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Beyond direct rebound: too complex a story for a single measure?

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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

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

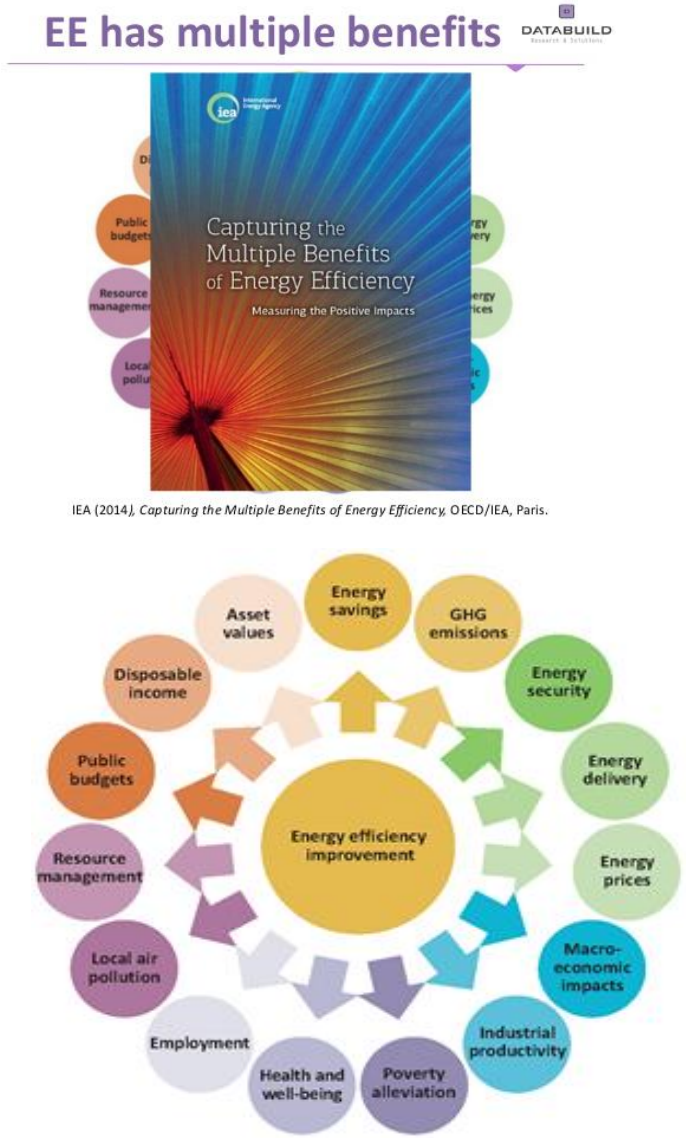
- Rebound triggered by fact that reduced physical energy requirement **reduces price of delivering *energy service***
  - Translates to considering energy in efficiency units, effective price of energy is the price using energy to deliver a given output (the energy service)
- **Direct rebound**
- But 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**



Direct rebound

- Even in context of direct rebound, there is a need to take welfare considerations into account
- Direct rebound studies have tended to focus on demand response to reduced price of a given energy service
- See Chan and Gillingham (2015) – introduce consideration of multiple fuels and multiple energy services in context of underlying consumer preferences
- Also Borenstein (2015) but with focus on how substitution between more and less energy intensive goods may produce negative rebound
- May be argued latter going beyond direct rebound
- **Problem with rebound taxonomies** (Turner 2013)

Substitution and rebound from ‘re-spending’ effects

- Energy embedded in supply chains of different types of goods/services
- Recent growth in use of **input-output** methods to consider impacts of reallocating spending away from energy use subject to (household) efficiency improvement
- But often a lack of clarity in how rebound is measured

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

- Guerra and Sancho (2010) – a general equilibrium measure of rebound should include reduced requirements on energy use embedded in energy supply chain in PES

Variation in rebound results – Turner and Katris (2016) experiment using WIOD data (Timmer et al., 2015)

Table 1. Changes in energy use and CO2 emissions associated with a 10% reduction ($5,525.8m) in UK household use of UK EGWS outputs

	Energy use (terajoules)	Related CO2 (kilotonnes)
A. Reduction in direct energy use by UK households	-152,591	**-6,172**
Reductions in energy use in UK EGWS supply chains:		
Total multiplier effect per $1m spend:	*38.14*	*1.89*
B. Direct - own-sector *(25.9tj/1.26kt per $1m)*	-143,142	-7,777
C. Indirect - own-sector *(8.33tj/0.41kt per $1m)*	-46,040	-2,501
D. Indirect - other UK *(1.06tj/0.08kt per $1m)*	-5,878	-471
Sub total UK	**-195,060**	**-10,749**
E. Indirect - outside of UK *(2.84tj/0.15kt per $1m)*	-15,713	-926
Global total	**-210,773**	**-11,675**
Total reduction in UK energy use	**-347,651**	**-16,921**
Total reduction in global energy use	**-363,364**	**-17,847**

Variation in rebound results – Turner and Katris (2016) experiment

Table 2. Reduction in EGWS spend: indirect rebound calculation [R= 1-(AES/PES)*100]

	Energy use	CO2
Actual energy savings (AES):		
UK level	347,651	**16,921**
Global level	363,364	**17,847**
Potential energy savings and indirect rebound:		
1. Guerra and Sancho (2010) - all included in PES		
UK level:		
PES (A, B, C, D)	347,651	16,921
Rebound	**0%**	**0%**
Global level		
PES (A, B, C, D, E)	363,364	17,847
Rebound	**0%**	**0%**
3. Turner (2013) - only household direct saving included in PES		
UK level:		
PES (A)	152,591	**6,172**
Rebound	**-128%**	**-174%**
Global level:		
PES (A)	152,591	**6,172**
Rebound	**-138%**	**-189%**

Variation in rebound results – Turner and Katris (2016) experiment

Table 3. Changes in energy use and CO2 emissions associated with reallocation of $5,525.8 spending between UK EGWS and Hotels & Restaurants outputs

	Energy use (terajoules)	Related CO2 (kilotonnes)
Increases in energy use in UK Hotels and Restaurants supply chain:		
Total multiplier effect per $1m spend:	*2.84*	*0.14*
F. Direct - own-sector *(0.41tj/0.02kt per $1m)*	2,287	101
G. Indirect - own-sector *(0.001tj/0.000kt per $1m)*	6	0
H. Indirect - other UK *(1.48 tj/0.94kt per $1m)*	8,199	413
Sub total UK	**10,492**	**514**
I. Indirect - outside of UK *(0.94tj/0.05kt per $1m)*	5,218	279
Global total	**15,711**	**794**
Net increase/decrease in UK and global energy use:		
Change in direct energy use by UK households (A)	-152,591	-6,172
EGWS shock - change in direct EGWS energy use (B)	-143,142	-7,777
All other change UK energy use in UK (C, D, F, G, H)	-41,426	-2,458
Net at UK level	**-337,159**	**-16,406**
Change in energy use outside of UK (E and I)	-10,495	-646
Net at global level	**-347,654**	**-17,053**

Variation in rebound results – Turner and Katris (2016) experiment

Table 4. Reallocation of UK EGWS spend to UK Hotels and Restaurants: indirect rebound calculation [R= 1-(AES/PES)*100]

		Energy use	CO2
Actual energy savings (AES):			
	UK level	337,159	**16,406**
	Global level	347,654	**17,053**
Indirect rebound:			
1. Guerra and Sancho (2010) - all included in PES			
	UK level:	3%	**3%**
	Global level:	4%	**4%**
3. Turner (2013) - only household direct saving included in PES			
	UK level:	-121%	-166%
	Global level:	-128%	-176%

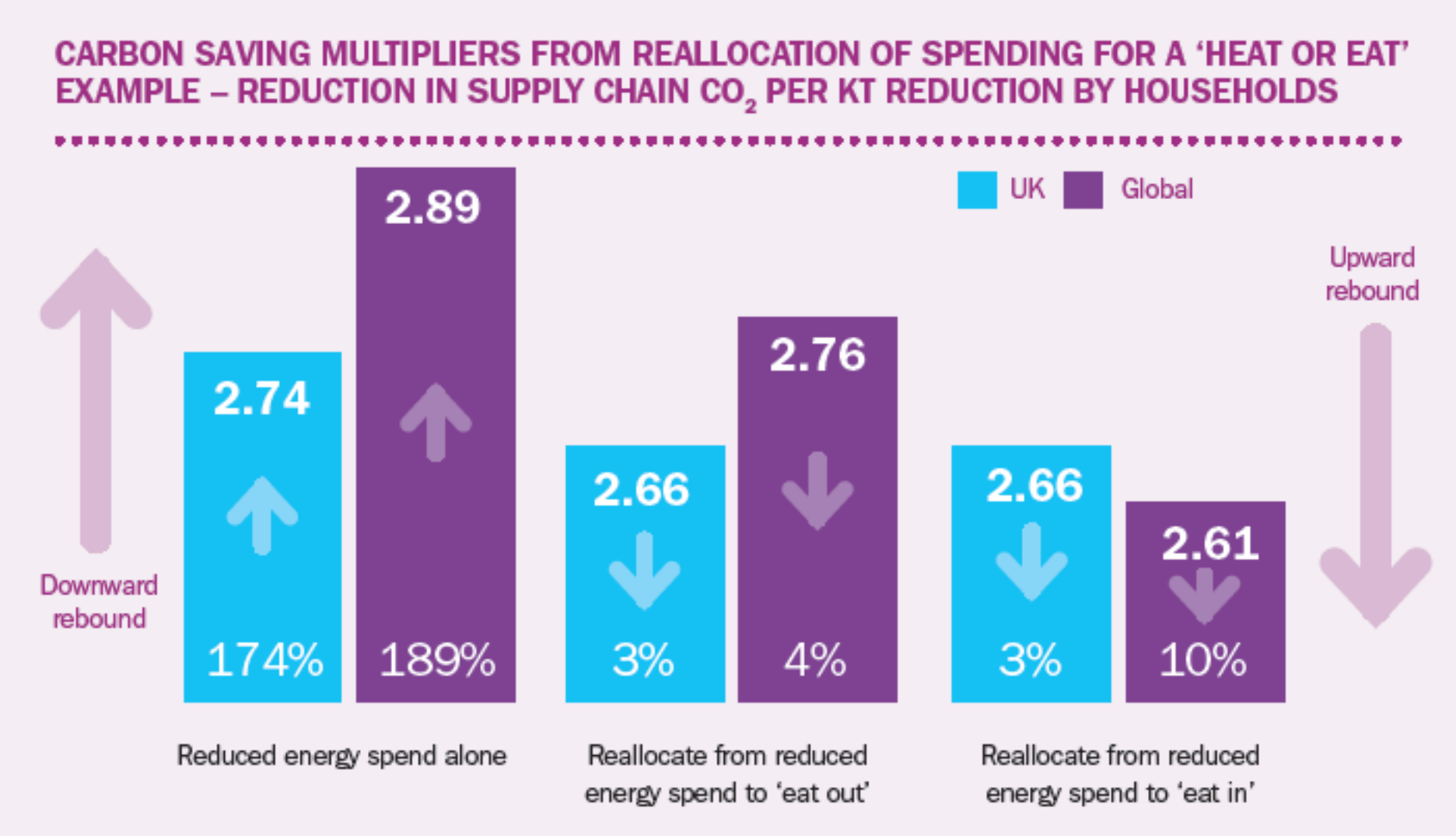
Information for policy analysts?

- Issue – discrepancy in rebound results for the **same changes in energy use** and both worked out for a case where we have ***net energy savings***
- Issue – rebound regarded as a ‘negative’, a ‘bad’ thing for energy efficiency policy
- Can we present the information in a more useful way?
- Consulted group of policy analysts – outcome, focus on use of **multipliers**
- Energy or carbon **saving** multiplier: (direct + indirect effects/direct effects)
- **A ‘positive’ (net energy savings) eroded by a ‘negative’ (positive rebound in re-spend)**

Information for policy analysts?

- Multiplier focuses on physical savings across all areas/sectors of the economy per unit of direct saving in household energy use
- Equates to AES/PES component of rebound if PES is household savings only (here no direct rebound)
- For case above
- Reduction in energy spend alone
  - At UK level CSM = 16,921/6,172 = 2.74
- Reallocation to ‘hotels and restaurants’ (‘eat out’)
  - At UK level CSM = 16,406/6,172 = 2.66

EPSRC project policy brief



More general problem with single rebound measure

- Aside from lack of clarity on how rebound is calculated, comparability across different studies
  - Both in terms of what is measured, how and case specific determinants
- Particularly in case of full economy-wide rebound
  - (Economy-wide rebound - how all energy use in the economy is impacted by a change in energy use in one specific sector, one specific type of energy use)
- Determined by a range of economy-specific factors
  - Also question of how we define 'the economy'
- And range of mechanisms that may cause positive or negative rebound effects - van den Bergh (2011) identifies 14 mechanisms
  - Including international trade effects: Koesler et al. (2016) find global rebound < national rebound due to changes in comparative advantage
- What is captured by model being used?

Example: ‘disinvestment’ in energy supply

- One potential energy supply response is ‘negative multiplier’ effect captured in fixed price input-output model
- We identify a second – a ‘disinvestment’ effect (Turner, 2009)
- If energy supply revenues fall with demand
- Decreased return to capital
- May mothball or reduce capacity
- Tightening energy supply conditions will put upward pressure on output price
  - Local ‘energy’ prices matter – we don’t consume crude oil – where there is local capacity and constraints on capacity
- Dampening economy-wide rebound over time

Example: ‘disinvestment’ in energy supply

- Disinvestment a necessary but not sufficient condition to cause economy-wide rebound to be bigger in the short-run than in long-run
- Contradicts Wei (2007) and Saunders (2008) predictions that economy-wide rebound will always be bigger in the long-run (as capacity constraints relax)
- Crucial: models of Wei and Saunders assume return to capital is fixed and exogenously determined
- **Just one element of model specification**

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 economic impacts
- Brings us back to ‘multiple benefits’ issue that concerns policy

Decoupling 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?

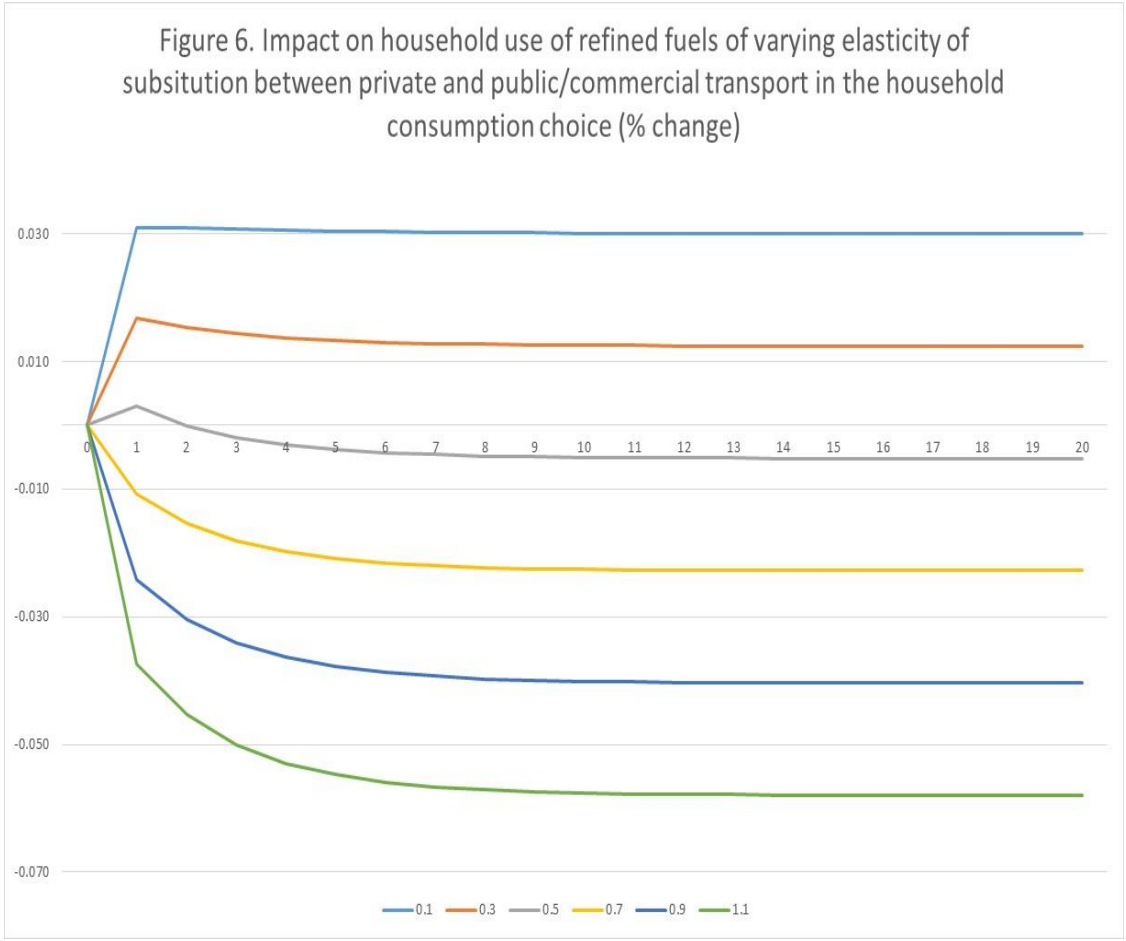
- UK CGE model - increase energy efficiency in ‘Road and Rail Transport’ (UK IO sector – freight and public transport)
- Macro level benefits
- At sectoral level, increased competitiveness public transport relative to private transport in household consumption choice
- Impact on transport activity and 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)

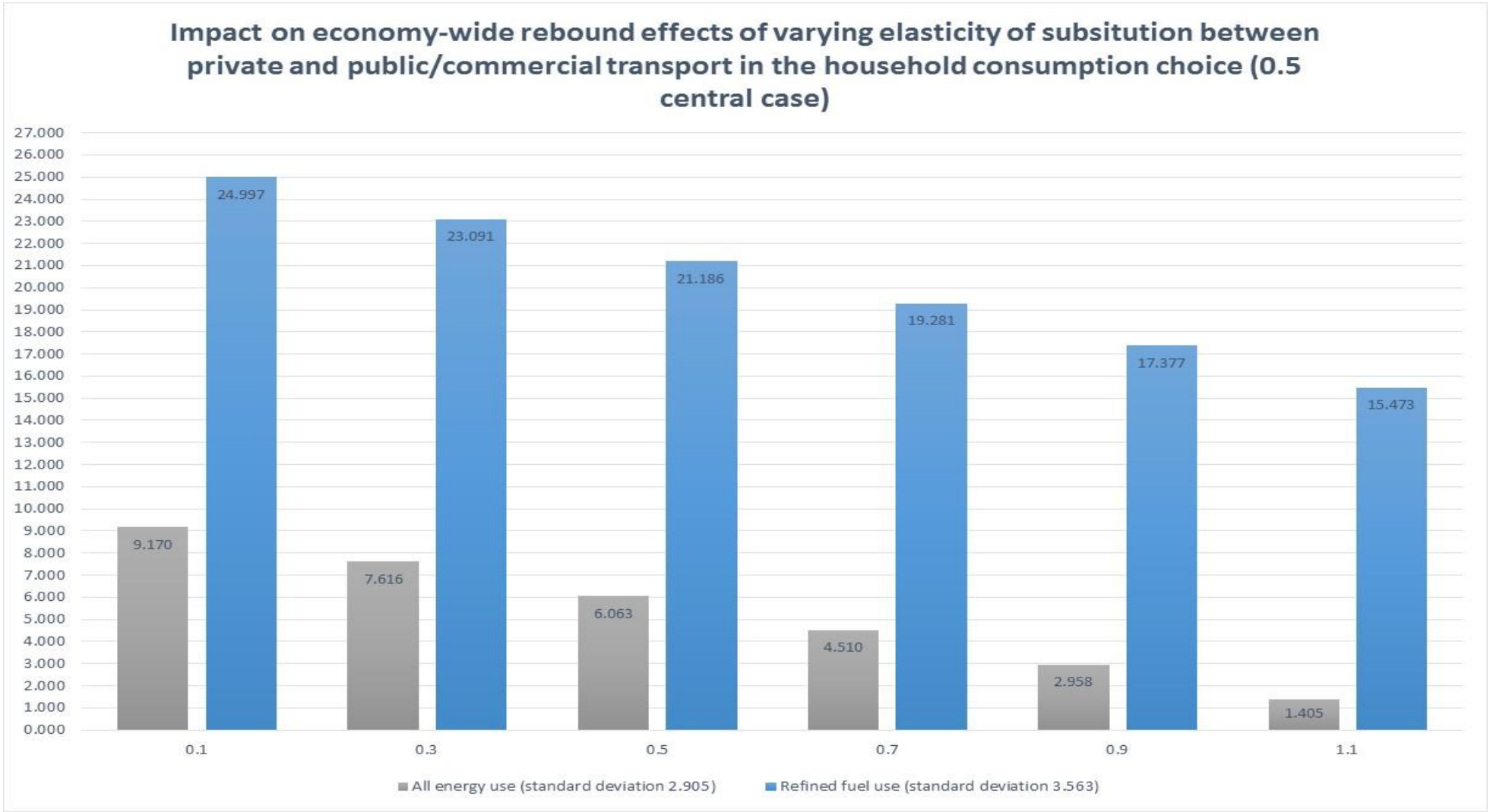
	Short run	Long run	
		No migration	Flow migration
GDP	0.004	0.011	0.038
Consumer Price Index	0.005	-0.007	-0.021
Unemployment Rate	-0.102	-0.146	0.000
Total Employment	0.007	0.009	0.036
Nominal Gross Wage	0.015	0.008	-0.021
Real Gross Wage	0.010	0.015	0.000
Labour supply	0.000	0.000	0.036
Replacment cost of capital	0.002	-0.009	-0.022
Investment	0.033	0.014	0.041
Capital Stock	0.000	0.014	0.041
Households 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

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!



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
- *Our* next challenge: will same lessons apply to other cases, e.g. electrification of heat and transport?

Pending issues?

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!)

Pending issues?

My thoughts on priorities for research

1. **Energy supply**
   - Continuing lack of attention to energy supply responses
   - Including implications of imperfect competition, price-setting behaviour

2. **Role of capital/durable goods**
   - 'Exogenous and costless' assumption
   - 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?
   - Relevant to our public vs. private transport study….and more generally

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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/