Energy Efficiency, Rebound and Societal Welfare

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KAPSARC Workshop on Modelling Energy Demand and Efficiency

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Project title: 'Energy Saving Innovations and Economy-Wide Rebound Effects'

Working with the [EPSRC EUED] Centres – working with Centre for Innovation and Energy Demand, Sussex and Fraser of Allander Institute, Strathclyde

Overview

- What is rebound and why does it matter?
- Policy perspective: potential multiple benefits of energy efficiency
- Modelling multiple economic, distributional and energy use impacts using CGE techniques
- Example 1: decoupling economic expansionary and economy-wide rebound effects of increased energy efficiency in public transport
- Example 2: asymmetric rebound across different household income groups for different types of energy efficiency
- Directions for future research

What is rebound and why are we so concerned about it?

$$R = \left(1 - \frac{AES}{PES}\right) x100$$

- Determined by ratio of **actual energy savings** to **potential energy savings** following an **energy efficiency** improvement
- PES generally stated in terms of potential **engineering or technical savings**
- Increase efficiency by 10%, require 10% less physical energy input to produce same level of production output or consumption utility
- AES depends on focus – direct rebound just energy use of more efficient user; economy-wide rebound is all energy use across economy

First question: why would we expect to realise full PES?

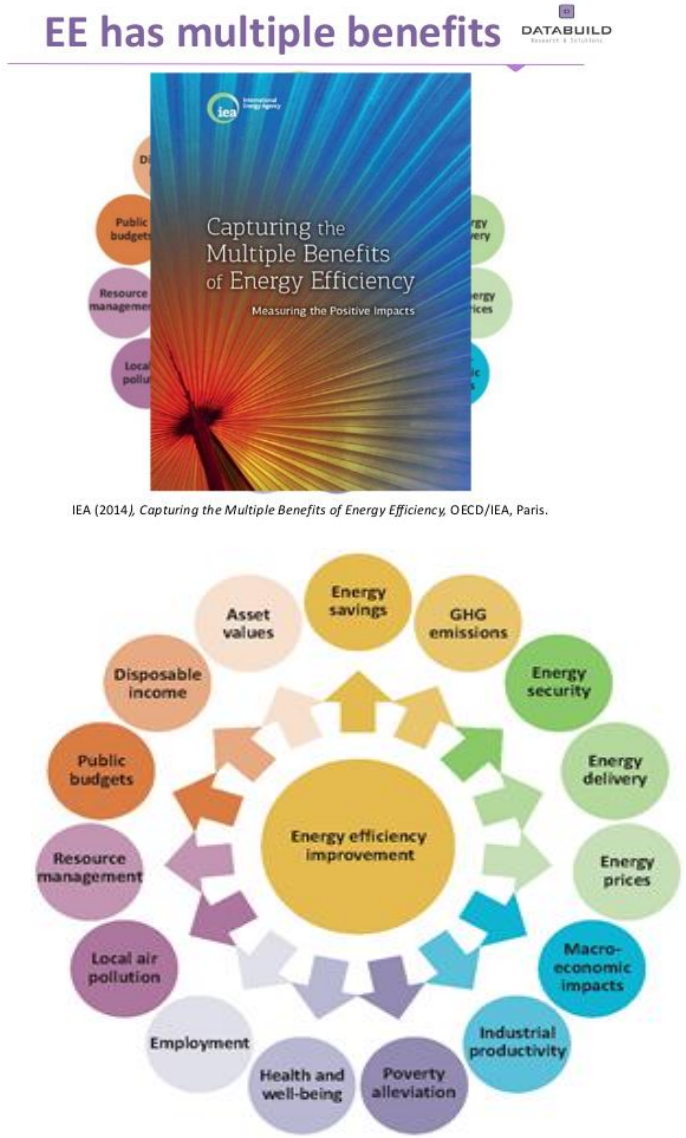
- Rebound triggered by fact that reduced physical energy requirement **reduces price of delivering *energy service***
  - Translates to considering energy in efficiency units, effective price of energy is the price using energy to deliver a given output (the energy service)
- **Direct rebound**
- But will trigger series of economic responses
- Zero rebound would imply no economic response whatsoever
- So would PES equate to **expected energy savings**?
- We wouldn't expect zero economic response with any other efficiency improvement, e.g. labour efficiency?

Why does rebound matter?

- The rebound process is driven by economic responses
- What is the objective function of energy efficiency initiatives/policy?
- To increase welfare?
- To reduce energy use?
- To reduce associated carbon emissions?

Policy perspective

- Primary aim of energy efficiency policy is to reduce energy use and emissions
- But policymakers tend to operate in context of multiple objectives
- Likely to welcome economic benefits that drive rebound
- **But need to know what energy savings will be delivered**
- **And where in the economy energy use and emissions may rise or fall**



Modelling economy-wide rebound using CGE techniques

- Multi-sector economy wide computable general equilibrium models the most commonly adopted method for considering economy-wide rebound
  - *Ex ante – ex post* (historical) analyses often conducted using econometric methods
- Key benefit of CGE – focus on causal process, importance of interactions between sectors and markets
- Assess in context of wide range of economic and energy use impacts
- Distributional impacts where identifying different household income groups
- Useful for ‘multiple benefits’ context that may concern policy

Our UK CGE model, UKENVI

- Multi-sector economy-wide CGE model of the UK national economy
- 2010 social accounting matrix
- 30 production sectors producing 30 outputs
- Here, government expenditure exogenous and no BOP or government budget constraint
- Competitive goods markets
- One exogenous region – rest of the world (ROW)
- UK and ROW products imperfect substitutes (Armington assumption) and export demand responds to changes in prices

Our UK CGE model, UKENVI

- Here, recursive dynamic/myopic adjustment process
  - option for fully intertemporal adjustment, perfect foresight
- Investment responds to return on capital at sectoral level (share of gap actual and desired in each period)
- Initially, labour supply fixed at national level, with pool of unemployed labour and real wage bargaining process (negatively related to unemployment)
- Sensitivity analysis allowing flow migration (relative wage, +ve, and unemployment rate, -ve, differentials UK and external labour market)
- To consider maximum macroeconomic expansion
- Key focus sensitivity analysis in first example – impact of varying substitutability between Private Transport and Road and Rail in household consumption decision (0.5 in central case; vary 0.1→1.1)

Fig. 1. New household consumption structure in our UKENVI multi-sector economy-wide CGE model

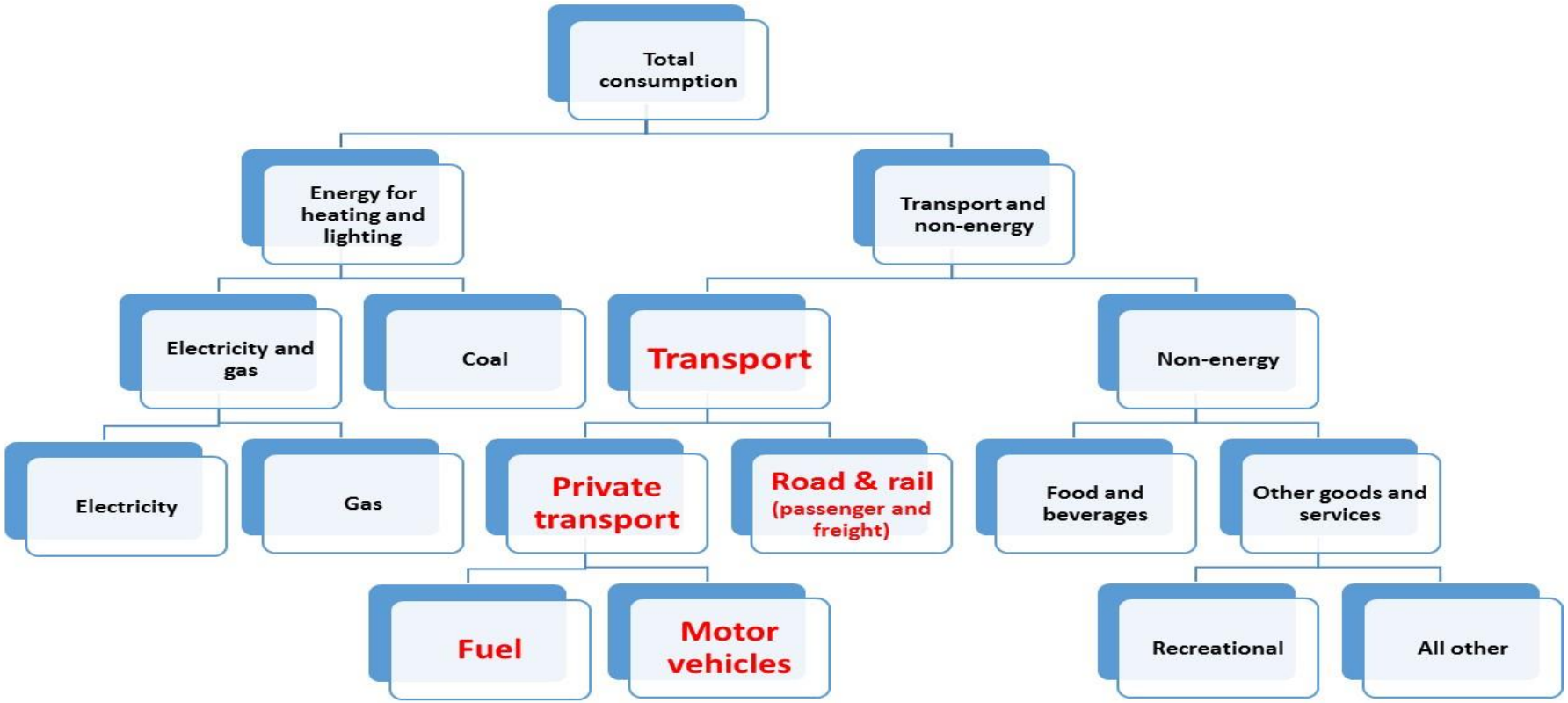
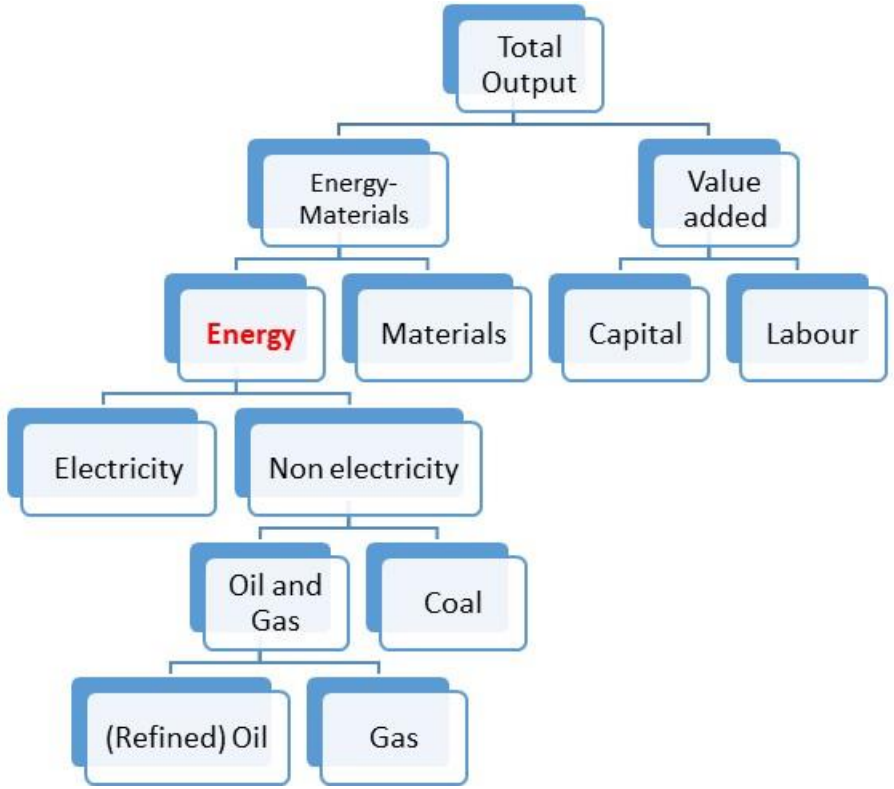


Fig. 2. KLEM production structure in our UKENVI multi-sector economy-wide CGE model



Question: can we decouple economy-wide rebound and economic expansion?

- Economy-wide rebound driven by same processes as economic expansion
- Does this make rebound a necessary ‘evil’?
- ***Can we reduce rebound without sacrificing macroeconomic benefits of increased energy efficiency?***
- Focus of energy efficiency often simply on the most energy intensive activities
- ***What if we increase energy efficiency in something that is a competitor for a relatively energy-intensive activity?***

Public vs. private transport?

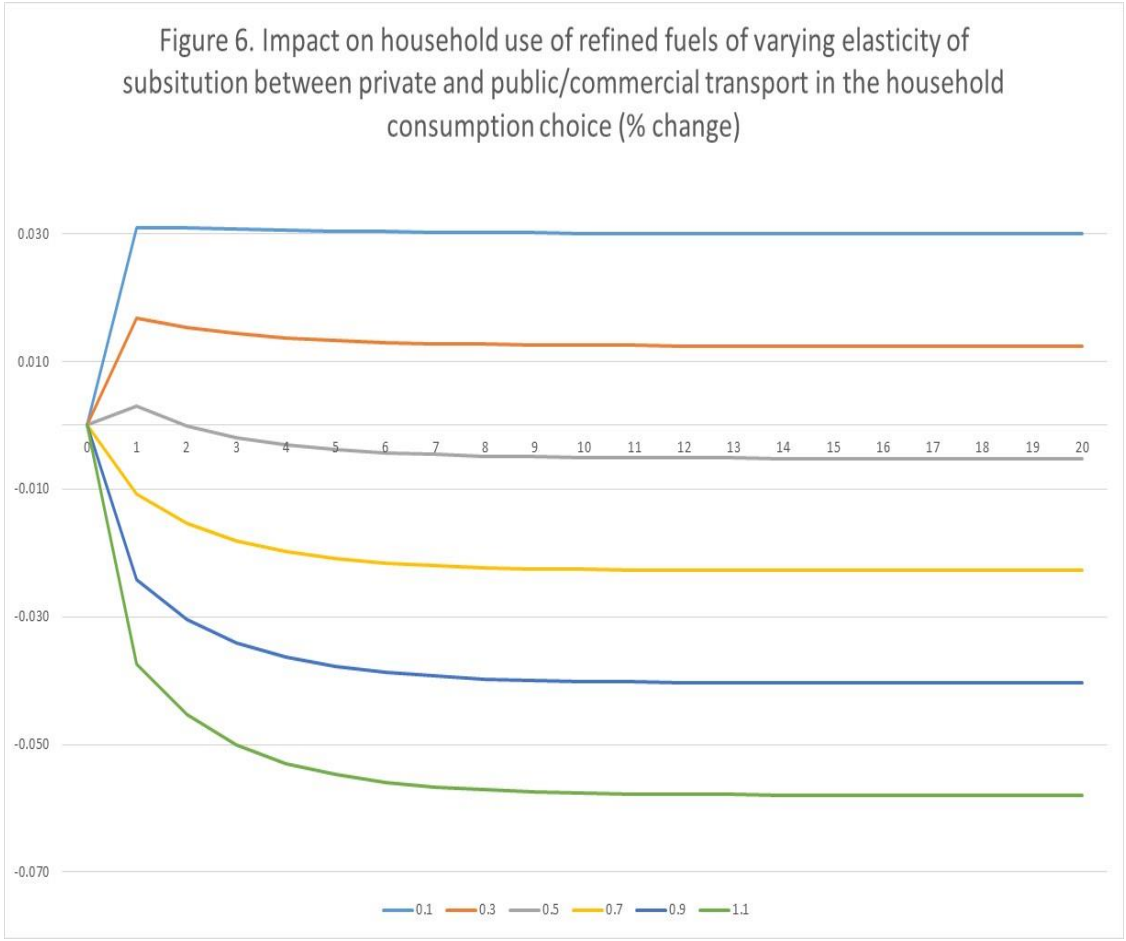
- UK CGE model - increase energy efficiency in ‘Road and Rail Transport’ (UK IO sector – freight and public transport)
- Macro level benefits
- At sectoral level, get increased competitiveness public transport relative to private transport in household consumption choice
  - Impact on transport activity and economy-wide rebound depends on one key parameter
  - **Elasticity of substitution between public and private transport in household consumption decision**

Table 1. Macroeconomic and key energy use impacts (%) of a 10% increase in energy efficiency in the 'Road and Rail ' industry (central case scenario)

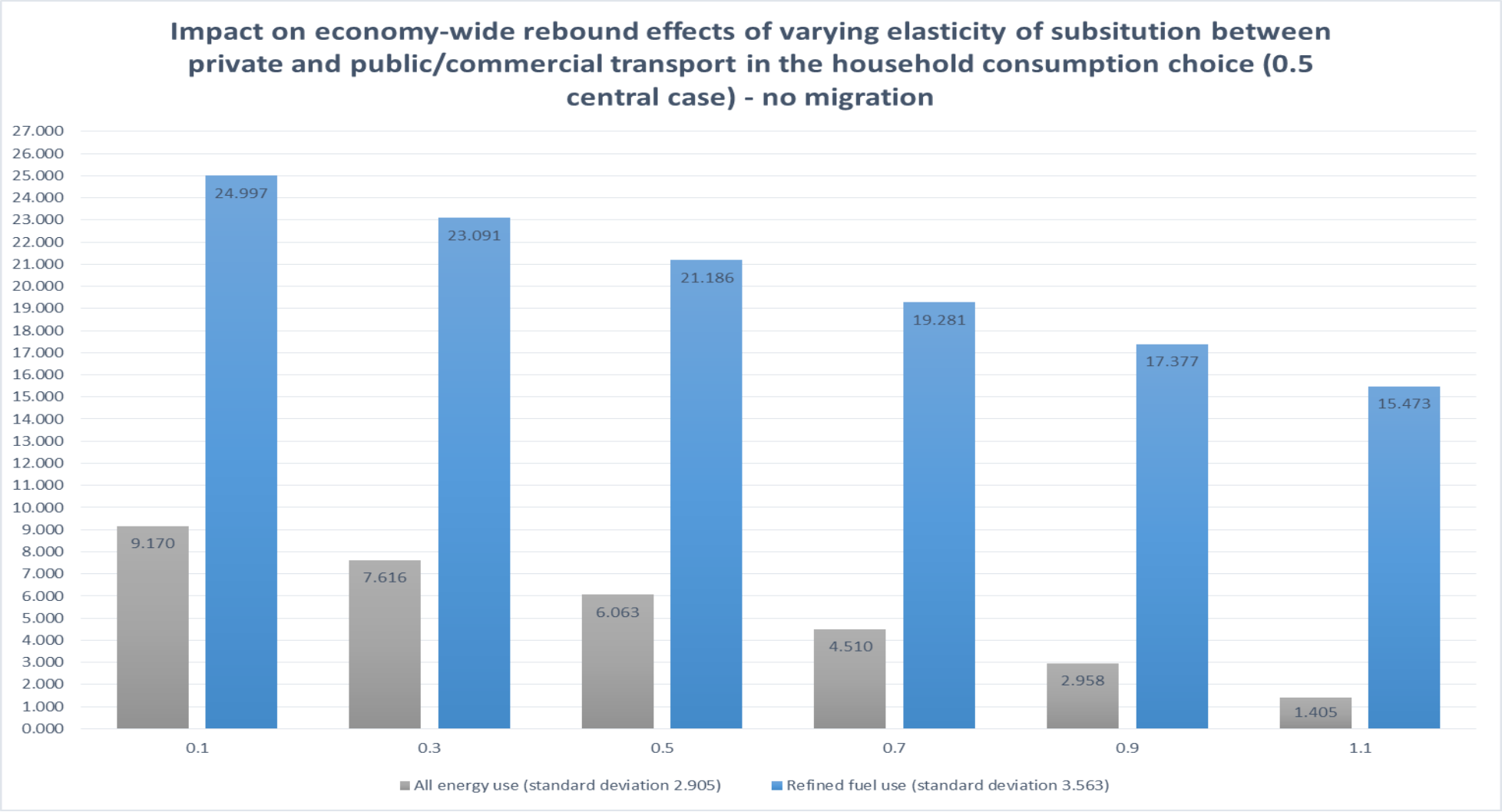
	Short run	Long run	
		No migration	Flow migration
GDP	0.004	0.011	0.038
Consumer Price Index	0.005	-0.007	-0.021
Unemployment Rate	-0.102	-0.146	0.000
Total Employment	0.007	0.009	0.036
Nominal Gross Wage	0.015	0.008	-0.021
Real Gross Wage	0.010	0.015	0.000
Labour supply	0.000	0.000	0.036
Replacment cost of capital	0.002	-0.009	-0.022
Investment	0.033	0.014	0.041
Capital Stock	0.000	0.014	0.041
Household Consumption	0.014	0.014	0.025
Household Income	0.013	0.015	0.025
Share of household income spent on energy	0.002	-0.007	-0.008
Gov deficit	-0.067	-0.085	-0.199
Export REU	-0.012	0.006	0.030
Export ROW	-0.014	0.006	0.032
Energy price	-0.005	-0.003	-0.014
Energy Productivity (GDP/energy use)	0.080	0.090	0.090
Energy use in households	0.015	0.008	0.017
Energy use in Industry	-0.119	-0.121	-0.095
Total energy use in UK	-0.082	-0.085	-0.064

Public vs. private transport?

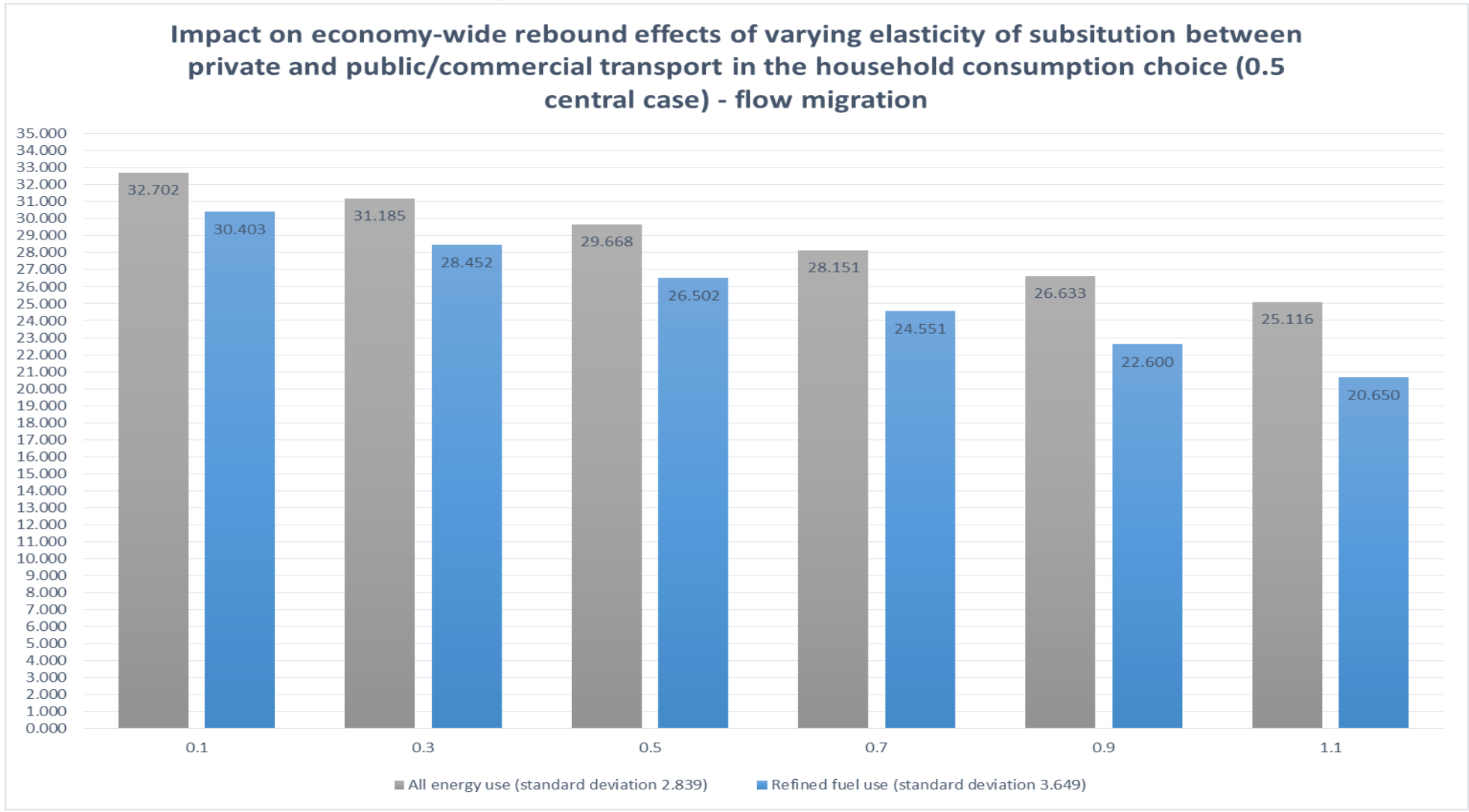
- When set very low, due to increased income, households increase use of both public and private transport
- Result for no migration case shown opposite
- As increase, demand for cars and refined fuels falls from outset



Key result from current EPSRC project – we can decouple!



With full macro expansion – bigger economy-wide rebound, but we can still decouple



A multi-disciplinary, multi-dimensional policy challenge

- Pathway to the low carbon economy: changing the ***composition of activity*** with directed energy (and other) efficiency improvements acting as driver/enabler
- TECHNOLOGY (DEVELOPMENT AND AVAILABILITY) – making public transport more energy efficient and widely available
- BUSINESS/MARKETS – ensuring efficiency improvements translate through prices to increased competitiveness
- USER BEHAVIOUR – getting people to respond to changes in relative prices
- Will same lessons apply to other cases in 'dematerialisation' agenda, e.g. electrification of heat and transport, shift from coal/oil to gas, or gas to hydrogen, and so on
  - Rebound in energy becomes less important than carbon intensity?

Question: do low income households benefit and rebound more from increased energy efficiency?

- Trying to capture fuel poverty issues by considering what happens to the share of income different household income groups spend on energy
- Rebound? If low income households are more energy intensive in their spending they may gain most in terms of income effects, but may also rebound more in their electricity and gas use
- ESRC/CEP funded PhD student (Gioele Figus) has looked at using a Scottish regional CGE model (2010 Scottish SAM)
- Key finding – depends on what type of energy use households improve their efficiency in
- E.g. gas use in heating homes or refined fuel use in personal transport

HG1	HG2	HG3	HG4	HG5
up to £32.0K	£32.1K - £41.0K	£41.1K - £52.0K	£52.1K - £69.0K	£69.1K and over

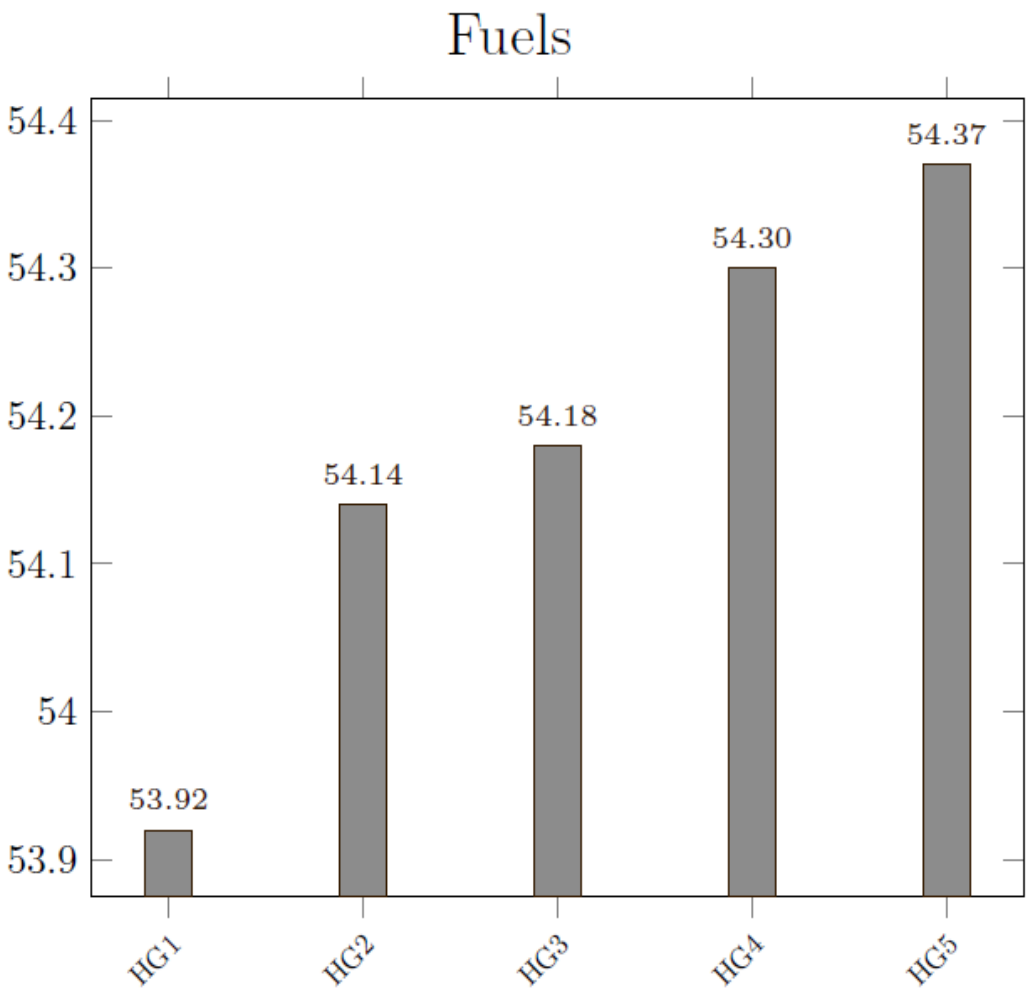
Shares of fuels consumption in total energy use and total consumption

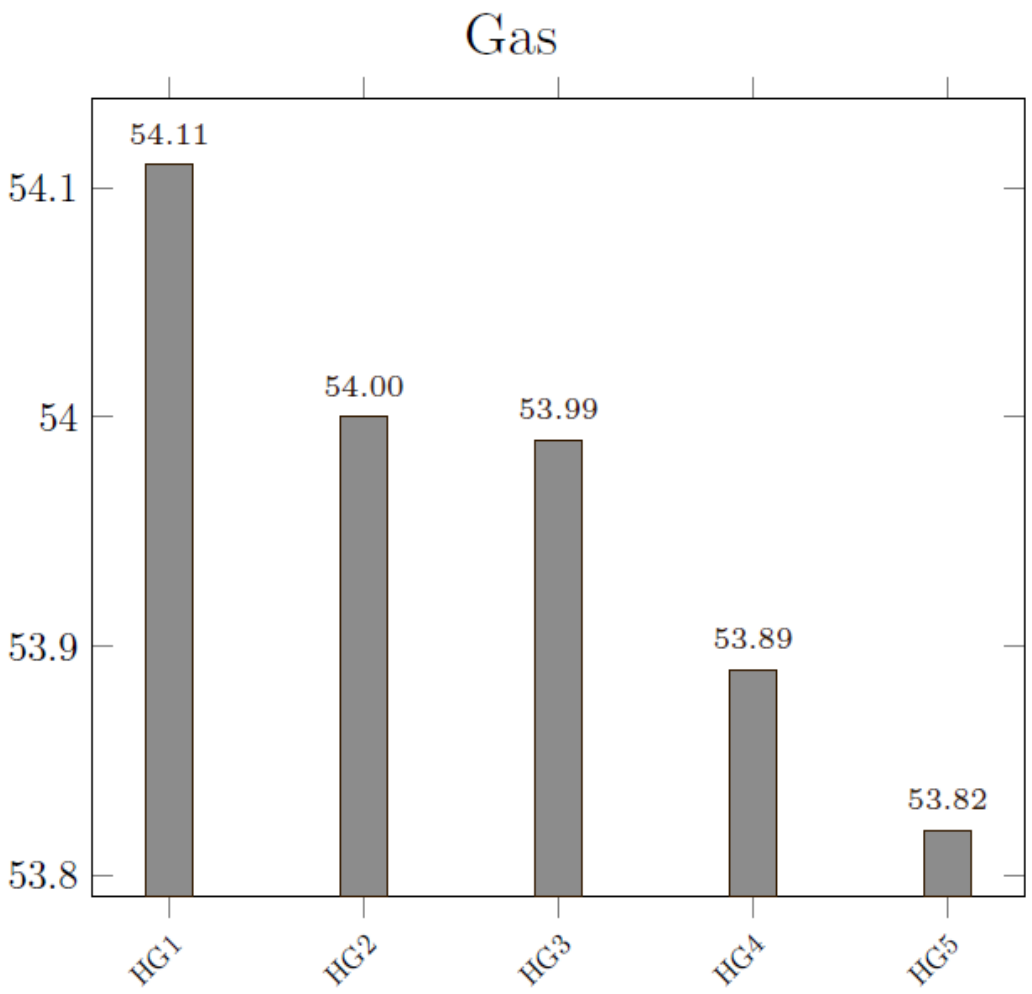
	HG1	HG2	HG3	HG4	HG5
Fuels/Tot Ene	10.0%	16.8%	17.1%	23.4%	29.4%
Fuels/Tot Con	0.88%	1.30%	1.25%	1.39%	1.47%

Shares of gas consumption in total energy use and total consumption

	HG1	HG2	HG3	HG4	HG5
Gas/Tot Ene	15.9%	14.5%	14.3%	12.9%	11.6%
Gas/Tot Con	1.39%	1.13%	1.04%	0.77%	0.58%

Asymmetric rebound effects for across different household income groups





Pending issues for future energy efficiency/rebound research?

Fundamental issue - *ensuring rebound research is policy relevant research*

1. Less focus on how a single rebound 'indicator' should be measured and more on reporting what policymakers need to know ***and pay attention to*** in considering impacts of rebound mechanisms
2. Need to drawing on insights from and work across multiple disciplines
   - Not just a problem for economists
   - Though lack of attention particularly to macroeconomic/fiscal implications of different technological solutions is problematic in terms of gaining policy traction (optimisation not sufficient!)

Our own immediate future research priorities

My thoughts on priorities for energy efficiency and rebound research

1. **Role of energy supply supply**
   - Continuing lack of attention to energy supply responses (rebound literature)
   - Including implications of imperfect competition, price-setting behaviour

2. **Role of capital/durable goods**
   - 'Exogenous and costless' assumption in most rebound research
   - Focus of debate on costs of investment and how impacts (or not) rebound
   - Key question – what if energy efficiency improvement is embedded in a capital or durable good?
   - E.g., fuel use and cars in providing private transport services and household energy efficiency

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Thank you for listening

Questions?

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EPSRC project web-site:
http://cied.ac.uk/research/impacts/energysavinginnovations

Personal web-site (papers): http://www.strath.ac.uk/staff/turnerkarenprof/