The effect of the UK Vehicle Scrappage Scheme on passenger car CO_2 emissions

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Abstract

The UK Government-backed Scrappage Incentive Scheme (SIS) that ran between May 2009 and March 2010 was an incentive for car owners to scrap a car of 10 or more years old in exchange for a discount against a new vehicle. Although designed to help the UK motor industry during the recession and not specifically an emissions reduction policy, it is shown that the SIS resulted in a total reduction in CO_2 emissions from the UK passenger car fleet in the range of 16,200—62,040 tonnes CO_2 over the lifetime of the scheme, depending on the size of the "rebound effect" of lower driving costs resulting in a potential higher mileage for the new car. This occurred despite the absence of an upper emissions limit for the new car as for most similar European schemes, and is due to the vast improvement of g CO_2 km^{-1} figures for cars manufactured in 2009-10 compared to those before 2000. This CO_2 saving figure includes the additional lifecycle emissions resulting from producing a new car and disposing of an old one prematurely. It is shown additionally that based on average emissions ratings of old cars replaced and new cars purchased under the scheme, a car lifetime of 10 years minimises lifecycle CO_2 emissions for this portion of the UK passenger car fleet.

Introduction

In 2009, the UK Government introduced the Scrappage Incentive Scheme (SIS) as an economic stimulant to assist the ailing motor manufacturing industry. The Government provided £1,000 towards the purchase price of a new car, with an additional £1,000 provided by the manufacturer, in exchange for a car that was ten or more years old and had been in the possession of the owner for at least 12 months (Department for Business Innovation and Skills, 2010). The scheme ran from May 2009 to March 2010 with an allowance for up to 400,000 vehicles to participate; nearly all vehicles taken up under the SIS were cars (SMMT, 2010a).

Similar schemes operated in other countries, including much of the EU, Japan, the US, Russia and Egypt (Aldred and Tepe, 2011; Kagawa et al., 2011). Many EU countries used their individual scrappage schemes as an opportunity to "green" their vehicle fleet by imposing emissions limits on the new cars purchased, however, in the UK, the Government had not proclaimed the scheme as a green initiative (Aldred and Tepe, 2011). The environmental message had been seized upon by key industry bodies such as the Society of Motor Manufacturers and Traders.

On average, new cars emit less CO_2 per km than old cars, due to tightening of emissions legislation in the EU and a consumer preference for cars that are cheaper to run (Edwards et al., 2012). Therefore in the driving phase of a car's life, if the same annual distance is accumulated, the replacement of a higher emissions car with a lower one will lower overall CO_2 emissions. However, there is evidence that newer cars tend to be driven further than older cars. This may be due to a number of factors: lower CO_2 cars are more fuel efficient and therefore cheaper to run, allowing some of the money saved to be used to purchase more fuel and drive further. This phenomenon is known as the (direct) rebound effect (Greening et al., 2000; Small and Van Dender, 2007). Other factors include the improved driving experience of a new car influencing the decision to use the car more often (Van Wee et al., 2000); and a new car is also likely to spend less time being repaired and therefore available to use more of the time. Inherently, measurement of the direct rebound effect is difficult and wide ranges from 0—87% have been estimated, but it is generally accepted to be in the range of 10—30% (Sorrell, 2007), meaning that 10—30% of the potential energy savings are lost in the form of increased consumption.

Besides the driving phase, other stages of a car's life cycle contribute significant CO_2 emissions. Early scrappage of an old but perfectly functional car creates a demand for a new car to be manufactured earlier than it otherwise would have been. If the old car would have been kept for a considerable amount of time in the absence of an incentivised retirement program and the fuel economy of the new car is not significantly higher, the additional emissions from manufacturing a new car could outweigh those saved from the driving phase of the more efficient new car compared to the old one.

Previous studies have analysed accelerated retirement of old cars. Van Wee et al. (2000) concluded that a lifetime extension reduced the environmental impact of Dutch passenger cars, with an optimal age of 19 years assuming a 1% increase in year-on-year fuel economy and 25% of the vehicle's energy input in the non-use phase. Spitzley et al. (2005) suggest 18 years is the optimum lifetime for a car to minimise total CO_2 emissions in the US. Spielmann and Althaus (2007), considering passenger cars in Switzerland, found that lifecycle CO_2 emissions were lower when extending the lifespan of a car from 12 to 15 years. A case study on the Japanese car fleet between 1990 and 2000 performed by Kagawa et al. (2011) also concluded that a lifetime extension results in lower lifecycle CO_2 emissions, requiring a fuel efficiency improvement of 12.7% to offset a reduction in mean vehicle lifetime by one year.

With the literature suggesting that lifetime extension is the best way to reduce total emissions, scrappage schemes would appear to be a poor environmental policy. However, the literature focuses on periods where fuel economy improvements in new cars were not occurring as rapidly as they have been in the EU since 2008 following mandatory emissions targets. Furthermore, none of the studies factor in a rebound effect explicitly, although it is acknowledged in two of the studies (Van Wee et al., 2000; Kagawa et al., 2011).

Methodology

Profile of cars scrapped and replaced

The cars scrapped and purchased under the scheme were different to the "average" car and it is important to focus on this particular subset. The average age of a car scrapped under the vehicle scrappage scheme was 12.7 years (SMMT, 2010b), compared to 13.29 years for a car in the non-scrappage scheme year of 2011 (Taylor, 2012). The fleet average age in 2009 or 2010 was not used as these years had mean averages below the recent trend, possibly due to the effect of the scrappage scheme. It is assumed therefore that the scrappage scheme reduced the life of a participating car by 0.59 years.

The emissions of old cars replaced under the scheme averaged 182.2 g km^{-1} based on weighted segment data from 1997 registrations (SMMT, 2010a). This is lower than the fleet average for 1997 registrations of 189.8 g km^{-1} (SMMT, 2010c). It is considered appropriate to use the 1997 segment-averaged data as the average age of cars scrapped under the scheme suggests that they were centred on 1997 registrations.

Against a background of rising diesel market share, 82.6% of the new cars registered under the scheme were petrol cars, compared to 57.8% of all new cars in 2010 and 53.1% in 2011 (Department for Transport, 2012a). Overall, 73% of the cars registered under the scheme belonged to the mini and supermini market segments, compared to 42% of total registrations over the period (SMMT, 2010b). As a result, the average emissions rating of a new car under the scheme was 132.4 g km^{-1} (SMMT, 2010b), significantly lower than the fleet average for the period of 146.9 g km^{-1} (SMMT, 2011a). This suggests that the scheme mainly resulted in a turnover of smaller cars.

Annual average distance driven

As more than 98% of scrappage registrations were private, the annualised private distance of 12,730 km will be assumed for a typical car (Department for Transport, 2011). It is not known whether the market segment of the cars making up the scrappage fleet are driven more or less than the private fleet average. 82.6% of registrations were petrol cars, therefore the fleet average for private cars is considered to be a more appropriate assumption than the fleet average for petrol cars.

Life-cycle analysis (LCA) of car manufacture

The usual method of quantifying the total environmental cost over all stages of a product's supply chain is the lifecycle analysis (LCA). For a car, an LCA will take into account all environmental inputs resulting from raw material extraction, electricity consumption in manufacture and disposal of the vehicle, residual emissions (e.g. from landfill), as well as its fuel consumption over its useful life. A total can therefore be ascribed to each stage of the car's life.

Generally, there are five main sources of emissions in a car's life cycle; production of the car, production of spare parts, fuel consumption during use, upstream emissions resulting from fuel production, and end of life. When considering the lifecycle of passenger cars, the boundary is usually drawn to include emissions from manufacturing and end of life processes but excluding the contribution from upstream fuel production and spare parts. Fuel production has been excluded on the basis that the emissions in the supply chain are often small compared to the emissions released from the final fuel combustion. Emissions from production of spare parts and energy usage in the car repair business have also been excluded as they are also assumed to be small, and difficult to quantify. It should be noted that the exclusion of repairs and upstream fuel emissions may be favourable to older cars which are likely to be repaired more often and be less fuel efficient.

Estimates for the embodied emissions of a new car vary substantially, however, knowing that the majority of registrations under the scrappage scheme were small petrol cars, it is appropriate to use a subset of LCA studies that focus on these vehicles (Table 1). The differing assumptions will depend on factors such as the manufacturing process used, carbon intensity of grid electricity in the location of manufacture, and the type and amount of materials used in construction. The mean value of these three studies of 4931 kg CO_2-eq is used in our analysis.

Table 1: Lifecycle analyses for production and disposal emissions for small petrol cars available in the literature

Study and Year	Car	Power (kW)	Weight (kg)	Fuel type	Non-use CO_2 emissions (kg)
Volkswagen (2009)	VW Polo	63	1104	Petrol	5015
Mercedes-Benz (2008)	Mercedes-Benz A Class	70		Petrol	5440
Nemry et al. (2008)	Generic	78	1240	Petrol	4339

Method

The proportion of life lost by a car under the scrappage scheme is

$$r = \frac{T - T_*}{T} \tag{1}$$

where T = 13.29 yr and T_* = 12.7 yr, leading to r = 0.0444. The quantity r becomes the proportion of the new car's non-use emissions that should be accounted for to assess the environmental benefits of accelerated scrappage. Letting C equal the total non-use life-cycle emissions of the new car (4931 kg), the amount that is required to be offset is rC = 219 kg CO_2.

It is assumed that the car purchased under the scrappage scheme has an identical emissions rating and lifespan to the one that would have been purchased 0.59 years later under organic replacement. In reality, delaying purchasing of a new car by a few months may mean that the car eventually purchased has lower CO_2 emissions than it may have done had it been purchased earlier, however, in this study the emissions of the new car are considered to be constant.

The average privately owned car was driven 12,730 km per year in 2010 (Department for Transport, 2011), or x = 1061 km per month. It is assumed that this figure is reasonable for May

2009. Data for the average CO_2 emissions for the years of 2009 and 2010 were used to derive an estimate of the average CO_2 figure for all cars on the road for the scrappage scheme period of 167.0 g km^{-1} from data available from the Department for Transport (2012b).

Earlier in this section it was stated that transport fuel price has a rebound effect of between 10—30%. A more efficient car may by driven further, but if the real pump price of fuel increases during the period, this will act to reduce total km driven. Using GDP as a proxy for personal income, the real price of petrol increased 13.6% over the period of scrappage (Department of Energy and Climate Change, 2012). The fuel price index each month relative to GDP is denoted by p_i, where i represents the number of months elapsed since May 2009.

To model the distance driven by the old car, it is first noted that as the CO_2 emissions of the old car are higher, the old car would cost more to run regardless of the fuel price. The change in vehicle-km demand for the average car, factoring in the rebound factor β, compared to May 2009 is given by (Litman, 2012)

$$d_{oi} = \left(\frac{\eta_{old}}{\eta_{avg}} \frac{p_i}{p_0}\right)^{-\beta} \tag{2}$$

where η_{old} = 182.2 g km^{-1}, η_{avg} = 167.0 g km^{-1} and β is either 0.3, 0.1 or 0 depending on whether a high, low or zero rebound scenario is modelled. The emissions ratio between an old and fleet average car of just over 1.09 leads to a reduction in demand if β > 0. The distance travelled by the old car each month is the product of the demand ratio to the May 2009 monthly mileage:

$$D_{oi} = x d_{oi} \tag{3}$$

CO_2 emissions from the old car each month are then derived by multiplying distance driven by per-km CO_2 emissions:

$$E_{oi} = \eta_{old} D_{oi} \tag{4}$$

By analogy, the emissions that would arise from the new car in month i is given by replacement in (2)—(4) of η_{old} with the emissions per km of the new car, η_{new}:

$$E_{ni} = \eta_{new} x \left(\frac{\eta_{new}}{\eta_{avg}} \frac{p_i}{p_0}\right)^{-\beta} \tag{5}$$

The overall emissions saving for a scrappage scheme car purchased on the first day of month i is given by

$$\sum_{j=i}^{i+6} (E_{oj} - E_{nj}) + 0.08\left(E_{o,i+7} - E_{n,i+7}\right) - rC \tag{6}$$

where 0.59 years is taken as 7.08 months and the slight difference in the length of the months is neglected.

Results

Equation (6) was analysed for all months of the scrappage scheme (i = 0,…,10) requiring fuel price data to be available until month 17 (October 2010), under three rebound scenarios.

Constant mileage (β = 0)

If there is no rebound effect, then the same monthly mileage of 1061 km is accumulated by a car regardless of its fuel efficiency or the price of fuel as d_{oi} = d_{ni} = 1 for all i. This leads to a CO_2 saving of 155.1 kg CO_2e regardless of when in the scrappage scheme period the new car was acquired.

Low rebound effect (β = 0.1)

The CO_2 saving under a rebound scenario depends on the fuel price. As the price increases, the old car would have been driven less, but in absolute terms the reduction of mileage of the new car is higher compared to May 2009. The CO_2 emissions to be overcome from the manufacturing processes to be offset remain the same at 218.9 kg, therefore as the fuel price rises, the scrappage scheme actually becomes less beneficial from an overall CO_2 perspective.

The total CO_2 savings from the scrappage scheme range from 115.1 kg if the new car is acquired in March 2010 to 118.5 kg in May 2009 (when the fuel price was lowest), with a mean value of 116.7 kg CO_2e.

High rebound effect (β = 0.3)

As the rebound effect increases, more of the monetary savings from cheaper car running costs are absorbed by driving further, reducing the effectiveness of the energy-saving measure. Once again, as fuel prices risen over the May 2009 to October 2010 period, the marginal gain of the new car versus the old car is reduced from 44.9 kg CO_2 for a May 2009 scrapping date to 36.9 kg CO_2 in March 2010, with a mean value of 40.5 kg.

Following on from this, it was found that the lifecycle emissions from the new car equalled the lifecycle emissions from the old car when β = 0.4075, and all rebound parameters above this result in an emissions penalty from the scrappage scheme.

Optimal scrappage age

Van Wee et al. (2000) gave the optimal age to scrap a car as

$$n = \frac{C}{x\eta_{old}(1-(1-\alpha)^n)} \tag{7}$$

where n is age in years and α is the improvement in fuel economy each year. Intriguingly, the fact that fuel efficiency has improved on average by 2.37% per year over the 1997—2010 period for scrappage scheme cars, and using our previous figures of non-use phase emissions and average lifetime, equation (7) gives an optimal scrappage age of 10.0 years, which is the lower age bound of vehicles targeted by the SIS. Improved efficiencies in manufacturing and higher end-of-life recycling rates have accounted for a reduction in non-use emissions in the ten years or so since the Van Wee et al. study, which recommended 19 years as the optimal car lifetime. Our figures result in 17.5% of total emissions in the non-driving phase, calculated as $C \quad (C + nx\eta_{old})$, which is consistent with the range of 15—21% estimated from lifecycle studies (Mercedes-Benz, 2008; Nemry et al., 2008; Volkswagen, 2009; SMMT, 2010b).

Discussion

One reason that small cars may have been favoured under the scheme is relative discount. Many new, small petrol cars are available for under £8,000. A £2,000 discount from the list price is a saving of more than a quarter of the car's value. The average new car in the UK during 2010 retailed for £19,370 (Campestrini and Mock, 2011), for which the scrappage incentive represents a lower relative discount. Diesel cars are also in general more expensive than petrol cars (Campestrini and Mock, 2011), another reason why many scrappage buyers may have favoured petrol models.

The consumer demand for small, low-cost cars under the SIS affected market dynamics considerably. Fiat, Hyundai, Kia and Suzuki took more than three times the market share of scrappage registrations compared to 2011 (SMMT, 2010a; SMMT, 2011b). Hyundai, a marque that did not even appear in the top 10 in 2011, outsold Ford in terms of total scrappage registrations, taking 11.7% of market share. Not surprisingly, luxury brands such as Porsche,

Lexus and Jaguar fared very poorly, but so did some of the higher volume prestige brands like BMW, Audi and Mercedes-Benz, all obtaining one-fifth or less of the market share in scrappage scheme incentive sales than they did in the calendar year of 2011.

It is not possible to determine whether the scrappage scheme caused consumers to choose smaller cars or conversely whether a higher proportion of small car drivers took advantage of the scrappage scheme. The reversal in the trend of increasing diesel market share in 2010, and resumption in 2011, shows that there may have been a shift in purchasing habits amongst the general vehicle-buying population. The old cars replaced under the scrappage scheme fell into larger market segment categories than the cars replacing them in general (SMMT, 2010a), with the relative discount and lower running costs perhaps incentivising consumers to downsize.

Conclusion

The scrappage scheme was shown to be environmentally beneficial by reducing total lifecycle emissions of CO_2. The extent of the benefit is dependent on the distance driven by the old and new cars and the emissions relating to manufacture of a new car and disposal of the old one. In both the constant mileage scenario and where rebound effects at the low and high end of estimates in the literature were considered, the scrappage scheme did confer an environmental benefit per car, which decreased with increasing rebound.

The CO_2 savings per car are in the range of 40.5—116.7 kg CO_2e for a rebound assumption, and are 155.1 tonnes of CO_2 for a constant mileage assumption. Whilst this is a relatively small amount compared to the average UK resident's annual emissions, when multiplied by the scrappage population of 400,000 vehicles, a total emissions saving of 16,200—62,040 tonnes CO_2e is observed. It was found that rebounds of up to 40.7% still resulted in an emissions benefit overall.

It is suggested that the individual customers who would have participated in the scheme would not have significantly changed their driving habits. However, the fuel price signal may influence the decision of transport mode for some journeys, making a small rebound effect appropriate. The indirect rebound effects of people choosing to lower, but non-zero-carbon, forms of transport in place of driving when the fuel costs are relatively high would reduce the emissions benefit of the scrappage scheme. Alternatively, higher fuel prices would also affect public transport costs, and people may simply choose to travel less or to cycle or walk for more shorter journeys. These secondary effects have not been investigated, but would merit further consideration.

It was shown that by considering the average emissions per km of cars scrapped and replaced under the scrappage scheme, a replacement interval of 10.0 years results in the minimum lifecycle CO_2 emissions, suggesting that a lifetime reduction (from 13.29 years) rather than extension is preferable. It is important to note that these results consider the UK SIS in isolation rather than the UK vehicle fleet as a whole. This would be valid further research, as recent reductions in emissions in the UK and the rest of the EU may result in a diversion from the prevailing opinion in the literature that lifetime extension is the best way to reduce CO_2 emissions from passenger cars on a lifecycle basis. Further work could include a larger set of LCAs for small petrol cars as only three were available in this study, and a sensitivity analysis to determine the main factor influencing the lifecycle emissions total.

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