity. When this very low intensity consumption is offset by the panel purchase, this results in a positive rebound effect.

#### 4.2 Government taxation and transfer system

Government spending also entails environmental costs from resource consumption and through negative environmental externalities such as greenhouse gas emissions. The government’s role in redistribution of wealth through taxation and transfer payments will have environmental consequences due to variation in the emissions intensity of households at different income levels, and for different government spending options.

Taking two levels of total household expenditure, one much higher than the mean and one much lower, can demonstrate how rebound effects appear from government taxation and transfer payments. Table 4 shows the marginal greenhouse gas intensity of expenditure for each of the household demand models at both the $1500/week and $250/week total household expenditure level. The final column shows that a transfer of funds from (A) to (B) will increase the greenhouse emission from consumption of the two households together by between 0 and 0.53kg CO2-e/$ of the transfer amount. This transfer may take the form of taxes and welfare payments facilitated by government agencies.

|  |  |  |  |
| --- | --- | --- | --- |
| Household demand model | Marginal GHG intensity of expenditure (kg CO2-e/$) | | Greenhouse gas rebound from transfer (kg CO2-e/$) |
| *At $1500/week (A)* | *At $250/week (B)* |
| *DSL* | *0.46* | *0.71* | *0.25* |
| *DSL2* | *0.44* | *0.60* | *0.16* |
| *WL* | *0.26* | *0.79* | *0.53* |
| *Linear* | *0.50* | *0.50* | *0.00* |

Table 3. Rebound effect from transfer payments between households.

Under the assumptions in this paper, progressive taxation and welfare payments to low income households will have an impact on greenhouse gas emissions, by transferring purchasing power to household with high marginal emissions intensity of consumption. This politically sensitive issue should be considered when determining environmental policies.

#### 4.3 Environmental taxes

With the recent popularity of environmental taxes as a way to correct for environmental externalities, one needs to address the potential magnitude of rebound effects of such taxes. For example, Brannlund et al. (2007) calculate that to curb increases in carbon emissions due to efficient technology change in Sweden, the carbon tax needs to be raised substantially.[[8]](#footnote-8) When the taxes raised are spent by governments, or used to reduce taxes elsewhere, they generate rebound effects. If a revenue neutral position is maintained after the introduction of such taxes, which many author believe can lead to a ‘double dividend’, the net effect is to encourage household consumption pattern changes, since real incomes should remain constant (Bovenberg and de Mooij, 1994; Ekins, 2000; Manresa and Sancho, 2005; Bento and Jacobsen, 2007; Lawn, 2007). Some authors however have found an intrinsic trade-off between the benefits of the first dividend, that of pollution reduction, and the second dividend from improved economic efficiency are being raised (Ekins, 2000; Bento and Jacobsen, 2007). Analysing the indirect rebound effect from a carbon tax can demonstrate why this trade-off occurs.

A simple example of the introduction of a carbon tax in Australia using the data at hand can be used to demonstrate this trade-off. The greenhouse gas emissions embodied in the consumption of the average Australian household is 27.76 tonnes per annum.[[9]](#footnote-9) If unitary price elasticity is assumed for all commodities, and a carbon tax of $AUD45 per tonne[[10]](#footnote-10), which is captured in final goods in proportion to the embodied greenhouse gas emissions, taxes raised amount to $1250 per annum for the average household. This corresponds to a reduction of embodied carbon emissions of 4.16 tonnes for the average household. If this tax revenue is then simply returned to individuals through income tax reductions, then expenditure will rise in proportion. In the case of unitary income elasticities for all commodities at the new prices, this will increase household consumption to the point where an extra 818kg of carbon emissions are produced by the average household, leaving a 3.34 tonne net reduction in greenhouse gas emissions. This equates to an indirect rebound effect of 20%.

Instead of assuming unitary income elasticity, using the MBS of the DSL2 model at the mean expenditure level for the ‘before carbon tax’ consumption pattern, even at the new after tax prices, gives a 552kg increase in carbon emissions, or a 13% indirect rebound effect.

An alternative option is for environmental tax revenues to be added to existing government expenditure. Referring to Table 5, the greenhouse gas intensity of government expenditure ranges from 0.33 to 0.97kgCO2-e/$. Given the $1250 per annum taxes raised from the average household, this can result in between 363 and 1,068kgCO2-e of greenhouse gas emissions, or a potential magnitude of rebound effects between 11 and 32%. This is quite a dramatic reduction in the environmental effectiveness of such taxes, and demonstrates how the trade-off between first and second dividends from environmental taxation occurs. This finding also supports the work of Brannlund and Nordstrom (2004), who model the distributional effects of recycling tax revenue, and raise that after recycling carbon taxes, the environmental benefit in terms of reduced carbon dioxide emissions is not clear cut due to increased household consumption.

|  |  |  |  |
| --- | --- | --- | --- |
|  | *Factor intensity* | | |
|  | *Greenhouse gases (kg CO2-e/$)* | *Energy (MJ/$)* | *Labour (emp-h/$)* |
| *Government administration* | 0.70 | 6.62 | 0.036 |
| *Defence* | 0.97 | 10.27 | 0.032 |
| *Education* | 0.39 | 3.87 | 0.042 |
| *Health* | 0.33 | 3.35 | 0.036 |
| *Libraries, parks and the arts* | 0.56 | 5.27 | 0.053 |

Table 4. Production factor intensities of government spending options, and marginal intensities for three household income levels based on 1993-4 data. Source: Lenzen and Dey(2002)*.*

The crux of the environmental taxation debate concerns the abatement costs of pollution. For such a tax to be more effective and avoid a rebound effect, it must be applied at a rate that is higher than the abatement cost of pollution, or the cost of substitute resource inputs. At a lower rate, the tax will not provide incentive for the adaption of pollution capturing technologies. Production processes will remain at existing pollution and resource intensities. Yet the evidence for the scale of environmental gains from changes to consumption patterns alone show little scope for large reductions to carbon emissions (Lenzen and Dey, 2002; Alfredsson, 2004). At a tax rate above the abatement cost, the profit maximising position for firms is to adopt cleaner but more expensive production techniques. This change to production techniques may provide substantial environmental benefits. Direct emissions standards are an alternative way to enforce the adoption of cleaner production technologies.

#### 4.4 Subsidies

The Australian government offers an $AUD 8,000 subsidy to households for the purchase PV panels (2008d). To subsidise the purchase cost of the panels, the government must allocate funds from elsewhere, by either raising taxes or reducing other spending. As seen in Tables 5 and 6, government spending on administration and defence typically has a higher greenhouse gas intensity than the marginal consumption pattern of households at all income levels, whereas spending on education and health has comparable intensities to high income households. Thus if government spending on defence is reduced to provide the subsidy, the maximum environmental benefit is gained, and negative indirect rebound effect would result.

# Discussion and conclusion

The focus of this paper was an examination of the rebound effects from consumption pattern changes with fixed technology. By first establishing the theoretical basis for each component of the rebound effect, insights into the scale and relationship of these effects have been gained, in particular:

1. Conservation measures have a lower rebound effect are more effective than those with efficiency elements.
2. Combining conservation measures increases their effectiveness beyond a straight addition, while combining efficiency measures decreases their effectiveness.
3. There is a trade-off between direct and indirect effects. Therefore estimates of a small direct effect from an action may be entirely misleading.
4. Associated cost savings reduce the effectiveness of pro-environmental behaviour, as shown in the vehicle fuel case.
5. Higher income households have lower total rebound effects, but relatively higher indirect effects.
6. Win-lose actions may result in negative rebound effects.
7. Due to variation in the MBS of greenhouse gas emissions of households at different income levels, a progressive tax structure, and low income welfare payments will increase greenhouse gas emissions.
8. Environmental taxes will offset the intended environmental benefits when spend by governments or used to reduce other taxes.
9. The choice of household demand model in rebound effect estimation is only important at the extreme high and low household income levels. All models provide close results at the mean household income level.

Regarding the economy-environment debate, these findings point to the ineffectiveness of win-win measures in comparison to win-lose measures, where negative rebound effect may occur. The potential for a ‘double dividend’ from environmental taxes is demonstrated to come at a substantial cost to the intended environmental dividend. For policy makers, these findings point to the limited effectiveness of DSM, and caution the methods for estimating their greenhouse gas reduction potential.

# References

2007a. *Be climate clever.* Australian Government, Canberra ACT.

2007b. *The Green Home Guide*, Southern Queensland Edition. Australian Conservation Foundation.

2008a. ECX EUA Futures Contract. European Climate Exchange. [Accessed 12th July 2008], Avaliable from <http://www.europeanclimateexchange.com/default_flash.asp>.

2008b. Reduce, reuse, recycle. Queensland government. [Accessed 7th July 2008], Avaliable from <http://www.epa.qld.gov.au/environmental_management/waste/waste_minimisation/reduce_reuse_recycle/>.

2008c. Reduce/reuse/recycle. Australian Government. [Accessed 7th July 2008], Avaliable from <http://www.environment.gov.au/land/vegetation/reuse.html>.

2008d. Solar homes and communities plan. Department of the Environment, Water, Heritage and the Arts. Australian Government. [Accessed 31st July 2008], Avaliable from <http://www.environment.gov.au/settlements/renewable/pv/index.html>.

ABS, 2004. *Household Expenditure Survey*, Household expenditure survey and survey of income and housing. Expanded CURF. Australian Bureau of Statistics, Canberra.

AGO, 2007. *Global Warming - Cool it!* . Department of Environment and Water Resources - Australian Greenhouse Office, Canberra.

Alcott, B., 2008. The sufficiency strategy: Would rich-world frugality lower environmental impact? *Ecological Economics* 64, 770-786.

Alfredsson, E.C., 2004. "Green" consumption--no solution for climate change. *Energy* 29, 513-524.

Bento, A.M., Jacobsen, M., 2007. Ricardian rents, environmental policy and the `double-dividend' hypothesis. *Journal of Environmental Economics and Management* 53, 17-31.

Bovenberg, A.L., de Mooij, R.A., 1994. Environmental levies and distortionary taxation. *The American Economic Review* 84, 1085.

Brannlund, R., Ghalwash, T., Nordstrom, J., 2007. Increased energy efficiency and the rebound effect: Effects on consumption and emissions. *Energy Economics* 29, 1-17.

Brannlund, R., Nordstrom, J., 2004. Carbon tax simulations using a household demand model. *European Economic Review* 48, 211-233.

Clifford, D., 2008. *Manager, Energy efficient projects.* Energex, Brisbane.

Deaton, A., Muellbauer, J., 1980. Economics and consumer behaviour. Cambridge University Press, Melbourne.

Dey, C., 2008. *Embodied energy of 2003-4 ABS HES commodity groups.* Centre for Integrated Sustainability Analysis, Sydney.

Ekins, P., 2000. Economic Growth and Environmental Sustainability. Routledge, New York.

Ghertner, D.A., Fripp, M., 2007. Trading away damage: Quantifying environmental leakage through consumption-based, life-cycle analysis. *Ecological Economics* 63, 563-577.

Haque, M.O., 2005. Income elasticity and economic development: Methods and applications. Springer, Dordrecht.

Lawn, P., 2007. Frontier issues in ecological economics. Edward Elgar, Cheltenham.

Lenzen, M., Dey, C., Foran, B., 2004. Energy requirements of Sydney households. *Ecological Economics* 49, 375-399.

Lenzen, M., Dey, C., Hardy, C., Bilek, M., 2006. *Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia*. Centre for Integrated Sustainability Analysis - University of Sydney, Sydney.

Lenzen, M., Dey, C.J., 2002. Economic, energy and greenhouse emissions impacts of some consumer choice, technology and government outlay options. *Energy Economics* 24, 377-403.

Manresa, A., Sancho, F., 2005. Implementing a double dividend: recycling ecotaxes towards lower labour taxes. *Energy Policy* 33, 1577-1585.

Vringer, K., Aalbers, T., Blok, K., 2007. Household energy requirement and value patterns. *Energy Policy* 35, 553-566.

Appendix B: Life cycle greenhouse emissions data at detailed commodity group level, using IO hybrid method.

|  |  |  |
| --- | --- | --- |
| Broad commodity group | Detailed commodity group | Life cycle Greenhouse gas intensity (kg CO2-e/$) |
| Domestic fuel and power | Domestic fuel and power | 7.333 |
| Food and non-alcoholic beverages | Bakery products | 0.403 |
| Condiments | 0.444 |
| Dairy products | 1.162 |
| Fish | 0.507 |
| Fruit and nuts | 0.391 |
| Meals out | 0.394 |
| Meat | 1.709 |
| Non-alcoholic beverages | 0.281 |
| Vegetables | 0.398 |
| Alcoholic beverages | Alcohol | 0.301 |
| Clothing and footwear | Clothing | 0.308 |
| Clothing services | 0.138 |
| Footwear | 0.299 |
| Household furnishings and equipment | Appliances | 0.738 |
| Blankets, linen and furniture | 0.349 |
| Furniture and flooring | 0.304 |
| Glass and tableware | 0.614 |
| Tools | 0.239 |
| Household services and operation | Household services | 0.205 |
| Medical care and health expenses | Health fees | 0.261 |
| Health insurance | 0.017 |
| Transport | Freight | 0.753 |
| Vehicle fuel | 2.600 |
| Motor vehicle purchase | 0.289 |
| Motor vehicle parts and accessories | 0.289 |
| Public transport | 0.540 |
| Vehicle charges | 0.152 |
| Vehicle registration and insurance | 0.016 |
| Recreation | Holidays | 0.850 |
| Pets | 0.356 |
| Recreational goods | 0.406 |
| Recreational services | 0.127 |
| Personal care | Personal care | 0.221 |
| Miscellaneous | Miscellaneous goods | 0.312 |
| Miscellaneous services | 0.157 |

Source: Dey (2008)

Appendix C: Regression results for double-semi log model. \*\*\*1% significance, \*\*5% significance, \*10% significance, with standard errors in parenthesis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *α* | *β* | *γ* | *Adj. r2* |
| *Alcohol* | -17.53  (11.91) | 0.025\*\*\*  (0.00048) | 3.73  (2.41) | 0.15 |
| *Appliances* | -12.53  (9.21) | 0.016\*\*\*  (0.0040) | 2.18  (1.88) | 0.052 |
| *Bakery* | -23.61\*\*\*  (1.98) | 0.0027\*\*\*  (0.00075) | 6.03\*\*\*  (0.39) | 0.23 |
| *Blankets/linen* | 6.98  (8.44) | 0.015\*\*\*  (0.0037) | -1.68  (1.73) | 0.059 |
| *Clothing* | 47.57\*\*  (23.54) | 0.068\*\*\*  (0.0095) | -10.62\*\*  (4.76) | 0.24 |
| *Clothing services* | 1.77  (1.21) | 0.0020\*\*\*  (0.00050) | -0.38  (0.25) | 0.036 |
| *Condiments* | -28.11\*\*\*  (3.57) | 0.0061\*\*\*  (0.0014) | 6.73\*\*\*  (0.72) | 0.25 |
| *Dairy* | -16.38\*\*\*  (1.40) | 0.0012\*\*  (0.00052) | 4.31\*\*\*  (0.28) | 0.18 |
| *Domestic fuel*  *and power* | -0.98  (4.72) | 0.0088\*\*\*  (0.0018) | 3.13\*\*\*  (0.94) | 0.18 |
| *Fish* | -2.92\*  (1.58) | 0.0023\*\*\*  (0.00068) | 0.81\*\*  (0.32) | 0.054 |
| *Footwear* | 3.13  (5.01) | 0.012\*\*\*  (0.0021) | -0.88  (1.02) | 0.079 |
| *Freight* | 8.12\*\*  (3.28) | 0.0065\*\*\*  (0.0015) | -1.66\*\*  (0.68) | 0.041 |
| *Fruit and nuts* | -12.73\*\*\*  (1.65) | 0.0030\*\*\*  (0.00065) | 3.24\*\*\*  (0.33) | 0.14 |
| *Vehicle fuel* | -72.15\*\*\*  (6.29) | 0.0080\*\*\*  (0.0025) | 15.79\*\*\*  (1.27) | 0.21 |
| *Furniture/*  *flooring* | 5.88  (17.65) | 0.042\*\*\*  (0.0076) | -2.49  (3.59) | 0.086 |
| *Glass/tableware* | 0.18  (5.24) | 0.0067\*\*\*  (0.0021) | -0.15  (1.06) | 0.067 |
| *Health fees* | -14.64\*\*  (6.91) | 0.015\*\*\*  (0.0030) | 2.85\*  (1.41) | 0.090 |
| *Health Insurance* | -34.70\*\*\*  (3.23) | 0.0080\*\*\*  (0.0013) | 7.52\*\*\*  (0.65) | 0.19 |
| *Holidays* | -15.50  (17.91) | 0.068\*\*\*  (0.0078) | 1.58  3.66) | 0.21 |
| *Household services* | -57.20\*\*\*  (9.79) | 0.031\*\*\*  (0.0041) | 14.51\*\*\*  (1.98) | 0.25 |
| *Meals out* | -50.20\*\*\*  (10.21) | 0.044\*\*\*  (0.0042) | 9.68\*\*\*  (2.07) | 0.36 |
| *Meat* | -30.96\*\*\*  (2.92) | 0.0040\*\*\*  (0.0011) | 7.70\*\*\*  (0.58) | 0.17 |
| *Miscellaneous*  *goods* | 21.96  (23.31) | 0.031\*\*\*  (0.0090) | -4.71  (4.68) | 0.13 |
| *Miscellaneous*  *services* | 133.18\*\*\*  (46.14) | 0.17\*\*\*  (0.019) | -29.81\*\*\*  (9.34) | 0.31 |
| *Motor vehicle*  *purchase* | 206.36\*\*\*  (52.30) | 0.20\*\*\*  (0.022) | -47.45\*\*\*  (10.61) | 0.24 |
| *Non-alcoholic*  *beverages* | -21.15\*\*\*  (1.74) | 0.0039\*\*\*  (0.0007) | 4.91\*\*\*  (0.35) | 0.25 |
| *Motor vehicle parts/*  *accessories* | -12.21  (7.33) | 0.021\*\*\*  (0.0029) | 2.45\*\*  (0.98) | 0.04 |
| *Personal care* | -6.10  (7.33) | 0.021\*\*\*  (.0029) | 1.39  (1.48) | 0.20 |
| *Pets* | 1.03  (10.14) | 0.012\*\*\*  (0.0045) | -0.15  (20.8) | 0.03 |
| *Public transport* | -6.99\*\*\*  (1.43) | 0.00058  (0.00054) | 1.57\*\*\*  (0.28) | 0.020 |
| *Recreational*  *goods* | 60.79\*  (34.35) | 0.083\*\*\*  (0.014) | -13.13\*  (6.92) | 0.22 |
| *Recreational*  *services* | -13.29  (10.67) | 0.025\*\*\*  (0.0045) | 2.40  (2.16) | 0.12 |
| *Tools* | -8.83\*\*  (4.18) | 0.0083\*\*\*  (0.0019) | 1.60\*\*  (0.085) | 0.050 |
| *Vegetables* | -15.52\*\*\*  (1.31) | 0.0019\*\*\*  (0.00049) | 3.97\*\*\*  (0.026) | 0.18 |
| *Vehicle charges* | 18.55  (17.98) | 0.036\*\*\*  (0.0073) | -4.42  (3.63) | 0.088 |
| *Vehicle*  *registration* | -40.62\*\*\*  (3.29) | 0.0066\*\*\*  (0.0013) | 9.44\*\*\*  (0.656) | 0.31 |

Appendix D: Regression results for double-semi log model with extra explanatory variables. \*\*\*1% significance, \*\*5% significance, \*10% significance, with standard errors in parenthesis.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | *α* | *β* | *γ* | *Persons/house* | *Urbanity* | *State* | *Age* | *Dwelling* | *Adj. r2* |
| *Alcohol* | -16.88  (12.92) | 0.026\*\*\*  (0.005) | 5.11\*\*  (2.46) | -3.65\*\*\*  (0.45) | 2.33\*\*\*  (0.85) | 1.19\*\*\*  (0.27) | -0.47\*\*\*  (0.07) | 0.35  (0.39) | 0.17 |
| *Appliances* | -18.47\*  (10.17) | 0.016\*\*\*  (0.004) | 3.91\*\*  (1.89) | -2.45\*\*\*  (0.55) | 0.52  (1.00) | 0.55\*  (0.30) | -0.018  (0.075) | -0.67\*  (0.35) | 0.56 |
| *Bakery* | -23.35\*\*\*  (2.17) | 0.0020\*\*\*  (0.0007) | 3.49\*\*\*  (0.39) | 4.45\*\*\*  (0.13) | -0.035  (0.22) | -0.098  (0.089) | 0.31\*\*\*  (0.018) | -0.097  (0.089) | 0.39 |
| *Blankets/linen* | 1.24  (9.14) | 0.015\*\*\*  (0.0038) | -0.69  (1.71) | -1.01\*\*\*  (0.38) | 0.088  (0.64) | 0.40\*  (0.22) | 0.059  (0.051) | -0.22  (0.26) | 0.061 |
| *Clothing* | 56.77\*\*  (24.09) | 0.068\*\*\*  (0.0095) | -13.01\*\*\*  (4.76) | 2.90\*\*\*  (0.70) | -0.32  (1.08) | -0.36  (0.35) | -0.092  (0.097) | 1.09\*\*  (0.54) | 0.24 |
| *Clothing services* | 0.72  (1.30) | 0.0019\*\*\*  (0.00050) | -0.19  (0.25) | -0.086\*  (0.051) | -0.29\*\*\*  (0.092) | 0.0004  (0.029) | 0.022\*\*\*  (0.0081) | 0.085\*  (0.047) | 0.039 |
| *Condiments* | -18.26\*\*\*  (3.88) | 0.0060\*\*\*  (0.0014) | 2.96\*\*\*  (0.72) | 4.69\*\*\*  (0.18) | 0.51\*  (0.30) | 0.19\*\*  (0.090) | 0.053\*\*  (0.024) | -0.042  (0.13) | 0.36 |
| *Domestic fuel*  *and power* | 5.28  (4.96) | 0.0089\*\*\*  (0.0017) | 0.65  (0.95) | 2.70\*\*\*  (0.17) | -0.041  (0.34) | 0.91\*\*\*  (0.094) | 0.084\*\*\*  (0.028) | -1.25\*\*\*  (0.16) | 0.24 |
| *Fish* | -5.02\*\*\*  (1.72) | 0.0020\*\*\*  (0.00069) | 1.13\*\*\*  (0.32) | 0.11  (0.093) | -0.69\*\*\*  (0.18) | -0.28\*\*\*  (0.051) | 0.11\*\*\*  (0.014) | -0.035  (0.067) | 0.065 |
| *Footwear* | 3.11  (4.96) | 0.012\*\*\*  (0.0021) | -1.27  (0.99) | 0.71\*\*\*  (0.24) | 0.023  (0.42) | -0.026  (0.13) | 0.033  (0.035) | 0.18  (0.18) | 0.080 |
| *Freight* | 7.80\*\*  (3.50) | 0.0065\*\*\*  (0.0015) | -1.17\*  (0.65) | -0.66\*\*\*  (0.18) | -0.60\*\*\*  (0.20) | -0.011  (0.079) | -0.061\*\*  (0.025) | 0.48\*\*\*  (0.15) | 0.049 |
| *Vehicle fuel* | -51.7\*\*\*  (7.01) | 0.0093\*\*\*  (0.0026) | 11.32\*\*\*  (1.31) | 3.19\*\*\*  (0.41) | 3.54\*\*\*  (0.75) | 0.61\*\*\*  (0.22) | -0.22\*\*\*  (0.057) | -2.36\*\*\*  (0.24) | 0.24 |
| *Furniture/*  *flooring* | -3.32  (18.97) | 0.043\*\*\*  (0.0076) | 1.071  (3.64) | -5.46\*\*\*  (0.81) | 2.75\*  (1.45) | 0.47  (0.45) | -0.26\*\*  (0.13) | -0.19  (0.67) | 0.093 |
| *Glass/tableware* | -2.93  (5.86) | 0.0065\*\*\*  (0.0021) | 0.26  (1.11) | -0.17  (0.13) | 0.0075  (0.25) | 0.0032  (0.087) | 0.057\*\*  (0.026) | 0.070  (0.14) | 0.068 |
| *Health fees* | -18.83\*\*  (7.97) | 0.014\*\*\*  (0.0030) | 3.85\*\*  (1.52) | 0.075  (0.39) | -3.63\*\*\*  (0.63) | -0.66\*\*\*  (0.23) | 0.29\*\*\*  (0.057) | -0.15  (0.28) | 0.095 |
| *Health Insurance* | -54.43\*\*\*  (3.83) | 0.0066\*\*\*  (0.0013) | 9.31\*\*\*  (0.68) | 0.34  (0.23) | -0.79\*  (0.45) | 0.12  (0.13) | 0.59\*\*\*  (0.036) | -0.74\*\*\*  (0.17) | 0.22 |
| *Holidays* | -56.53\*\*\*  (19.05) | 0.066\*\*\*  (0.0077) | 10.23\*\*\*  (3.66) | -7.08\*\*\*  (0.87) | -5.31\*\*  (1.74) | 0.17  (0.52) | 0.62\*\*\*  (0.15) | 0.70  (0.68) | 0.22 |
| *Household services* | -20.72\*  (10.74) | 0.031\*\*\*  (0.0041) | 9.23\*\*\*  (2.03) | 3.97\*\*\*  (0.55) | -4.12\*\*\*  (0.98) | -0.67\*\*  (0.31) | -0.27\*\*\*  (0.078) | -1.81\*\*\*  (0.36) | 0.27 |
| *Meals out* | -28.14\*\*\*  (10.74) | 0.044\*\*\*  (0.0042) | 9.26\*\*\*  (2.14) | -0.56  (0.51) | -7.19\*\*\*  (0.83) | -1.79\*\*\*  (0.28) | -0.41\*\*\*  (0.079) | 2.23\*\*\*  (0.45) | 0.37 |
| *Miscellaneous*  *goods* | 21.20  (24.73) | 0.031\*\*\*  (0.0091) | -5.07  (4.81) | 0.98\*\*  (0.42) | -1.26\*  (0.68) | 0.088  (0.20) | 0.065  (0.062) | 0.60\*  (0.34) | 0.13 |
| *Miscellaneous*  *services* | 150.05\*\*\*  (48.59) | 0.17\*\*\*  (0.019) | -31.36\*\*\*  (9.33) | 0.61  (1.44) | -0.14  (2.48) | -1.13  (0.73) | -0.70\*\*\*  (0.19) | 4.48\*\*\*  (1.21) | 0.31 |
| *Motor vehicle*  *purchase* | 159.39\*\*\*  (55.25) | 0.20\*\*\*  (0.022) | -38.09\*\*\*  (10.69) | -12.80\*\*\*  (1.64) | 16.90\*\*\*  (3.10) | 2.04\*\*  (0.94) | -0.43\*  (0.24) | -0.34  (1.21) | 0.25 |
| *Non-alcoholic*  *beverages* | -12.39\*\*\*  (1.89) | 0.0040\*\*\*  (0.00066) | 2.85\*\*\*  (0.35) | 2.24\*\*\*  (0.12) | -0.49\*\*  (0.22) | -0.10  (0.067) | -0.043\*\*  (0.017) | 0.072  (0.096) | 0.30 |
| *Motor vehicle parts/accesories* | -8.11  (5.26) | 0.0057\*\*\*  (0.0020) | 1.68\*  (0.99) | 0.19  (0.30) | 1.44\*\*\*  (0.54) | 0.27\*  (0.15) | -0.12\*\*\*  (0.041) | -0.34\*  (0.20) | 0.043 |
| *Personal care* | -11.10  (7.72) | 0.020\*\*\*  (0.0029) | 1.87  (1.52) | 0.33  (0.29) | -0.94\*  (0.54) | -0.19  (0.17) | 0.14\*\*\*  (0.045) | 0.48\*\*  (0.23) | 0.20 |
| *Pets* | 1.59  (10.63) | 0.013\*\*\*  (0.0045) | 0.46  (2.046) | -1.53\*\*\*  (0.37) | 1.21  (0.74) | 0.18  (0.20) | -0.052  (0.072) | -1.29\*\*\*  (0.30) | 0.040 |
| *Public transport* | -0.97  (1.65) | 0.00035  (0.00052) | 1.27\*\*\*  (0.30) | 0.49\*\*\*  (0.13) | -2.20\*\*\*  (0.19) | -0.95\*\*\*  (0.071) | -0.052\*\*\*  (0.018) | 0.89\*\*\*  (0.14) | 0.068 |
| *Recreational*  *goods* | 80.93\*\*  (36.35) | 0.085\*\*\*  (0.014) | -15.08\*\*  (6.98) | -0.097  (0.82) | 0.55  (1.43) | -0.054  (0.48) | -0.66\*\*\*  (0.11) | 1.54\*\*  (0.71) | 0.22 |
| *Recreational*  *services* | -20.06\*  (11.91) | 0.024\*\*\*  (0.0045) | 2.50  (2.22) | 0.89  (0.55) | 0.51  (1.06) | 0.0063  (0.29) | 0.20\*\*\*  (0.075) | 0.11  (0.37) | 0.12 |
| *Tools* | -9.52\*\*  (4.67) | 0.0084\*\*\*  (0.0019) | 1.69\*  (0.89) | -0.36  (0.35) | 0.72  (0.54) | 0.32\*\*  (0.14) | -0.016  (0.040) | -0.42\*\*  (0.17) | 0.051 |
| *Vegetables* | -21.16\*\*\*  (1.56) | 0.0012\*\*  (0.00049) | 3.82\*\*\*  (0.27) | 1.35\*\*\*  (0.098) | -0.55\*\*\*  (0.19) | -0.022  (0.058) | 0.26\*\*\*  (0.016) | -1.47\*\*\*  (0.16) | 0.23 |
| *Vehicle charges* | 12.82  (19.56) | 0.036\*\*\*  (0.0074) | -1.68  (3.70) | -3.64\*\*\*  (0.64) | 0.91  (1.20) | -0.62\*  (0.36) | -0.023  (0.10) | -0.75\*  (0.43) | 0.093 |
| *Vehicle*  *registration* | -26.33\*\*\*  (3.65) | 0.0067\*\*\*  (0.0013) | 7.88\*\*\*  (0.68) | 1.12\*\*\*  (0.19) | -2.63\*\*\*  (0.35) | -0.63\*\*\*  (0.11) | 0.0045  (0.029) | -1.47\*\*\*  (0.16) | 0.33 |
| *Dairy* | -13.74\*\*\*  (1.57) | 0.00098\*\*  (0.00051) | 2.31\*\*\*  (0.28) | 2.81\*\*\*  (0.10) | 0.49\*\*\*  (0.18) | 0.22\*\*\*  (0.054) | 0.11\*\*\*  (0.014) | -0.19\*\*\*  (0.074) | 0.30 |
| *Fruit and nuts* | -22.60\*\*\*  (1.87) | 0.0019\*\*\*  (0.00063) | 3.75\*\*\*  (0.33) | 1.25\*\*\*  (0.11) | -1.19\*\*\*  (0.21) | -0.36\*\*\*  (0.065) | 0.39\*\*\*  (0.019) | 0.078  (0.094) | 0.20 |
| *Meat* | -36.37\*\*\*  (3.31) | 0.0030\*\*\*  (0.0011) | 5.78\*\*\*  (0.59) | 4.17\*\*\*  (0.20) | -0.089  (0.39) | 0.20\*  (0.12) | 0.50\*\*\*  (0.031) | -0.98\*\*\*  (0.13) | 0.25 |

Outline

1. Intro

The rebound effect from environmental policies that reallocate funds amongst economic agents are unknown. This paper seeks to estimate the rebound effect from carbon taxes, photovoltaic subsidies, and the general tax and transfer system.

EKC debate? Kyoto and policy response? Raise exporting pollution argument.

1. Reallocation rebound

Talk about marginal changes, therefore marginal household expenditure. The role of government in redistribution of wealth.  
Fixed technology and production techniques.  
DATA?

1. Estimation method  
   Use of household demand system and government expenditure. Show results of demand systems.
2. Cases

1. Total expenditure is used as a proxy for income, which is common in household demand studies (Deaton and Muellbauer, 1980; Haque, 2005; Brannlund et al., 2007). [↑](#footnote-ref-1)
2. Some non-housing commodity groups have also been excluded. Tobacco expenditure in particular has been excluded due to its low correlation with income and very low occurrence of its consumption amongst survey respondents. A non-smoker does not increase his/her consumption of tobacco simply because disposable income increases. Furthermore, only 27% of households from the HES reported consuming tobacco at all.Other commodity groups excluded for these reasons are edible oils, eggs, and other medical expenses [↑](#footnote-ref-2)
3. These are turning points in the Engel curve, characteristic of goods becoming inferior above a particular income level. [↑](#footnote-ref-3)
4. The adding-up criterion specifies that at all levels of total expenditure, the sum of expenditure on each commodity adds up to total expenditure. [↑](#footnote-ref-4)
5. This functional form was determined by Haque (2005) to provide the best fit to the 1976-77 HES data. [↑](#footnote-ref-5)
6. In terms of energy output. [↑](#footnote-ref-6)
7. This static model is illustrative of the rebound effect for this case, but is by no means an accurate dynamic model of what is likely to happen over a 27 year period. Incorporating discounting into such a calculation presents difficulties with the treatment of the LCA data, the environmental cost of forgone opportunities for investment, and potentially with assigning an environmental cost to loan repayments. [↑](#footnote-ref-7)
8. Refer to discussion in Chapter 2. [↑](#footnote-ref-8)
9. At the mean expenditure level of $37,368 per household per annum (excluding housing costs and tobacco.) [↑](#footnote-ref-9)
10. This is approximately the price of European Union tradeable carbon permits in June 2008. (2008a). [↑](#footnote-ref-10)