CHAPTER 9
MODELLING THE IMPACT OVER TIME – CONSUMER TRANSPORT

9.1 INTRODUCTION

This chapter considers a few simple scenarios that introduce some potential scale to the input-output multiplier model analyses in Chapters 3, 4 and 6 in considering the potential wider economic impacts of a projected shift to a hydrogen economy. Again, focus is mainly on the case of private transportation and the shift from petrol/diesel (refined fossil fuels) to hydrogen, with the supply chain of the latter proxied by those of the existing UK gas and/or electricity supply sectors. The key characteristic of these proxies is the markedly stronger up-stream supply chain linkages *within* the UK economy as compared to the more import-intensive refined fuel supply industry. A central conclusion of the modelling work in this paper is that if a future hydrogen sector shares this characteristic, net positive impacts on the UK economy as whole are likely when/if private transportation transitions to the use of hydrogen as a fuel source.

In this context, the simulations in this chapter focus on the extent to which spending on hydrogen fuel in private transportation may be able to 'absorb' GDP and employment losses resulting from reduced demand for petrol/diesel. These are variables that may be of particular political and policy concern in any development of the energy system. Impacts are considered over several longer timeframes up to 2050.

The first step taken is to introduce forecasted scenarios across different discreet time periods for reduced demand and use of petrol and diesel as refined fossil fuels for use in private vehicles. This is translated to the projected reduction in UK household expenditure required to conduct a simulation using the input-output model. The results are then taken as a base against which to scale and compare potential uptake of hydrogen fuels (based on the gas and electricity proxies introduced in Chapter 3).

In setting up the scenario regarding reduced demand for UK refined fuels sector (which supplies petrol and diesel), this chapter draws loosely on scenario analyses conducted for the White Paper 3. However, the core of the analysis is applying multiplier tools used in Chapters 4 and 6 to consider the sectoral breakdown of the refined fuel and gas/electricity hydrogen proxy sector. That is, the current chapter introduces some potential scale to the marginal potential impacts considered in Chapters 4 and 6. Two scenarios are analysed:

Scenario 1: What are the economy-wide impacts of a change in UK household demand for refined fuel products (petrol and diesel) if demand/expenditure falls as a result of a transition to lower carbon fuel sources. This scenario is considered for various time frames between 2015 and 2050.

Scenario 2: What are the potential economy wide implications if reduced UK household expenditure on refined fuels is reallocated, to some degree, to spending on hydrogen, where the supply chain for the latter is given by one of the two proxies identified in Chapter 3 (and applied in Chapters 4 and 6). Specifically, how much spending on hydrogen may be required to prevent a net contraction in GDP and/or employment (as key macroeconomic variables) as a result of the fuel spending shift? The approach is also motivated by the fact that appropriate information (i.e. in format required to inform the economic input-output model) is not available on the level and particularly the likely price of spending required to hydrogen vehicles.

At this stage it is important to reflect on a couple of issues that are relevant in considering the transition to a hydrogen economy. First, while ideas around targets for supporting the transition to a hydrogen economy/low carbon economy are beginning to emerge, it is valid to question whether the UK is at the stage of setting a strategic plan; that is, whether goals in this respect are actually executable and achievable. Secondly, but linked to the latter point, it is not yet clear who would be responsible for making the transition to use of hydrogen fuel happen. While there is a clear role for Government in supporting such a shift, and this may be motivated by the type of potential for wider economic expansion considered here, the motivation for private firms to play a role in the hydrogen supply chain is less obvious. Similarly, the motivation and incentives for households to assume responsibility for the private investment spending (on vehicles) required for them actually use hydrogen technology and fuels is not established or straightforward. Therefore, the scenarios and potential economy-wide impacts identified here must be viewed with caution, assuming as they do that the shift takes place.

In this context, one of the overarching objectives of the economy-wide analysis in this paper is to begin to consider what may possibly happen if all actors can be persuaded to participate in the transition to hydrogen economy. In order to do so, this chapter focuses on demonstrating how the input-output multipliers identified in Chapters 3, 4 and 6 may be used to consider scaled scenarios to inform an evidence-base on the wider potential societal benefits of the transition to a hydrogen economy.

However, there is need for caution in that the scenarios considered in this chapter involve a marked change in the scale of activity in different sectors so that the restrictive assumptions (discussed in Section 3.4, chapter 3) become particularly relevant.

9.2 APPLYING MULTIPLIER ANALYSIS FOR SCENARIO ANALYSIS IN POTENTIAL DEPLOYMENT OF HYDROGEN IN THE UK

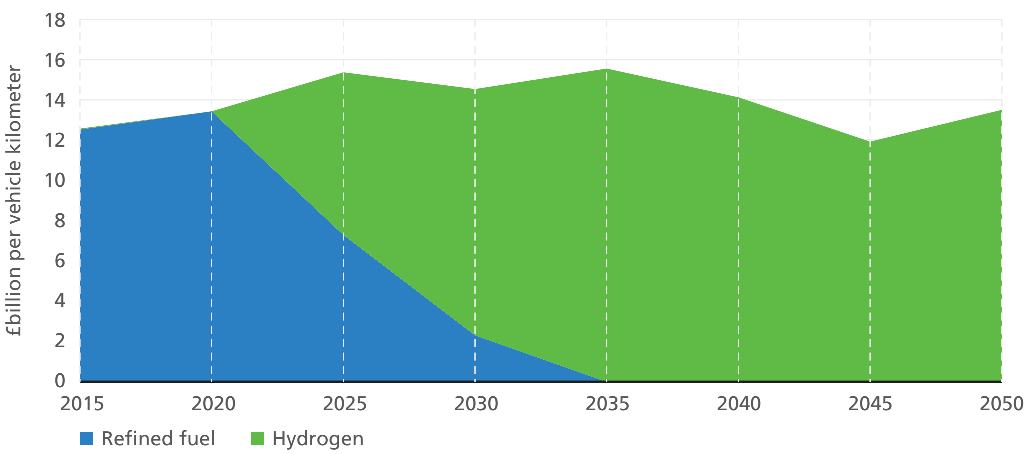
The underpinning argument of the modelling work in this White Paper is that the UK ‘Refined Fuels’ sector (sector details in Table 9.3 below), which supplies the petrol and diesel currently used to run most private cars, is import-intensive and has relatively weak upstream linkages within the UK economy. Specifically, its headline multipliers – for GDP, output, employment and wage income – are the lowest of all 103 industries identified in the UK input-output framework. The implication is that any reallocation of spending away from refined fuels towards any other UK industry is likely to result in a net positive impact on the production of goods and services and associated creation of value-added and jobs within the UK economy.

Under Scenario 2 below, the impacts of a potential contraction in the UK economy will be examined in context of the scaled reallocation of household spending towards hydrogen that would be required to deliver zero net impact on GDP, and no job losses across the economy as a while, from switching fuel sources. Before that, this section first considers the gross impacts of a reduction in total final household demand for the output of the UK Refined Fuel sector.

This chapter examines the potential of a near term to long term role of hydrogen in the UK Transport sector, at discreet points between 2015 and 2050. For modelling purposes, the input-output base year of 2010 is considered as a period where no hydrogen supply is present. Thus, the post 2010 period, specifically from 2015–2020, may be considered as a critical path in the transition to a hydrogen economy. At this stage it expected that investment hydrogen-enabling infrastructure is on-going and the UK is getting 'hydrogen ready' to facilitate long term use of hydrogen throughout the economy (the third scenario below focuses on the potential impacts of R&D investment at this stage). However, there is no deployment of hydrogen in transport sector over this period. This would be consistent with an assumption of non-uniform deployment of hydrogen across the economy (i.e. hydrogen supply for non-transport purposes may come into effect). Moreover, investment in hydrogen technologies and infrastructure would take time to be realised, which will involve factoring in consumer acceptance.

Figure 9.1 provides an illustration of the projected contraction in demand for refined fossil fuels (petrol and diesel) relative to the estimated demand and contribution of hydrogen in the UK transport sector. Specifically, it illustrates the potential expenditure (in billions of UK pounds) on refined fossils fuels in comparison to expected spend on hydrogen for all (not just private/household) car transport from 2015–2050. The blue shaded area captures what may be a 'critical path' through the 2015 to 2025 period where the UK economy is developing and implementing all necessary technologies, investment and innovation to support a transition to a hydrogen economy. Hence, expenditure and demand for traditional refined fossil fuels in transport remain dominant from 2015–2025. On the other hand, the green-shaded area represents what may be regarded as a 'full contribution' path, where it is expected the fuel used in cars is fully diversified with low carbon energy sources and hydrogen is the dominant fuel choice in UK car transport.

Figure 9.1 Expenditure on fuel/energy on all (not just household/domestic) car travel in the UK.



Source: The projected expenditure on fuel/energy for car travel in Figure 9.1 are the authors' calculations using UK Department for Transport Statistics (2015) average new car fuel consumption: Great Britain, 1997–2014 figures[86] and Mckinsey Company (2010) A portfolio of power-trains for Europe: A fact-based analysis: The role of battery electric vehicles, plug-in hybrids and fuel cell electric vehicle report.[87]

86 www.gov.uk/government/collections/transport-statistics-great-britain.
87 https://europeanclimate.org/documents/Power_trains_for_Europe.pdf.

For instance, if we read down the third numerical in Table 9.1, it is estimated that by 2025 hydrogen begins on a near term small scale in car transport. From this point, a gradual diversification of the fuel mix is projected, with petrol/diesel disappearing by 2035. The estimated potential direct impact of this is that UK car users will require 14billion litres of petrol and diesel to travel 259.31 Bvkm. This corresponds to a point in Figure 9.1 where there is a total spend of around £7billion. In contrast 1.82 billion kg of hydrogen would be potentially required to travel 249.03 Bvkm for hydrogen fuelled vehicles with total spend of £9million.

Table 9.1 **Fuel consumption for car travel 2015–2050.**

Distance travelled	2015	2020	2025	2030	2035	2040	2045	2050
Refined fuel (Billion vehicle kilometres)	437.46	472.70	259.31	82.48	0.00	0.00	0.00	0.00
Hydrogen (Billion vehicle kilometres)	0.69	0.24	249.03	436.02	595.16	567.59	497.73	583.16
Units of fuel/energy								
Refined fuel (Billion litres)	26.42	27.61	14.61	4.56	0.00	0.00	0.00	0.00
Hydrogen (Billion kg)	0.01	0.00	1.82	3.03	4.02	3.72	3.18	3.60

Source: The projected distance travelled by fuel/energy in Table 9.1 are the author's calculations using UK Department for Transport Statistics (2015) average new car fuel consumption: Great Britain, 1997–2014 figures and Mckinsey & Company (2010) A portfolio of power-trains for Europe: A fact-based analysis: The role of battery electric vehicles, plug-in hybrids and fuel cell electric vehicle report.

It is important to flag up again that the figures in Table 9.1 are approximations and should be treated cautiously. Projections are required because there are obviously no observed figures for hydrogen use in the future at the time of this exercise, and no or incomplete information is available on actual or relative hydrogen/fossil fuel prices and likely quantities involved. Therefore, comparative expenditures for refined fuels in conventional cars versus hydrogen use in appropriate new vehicle types may likely to be under or over estimated at the current time. However, the projections provide a useful basis to approximate the likely relative negative and positive impacts on UK GDP and employment through the transition period.

9.2.1 Scenario 1: Change in household demand for UK refined fuel

The previous section gives a forecast of the potential change in fuel use, focussing on petrol/diesel as refined fossil fuels in comparison to hydrogen, in different discreet time periods. Given that the economic modelling work here has placed emphasis on the fact that transition to hydrogen would involve contraction in the UK Refined Fuel supply industry, as well as any expansion around new activity involved in supply hydrogen, the period of contraction in refined fuel supply (including its domestic supply) will ultimately have implications on some UK household incomes and expenditure across different goods and services and spend across various uses.

In first scenario the potential impacts of such a contraction over discrete time periods is considered. Drawing on results from the projections discussed above, Table 9.2 provides a breakdown of potential changes is household demand for and expenditure on refined fossil fuel products supplied by the UK industry. Note that, in contrast to Figure 9.1 and Table 9.1, the information in Table 9.2 focuses on household use of fuel in cars only. However, the percentage change in the demand for refined fuels is taken to be the same as percentage change in overall car transport activity. This information is then applied to the 2010 input-output data on UK household expenditure on the domestic 'Refined Fuels' supply sector (which includes imported fuels distributed in the UK). That is, we assume that the percentage change in demand is the same as the percentage change in expenditure on the input-output sector.

Table 9.2 Reduction in UK household demand for refined fuels.

	2015	2020	2025	2030	2035	2040	2050
% Change demand for refined fuels	-2%	5%	-43%	-82%	-100%	-100%	-100%
Change in household expenditure (£million)	-148	311	-2,821	-5,373	-6,556	-6,556	-6,556
New household expenditure (£million)	6,408	6,867	3,734	1,183	0	0	0

The figures in each column Table 9.2 must be taken as independent of one another and applying in absolute terms in the year indicated in the column header. They are not cumulative. The percentage change in each year is relative to spending in the base accounting year of 2010, when the UK input-output data report a total of £6,556million (£6.5billion) in household spending on the outputs of the UK Refined Fuels sector.

For example, taking the case of 2025, Table 9.2 reports that UK total household demand and expenditure for refined fuel products is projected to decrease by 43% relative to 2010. The direct impact of this is that household expenditure on refined fuels fall by £2821million (43% of the £6,556million base). In order to consider what this means for the wider economy, simple multiplier calculations can be conducted using the various output multipliers initially reported in Table 3.1 (Chapter 3), and decomposed in Chapter 4. In this chapter focus is on overall GDP and employment impacts. However, the impacts on supply chain sectors affected may informed by sectoral level results reported in, for example, Figure 4.2 (GDP requirements embedded in supply chain sectors for Refined Fuels), although it is important to note that this abstracts from own-sector employment in Refined Fuels. The focus in this chapter is on aggregate level results, although attention is drawn to key sectoral level impacts.

Table 9.3 is an abridged version of Table 3.1. It focuses on the value-added, or GDP, and employment multipliers for the Refined Fuels sector, the two hydrogen proxies and also the R&D sector that are the subject of simulations here. GDP and employment are selected as the macroeconomic indicators that are likely be of most interest to policy. However, results could be calculated for output and/or wages.

Reminding the reader that multipliers are stated in terms of impacts per £1million of final demand expenditure, calculating the high level economy-wide impacts simply involves taking the product of the multiplier from Table 9.3 and the change in UK household spending on the sector from Table 9.2. For example, the GDP impact of the £148million reduction in spending in the 2015 column of Table 9.2 is calculated using the 0.33 output-GDP multiplier for Refined Fuels giving the result of a £49million contraction in UK GDP (0.33x148).

Table 9.3 Output multiplier values for selected UK industries.

		Multiplier (activity per £1million final demand)			
SIC	Sector/industry name	Output (£million)	Value-added (£million)	Employment (FTE jobs)	Wage income (GDP) (£million)
19	Refined fuel (Manufacture of coke and refined petroleum products)	1.47	0.33	2.93	0.19
35.1	Hydrogen proxy 1 (Electric power generation, transmission and distribution)	2.56	0.78	8.05	0.32
35.2	Hydrogen proxy 2 (Manufacture of gas; distribution of gaseous fuels)	2.25	0.81	8.04	0.32

Table 9.3 shows the results of conducting this calculation for each of the discreet time periods identified in the projections above. The key results selected are the change in total UK employment, and the value (in £million) of the change in UK GDP, both relative to the 2010 base in each time period simulated. The impact on UK GDP of even a 100% reduction in UK household demand for the output of the Refined Fuels supply sector is relatively small, translating to a 0.17% contraction relative to the 2010 value. Please note that there is no attempt to forecast the general growth path of the UK economy so that the focus of the results is to isolate the impacts of the reduction in spending relative to what the economy would look like with no other changes in UK real GDP. Moreover, note that the input-output model does not consider the implications of any reduced government revenues from spending on refined fuels. This would require a more sophisticated economy-wide model and analysis.

Table 9.4 Economy-wide impacts of change in demand for refined fuels: Effects in different time periods.

Economy-wide impacts of reduction in expenditure for refined fuel							
	2015	2020	2025	2030	2035	2040	2050
% Change in expenditure	-2%	5%	-43%	-82%	-100%	-100%	-100%
Employment (FTE)	-434	913	-8,274	-15,757	-19,225	-19,225	-19,225
Value added (GDP) (£M)	-49	104	-941	-1,793	-2,187	-2,187	-2,187

However, the impact on employment may cause greater public and policy concern. As soon as 2025, 8,274 full-time equivalent (FTE) jobs are lost. The main loser is the Refined Fuels sector itself, with 1,157 FTE jobs lost. However, this is only 14% of the total job losses throughout the UK economy. Losses are felt in every one of the 103 UK input-output industries. The distribution of job losses is given by Figure 6.1, and this impact is largely concentrated in the Refined Fuels industry, where the second biggest loser is the wholesale/retail distribution sector. By 2035, when household spending on the UK Refined Fuels sector disappears all together, total job losses rise to 19,225 FTE posts, and 3,277 of these are in the refined fuel and distribution sectors.

This type of result motivates the focus of the second scenario simulated. People will still need to buy fuels (Figure 9.1 shows little over all drop in fuel use to run cars), it is just the type of fuel that changes. The focus in Scenario 2 is on how much spending on hydrogen is required to absorb the key economy-wide losses reported in Figure 9.3.

9.2.2 Scenario 2: (Partial) reallocation of fuel spend to hydrogen (using proxies)

This scenario considers how much of the reduced UK household spending on petrol/diesel as refined fossil fuels to run cars would have to be reallocated to spending on hydrogen in order that there be a zero net impact at the macroeconomic level from the transition from one fuel type to another. The selected focus in the results reported here is to determine the level of spending reallocation required to deliver a zero net impact on GDP. Modelling experiments revealed that GDP losses are more difficult to compensate than employment losses. Policy and public communities are likely to prefer an outcome where GDP is unchanged but employment rises, rather than no net job gains coupled with even a slight GDP loss.

Table 9.5 shows the results of the simulation where the structure of the current (2010) UK electricity supply sector is taken as a proxy for hydrogen supply. That is the electricity industry multipliers (Table 9.3 above) are applied to the projected spending on hydrogen (the actual electricity sector is assumed to exist independently). Focus in Table 9.5 is limited to 2025 (where first hydrogen spending is present), 2030 (the last time frame before full contraction of refined fuel spending) and 2050. The hydrogen spending required to deliver the net zero GDP impact in each case is calculated by taking the contraction GDP reported in Table 9.4 (e.g. £941million in 2025) and dividing by the output-GDP multiplier of the electricity proxy from Table 9.3 (0.78). The impact on employment associated with spending on hydrogen is are calculated simply by the product of the required change in the final demand proxy (£9,729million in 2025) by the electricity proxy output-employment multiplier from Table 9.3 (8.05). The net impact of the reallocation of spending (1,455 jobs gained in 2025) is calculated by adding the latter result (9,729 FTE jobs in 2025) to the gross losses from the contraction in refined fuel spending (repeated in Table 9.5 as 8,274 jobs in 2025).

The results in Table 9.5 show that net employment gains of up to 3,382 may be delivered by 2050 if sufficient spending is reallocated from refined fuels to hydrogen fuel. Note that the amount of spending required to deliver the zero net impact on GDP in any of the time periods is markedly less than the total amount no longer required for spending on petrol/diesel. For example, in 2025, only £1,208millon of the £2,821million reduction in refined fuel spending needs to be spent on hydrogen (electricity proxy) in order to deliver a zero net impact on GDP (and create 1,455 FTE jobs). The remaining £1.61million is freed up to spend either on more hydrogen (and the projections in Figure 9.1 suggest more spending would be made/required) or on other goods and services, or a combination of both. The key point is that there will be an additional spending and, as long as this has at least some UK component (rather than being entirely imported) there will be further positive impacts on GDP and employment.

Table 9.5 Summary of Scenario 2 results – Hydrogen proxy 1 (electricity supply).

Electricity proxy			
Summary of scenario 2 results	**2025**	**2030**	**2050**
% decrease in expenditure on refined fuels	-43%	-82%	-100%
Change in spending on refined fuel (£million)	-2,821	-5,373	-6,556
Change in GDP from contraction in refined fuel spending (£million)	-941	-1,793	-2,187
Change in employment from contraction in refined fuel spending (FTE jobs)	-8,274	-15,757	-19,225
Required spending on hydrogen proxy (£million)	1,208	2,301	2,808
Gross impact on employment from spending on hydrogen proxy (FTE jobs)	9,729	18,528	22,607
Net impact on GDP from fuel spending reallocation (£million)	£0	£0	£0
Net impact on employment from fuel spending reallocation (FTE jobs)	1,455	2,772	3,382
Freed up funds for spending on hydrogen or other goods and services (£million)	1,613	3,072	3,748

However, an important qualification regarding the use of the electricity proxy (and corresponding gas one below) detailed in Section 4.3 of Chapter 4 must be noted. The supply chain jobs (and GDP) in the proxies include jobs in the UK off-shore oil and gas extraction sector. If the resource used to produce hydrogen is not one that would be extracted by the UK off-shore industry (SIC 6) then the employment and value-added components of the impacts calculated using either electricity or gas proxies will be reduced. For example, in 2050, 199 of the 22,607 gross jobs created by spending on hydrogen are located in the off-shore oil and gas sector.

As noted elsewhere employment and money figures make no account of the additional 'HFC layer' directly involved in hydrogen production itself or of its likely more distributed nature. Figures given are likely to be significantly underestimated relative to those which might be obtained from a more sophisticated model. They do however indicate the direction of travel.

Table 9.6 Summary of Scenario 2 results – Hydrogen proxy 2 (gas supply).

Gas proxy			
Summary of scenario 2 results	**2025**	**2030**	**2050**
% decrease in expenditure on refined fuels	-43%	-82%	-100%
Change in spending on refined fuel (£million)	-2,821	-5,373	-6,556
Change in GDP from contraction in refined fuel spending (£million)	-941	-1,793	-2,187
Change in employment from contraction in refined fuel spending (FTE jobs)	-8,274	-15,757	-19,225
Required spending on hydrogen proxy (£million)	1,169	2,226	2,716
Gross impact on employment from spending on hydrogen proxy (FTE jobs)	9,395	17,892	21,830
Net impact on GDP from fuel spending reallocation (£million)	0	0	0
Net impact on employment from fuel spending reallocation (FTE jobs)	1,121	2,135	2,605
Freed up funds for spending on hydrogen or other goods and services (£million)	1,652	3,147	3,840

In Table 9.6 a corresponding set of results are shown if the gas proxy is used for a potential hydrogen supply sector rather than the electricity one above. The key point to note is that the gas proxy has a larger output-GDP multiplier than the electricity proxy (0.81 compared to 0.78). This means that a smaller reallocation of spending to hydrogen (e.g. £1,169million in 2025) is required to deliver a zero net impact on GDP. However, this also means that a smaller net boost to employment (1,121 FTE jobs in 2025) is associated with the required reallocation of spending (the gas and electricity employment are almost the same at 8.04 and 8.05 respectively). However, this simply means that more funds (£1,652million in 2025) are freed up to spend on other things.

9.3 CONCLUSIONS

In the absence of appropriate information to inform fuller simulation analysis using the economic input-output models of changes in projected expenditure on hydrogen fuels, this chapter has focussed instead on considering the amount of hydrogen spending that would be required to absorb any GDP losses arising from contracted household spending on petrol/diesel. The results show that it is likely that only a partial reallocation of previous spending on refined fossil fuels would be required to compensate GDP losses and deliver an employment boost. **This is because of the stronger domestic up-stream supply chain linkage associate with a hydrogen supply sector that shares characteristics of the current UK gas and electricity supply proxies.** In short, as long as hydrogen supply is less import-intensive and has relatively strong domestic linkages, it is likely that any fuel switch will deliver gains at the economy-wide level.

However, it is important to note that there are likely to be sectoral 'losers'. In Chapter 4, Section 4.4, input-output modelling results suggested that only around three or four (out of 103) UK industries would suffer net losses in terms of output, GDP (and the same is true of employment). However, this was in terms of considering a pound for pound reallocation spending. In this chapter, the key result is that the compensating (at economy-wide level) hydrogen spend would be less than one pound for every pound lost to refined fuel. Therefore, the number of UK industries losing out is likely to be greater. However, the largest overall losses should be expected in the Refined Fuels industry itself: again, a key point to note is that the modelling results here suggest that the petrol/diesel to hydrogen fuel switch will free up income to spend on other things, and these in turn (depending on where money is spent) will have positive multiplier effects throughout the UK economy.