Incorporating Social Influence Effects in Global Energy-Economy Models

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BE4 Workshop

London, April 2015

Tyndall°Centre®
for Climate Change Research

ADVANCE

Advanced Model Development
and **Validation** for the **Improved**
Analysis of **Costs** and **Impacts**
of **Mitigation Policies**

Improving **behavioural realism** of global energy-economy models: model-pull or evidence-push

model   < - - - -   observed behaviour

=

observed behaviour   - - - - >   model

?

(1) What 'behavioural features' are there?

(2) Are behavioural features included in models?

(3) Is there robust evidence for behavioural features?

(4) Is there a conceptual basis for behavioural features?

(5) How strong is effect of behavioural features?

(6) How can behavioural features be modelled?

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Many **features** of human **behaviour** could be modelled to improve mitigation **policy analysis**

Typology of 'behavioural features' (relating to energy demand)

- **decision making:** e.g., non-monetary preferences, non-optimising heuristics
- **social influences:** e.g., imitation, conformity, status, social networks
- **contextual influences:** e.g., infrastructure, governance, culture

and an enabler

- **heterogeneity:** e.g., end-user preferences

'behavioural features' =
anything beyond price-responsiveness under income constraints
(or: a narrowly financial utility maximiser)

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Global energy-economy models analyse **long-term** climate change mitigation potentials, costs …

Energy-Economy Models
Complete the crossword below
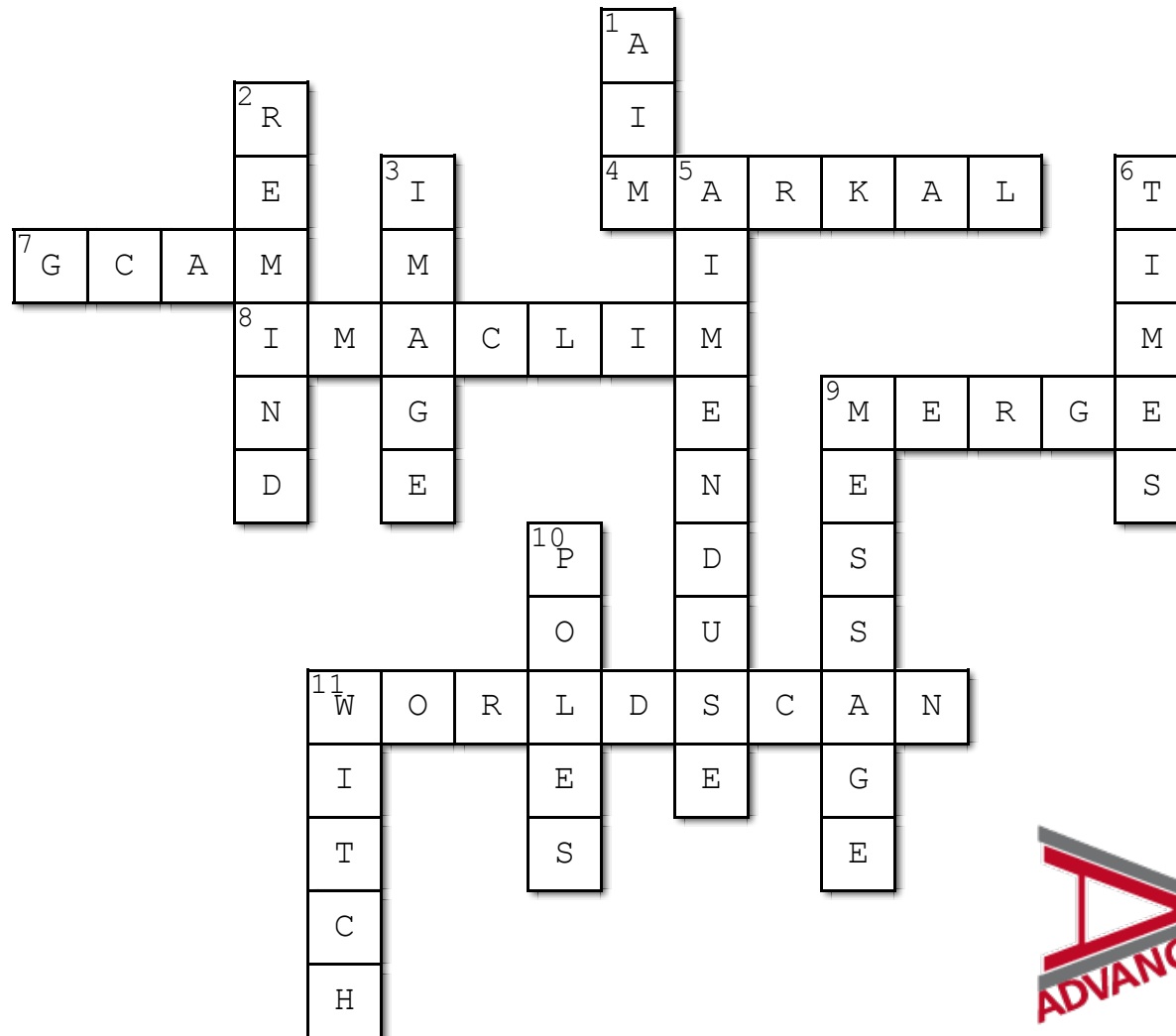
many differences between models

technological resolution & endogenous technical change

macroeconomic feedback

optimisation v simulation

growth constraints

…

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Global energy-economy models have **limited** and **partial** representations of behavioural features

BEHAVIOURAL FEATURES		BUILDINGS	BUILDINGS	BUILDINGS	TRANSPORT	TRANSPORT	INDUSTRY	SUPPLY	SUPPLY	GENERAL
DESCRIPTION	CATEGORY	Building efficiency (retrofits & new builds)	Appliance adoption & use	Cooking & heating (less developed countries)	Mode choice & demand for mobility	Vehicle purchase	Furnace type (iron & steel)	Resource extraction investments	Power plant investments	All model contexts / General market effects
Heterogeneous preferences for or weighting of decision outcomes. Heterogeneous individual or firm propensities for technology adoption (innovators, early adopters, followers). Heterogeneous risk-preferences. Heterogeneous socio-economic characteristics (income, age, education) and responsiveness to price or other variables. Heterogeneous other-regarding preferences and social behaviour (see under social influence).	Heterogeneous decision makers	UEA (some evidence base mainly in UK)	IIASA - MESSAGE-ACCESS (some modelling experience: income-dependent price elasticities of electricity use) van Ruijven/NCAR - iPETS (evidence base for demographic heterogeneity in preferences and responses)	IIASA - MESSAGE (modelling experience: electrification, access) van Ruijven/NCAR - iPETS (evidence base for demographic heterogeneity in preferences and responses)		IIASA - MESSAGE (some experience: captured through disutility cost factors that vary by consumer group and vehicle technology; consumer groups include (1) early adopter/early majority/late majority (2) where people live/work - rural/suburban/urban (3) annual travel demand - low/medium/high; etc.)				Pfenning/DLR - empirical evidence Strachan/UCL - Range of stylised modelling approaches to technology diffusion and heterogeneous groups, with application to full systems models Kyle/PNNL - Calibrated logit sharing mechanism for
Decisions are not made based on perfect information. Searching for and acquiring information on alternatives and outcomes is costly (transaction costs, myopia). Expectations of outcomes are uncertain as future is unknown (temporal myopia, limited foresight), prospective behaviour of others is unknown (collective outcomes). Errors are also made in decision process (stochasticity, randomness).	Bounded rationality	UEA (some evidence base mainly in UK) Giraudet/CIRED - Fixed intangible costs reflect hidden costs (eg., hassle generated by insulation works) Emmerling/FEEM - interested in myopia and bounded rationality in building efficiency improvement Bertram/PIK - no experience but general interest	Emmerling/FEEM - interested in including BR for purchase of appliances Bertram/PIK - no experience but general interest		Emmerling/FEEM - interested in myopia and bounded rationality in mobility demand Bertram/PIK - no experience but general interest	IIASA (no experience: could potentially be explored based on disutility cost work, but cannot say for sure) Emmerling/FEEM - interested in myopia and bounded rationality in car purchases Bertram/PIK - no experience but general interest		Pfenning/DLR - knowledge based interests in renewable energy, science image	UEA (no experience, but would like to work on this) Pfenning/DLR - interests in local energy autonomy by rural villages, autonomy as belief	Edelenbosch/PBL - IMAGE 3.0, In our energy model TIMER we use the Multinominal Logijt to make decisions, which is not based on perfect information and does not optimize. We are interested to compare our results with descision making, which has an empirical basis. Daly/UCL - Myopic foresight is a model option for TIMES, though not used in TIAM-UCL Wada/RITE - DNE21+ uses discount rates as a parameter to
Many non-optimising heuristics or decision rules are used, and are linked to decision contexts. Decisions in familiar, repeated contexts are influenced by past experience (habit, path dependence, inertia, loyalty). Certain types of information are used and relied upon more (availability, recency heuristics). Tendency to follow 'default option' (status quo bias). Capacity to remember outcomes of past decisions is also limited (memory, forgetting).	Non-optimising heuristics								UEA (some evidence base mainly for renewables)	Edelenbosch/PBL - IMAGE 3.0. We have not done anything with this so far, and would like to be kept updated on ideas of how to model this type of behavior.
Preferences for attributes of an appliance-energy combination (energy service) that are other than monetary might also vary (e.g., convenience, pollution, efficiency, etc)	Non-monetary preferences	Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand model.	Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand model.	IIASA - Inconvenience costs that capture non-monetary preferences regarding stove-fuel combinations used in MESSAGE-Access Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand	Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand model Kyle/PNNL - average value of time in transit influences decisions, both in modal shares and in total service demands.	Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand model.	Edelenbosch/PBL - IMAGE 3.0., Applied in the energy demand model.			Wada/RITE - DNE21+ uses discount rates as a parameter to reflect people's behavioural aspects, such as risk preference, bounded rationality and consumer's heterogeneousity (but it's difficult to disentangle the contribution of each)

current 'behavioural modelling':
1) variable discount rates, 'intangible' costs (*buildings &/or transport*)
2) logit formulations for market heterogeneity (*simulation models*)

Preferences for decision outcomes may vary across different contexts (e.g., effort-minimisation at home, cost-minimisation at work). Preferences for decision outcomes may change as a function of experience, time, or others' behaviour (reinforcement, memory, learning). Potential for social learning from collective outcomes. (See under bounded rationality and decision heuristics).	Context-dependent preferences		IIASA (no experience, but would like to work on income-based appliance diffusion in developing countries) van Ruijven/NCAR (no experience in iPETS, have experience in IMAGE)	IIASA - Inconvenience costs that capture non-monetary preferences regarding stove-fuel combinations used in MESSAGE-Access van Ruijven/NCAR (no experience in iPETS, have experience in IMAGE)					UEA (no experience, but would like to work on this)	Edelenbosch/PBL - IMAGE 3.0. The lambda in our MNL accounts for certain preferences, which is estimated based on calibration with historical data. It would be interesting to compare this data to other sets.
Decisions and behaviours are influenced by what others are doing (descriptive social norms) and by what others approve of (injunctive social norms). Preferences for decision outcomes may be other-regarding as well as self-regarding. Normative effects include imitation (herding, bandwagon, network externalities) and distinction (status-seeking, snob). Structure of social networks (types and strengths of interaction) also matter. Media impact and effects, opinion-leader-concepts, individual networks and mass media (maybe cumulating in to cognitive effects).	Social influence & information networks	UEA (some evidence base mainly in UK)	IIASA (no experience but would like to work on how social networks & externalities influence appliance adoption)	IIASA (no experience but would like to work on how social networks & externalities influence advanced stove adoption)		IIASA - MESSAGE (some experience: captured partially through a new technology risk premium cost factor, which varies by consumer group and vehicle technology)		Pfenning/DLR - role of local opinion leaders, information sources and cognitive belief systems		Pfenning/DLR - participation as a societal civic culture principle	Edelenbosch/PBL - IMAGE 3.0. We have no experience and are curious what data is available on this phenomena and how this can be modelled.
Decisions may be strategic based on self-regarding preferences, expectations about others' decisions, and aspects of the decision context (e.g., anonymity, one-off or repeated interactions, sanctions, etc.). Explored extensively by game theory.	Strategic decision making	UEA (some evidence base mainly in UK)	IIASA (some experience, would like to work on the influence of infastructure availability and reliability of supply in developing nations) van Ruijven/NCAR (some experience including H2 in IMAGE, interested to pursue)	van Ruijven/NCAR (some experience including H2 in IMAGE, interested to pursue)	IIASA (some modelling experience: time budgets, speed) Daly/UCL - Stylised TIMES model of mode choice (speed and infrastructure); interested in developing further Kyle/PNNL - exogenous reduction of shares of alternative-fuel vehicles allocated by economic-based sharing equations due to infrastructure-related constraints (for refueling)	IIASA - MESSAGE (some experience: captured partially through cost factors for limited vehicle range and refueling station availability, which vary by consumer group and vehicle technology)				
Behaviour is heavily influenced, shaped or even determined by contextual conditions. Physical infrastructure can determine transport modes or heating fuels. Availability of technologies and supply chains can determine efficiency of home renovations or power plant installations. Social norms can determine extent of market heterogeneity. The design of a technology can determine how and how often it is used. And so on.	Contextual constraints									
Different governments or governance institutions have different mandates, policy instrument preferences, responsiveness to electorates, institutional histories, modes of rule. Extents of centralisation, distributive concerns, political constraints, may all vary widely. Policy may ultimately be an endogenous consequence of social change or social preferences. Legitimation and legitimacy, participation approaches and concepts, social system impacts.	Governance, Participation, Social Institutions	Emmerling/FEEM - Optimal energy and climate policy mix for residential sector	Emmerling/FEEM - Optimal energy and climate policy mix for residential sector		Emmerling/FEEM - Optimal energy and climate policy mix for transport sector!				Pfenning/DLR - participation as a societal civic culture principle Kyle/PNNL - lower capital recovery factors for renewable technologies in all regions to represent favorable financing conditions due to government programs (mostly OECD at present)	

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There is strong empirical evidence that behavioural features are **influential** and **policy-relevant**

<u>Extensive literatures of empirical studies (stated & revealed preferences)</u>

- **systematic review** of empirical studies (n>70)
- focus on **vehicle choice**

- good evidence of moderate-to-strong effects across typology of behavioural features

  - non-monetary preferences
  - **social influence**

Project No 308329

ADVANCE
Advanced Model Development and Validation for Improved Analysis of Costs and Impacts of Mitigation Policies

FP7-Cooperation-ENV
Collaborative project

DELIVERABLE No 3.2
Report on micro-studies on behavioural changes and socio-spatial heterogeneities

Due date of deliverable: 30 June 2015
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Duration: 48

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Revision: 0

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Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 308329 (ADVANCE)
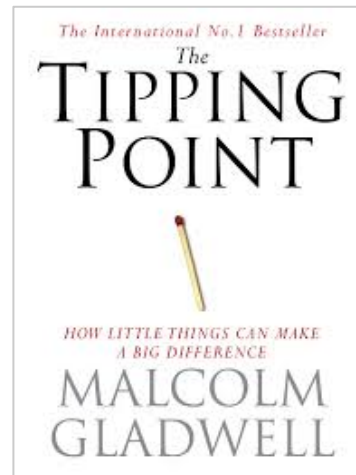
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Social influence on technology adoption has strong **conceptual foundations**

Diffusion = communication over time about an innovation among members of a social system

early adopters reduce perceived risks:
social influence

high initial risk aversion

high adoption propensity

Innovators 2.5 % | Early Adopters 13.5 % | Early Majority 34 % | Late Majority 34 % | Laggards 16 %

Market share %

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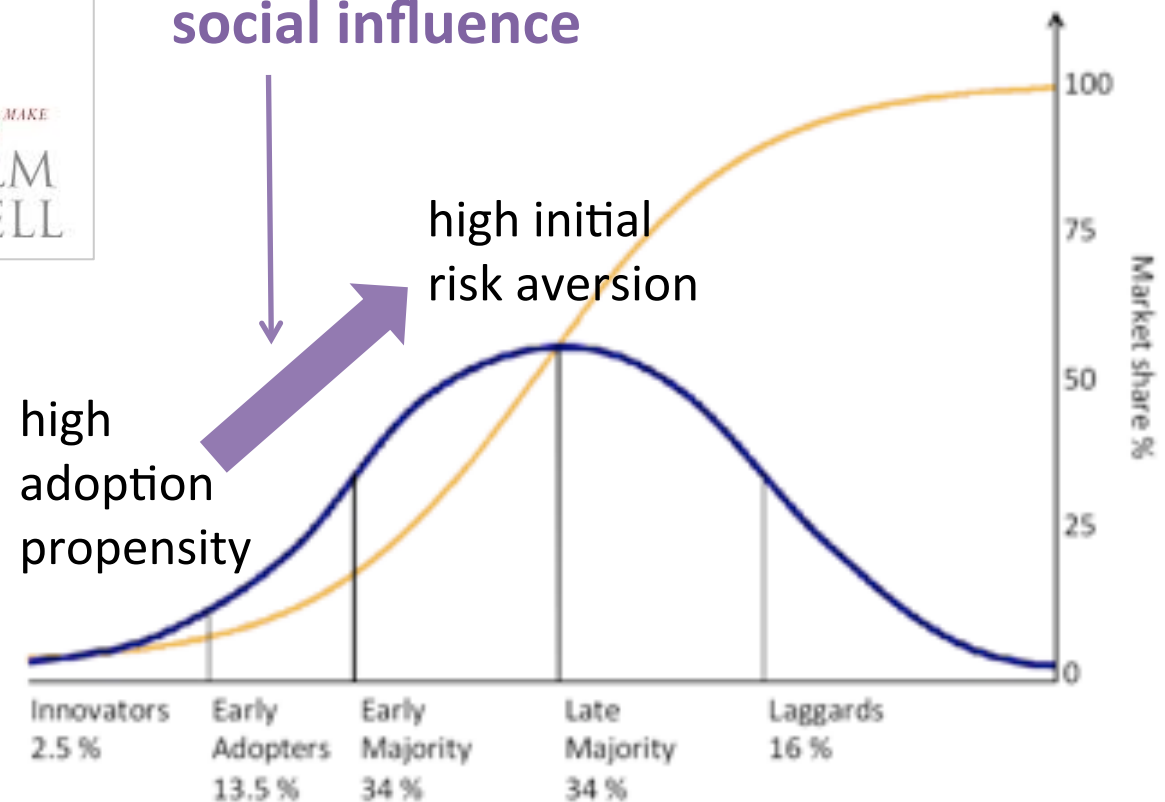
(6) How can behavioural features be modelled?

A **meta-analysis** of 21 empirical studies found robust evidence of moderate **social influence** on vehicle choices

Author(s)	Social Influence Type	Corr 'r'	CI lower	CI Upper	Z Value	p Value
Adjemain et al 2010	Neighbourhood effect	0.207	0.126	0.285	4.947	0.000
Aini et al 2013	Social norms	0.310	0.179	0.430	4.510	0.000
Axsen et al 2013	Interpersonal networks	0.213	0.074	0.344	2.975	0.003
McShane et al 2012	Neighbourhood effect	0.219	0.159	0.277	7.029	0.000
Baltas et al 2013	Interpersonal networks	0.289	0.134	0.430	3.593	0.000
Gaker et al 2010	Interpersonal networks	0.362	0.107	0.573	2.735	0.006
Goetzke et al 2012	Neighbourhood effect	0.560	0.536	0.583	36.458	0.000
Grinblatt et al 2008	Neighbourhood effect	0.031	0.031	0.031	466.815	0.000
Heutel et al 2010	Social norms	0.456	0.433	0.479	33.484	0.000
Hsu et al 2013	Information transmission	0.000	-0.049	0.049	0.012	0.990
Hutter et al 2013	Information transmission	0.150	0.039	0.257	2.653	0.008
Mohammad et al 2011	Information transmission	0.574	0.498	0.641	12.014	0.000
Jansson et al 2010	Social norms	0.436	0.398	0.472	19.984	0.000
Kulkarni et al 2012	Information transmission	0.154	0.054	0.252	3.007	0.003
Moons et al 2012	Social norms	0.132	0.076	0.187	4.580	0.000
Schuitema et al 2013	Interpersonal networks	0.220	0.184	0.255	11.677	0.000
Shemesh et al 2014	Neighbourhood effect	0.351	0.333	0.369	34.713	0.000
Wiedman et al 2011	Social norms	0.100	0.011	0.188	2.191	0.028
Sha et al 2012	Information transmission	0.020	-0.009	0.049	1.348	0.178
Zhang et al 2011	Interpersonal networks	0.115	0.039	0.189	2.975	0.003
Zhu et al 2013	Social norms	0.036	0.020	0.052	4.537	0.000
Summary Effect		0.241	0.157	0.322	5.505	0.000

mean effect size of 0.241**

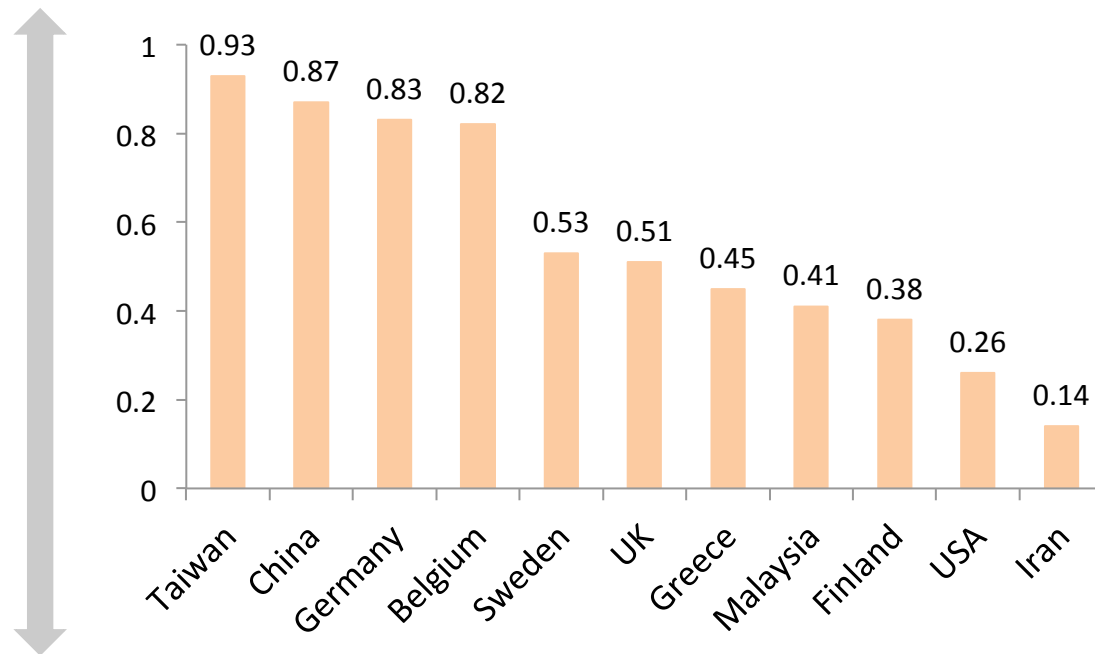Effect size (correlation 'r')
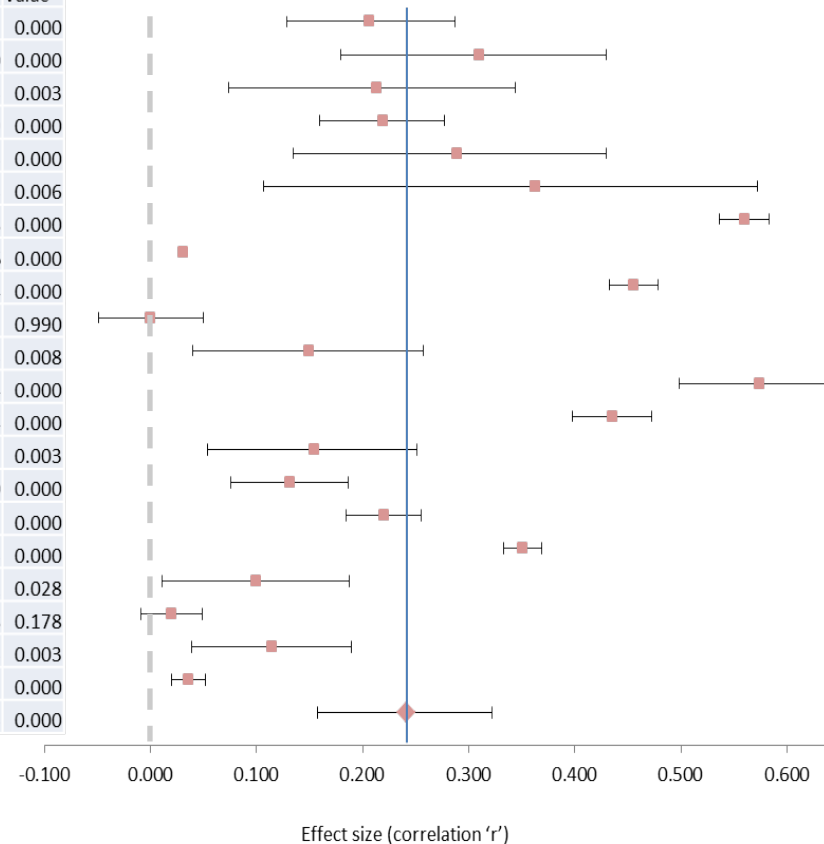
Social Influence → Vehicle choice / Propensity to purchase

+1 s.d. increase → +0.24 s.d. increase

Social influence effect size varies between countries, as predicted by measures of **cultural difference**

Pragmatic: greater individuality, acceptance of change, old traditions replaced

Hofstede, G. and M. Minkov (2010). "Long- versus short-term orientation: new perspectives." Asia Pacific Business Review 16: 493-504.

Country	Value
Taiwan	0.93
China	0.87
Germany	0.83
Belgium	0.82
Sweden	0.53
UK	0.51
Greece	0.45
Malaysia	0.41
Finland	0.38
USA	0.26
Iran	0.14

Normative: traditions and norms important, looking to others for support

World Values Survey

scores on standardised measurement scales for >200 countries

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Empirical evidence can support **existing modelling efforts** (shaped by model structure and function)

model   < - - - -   observed behaviour
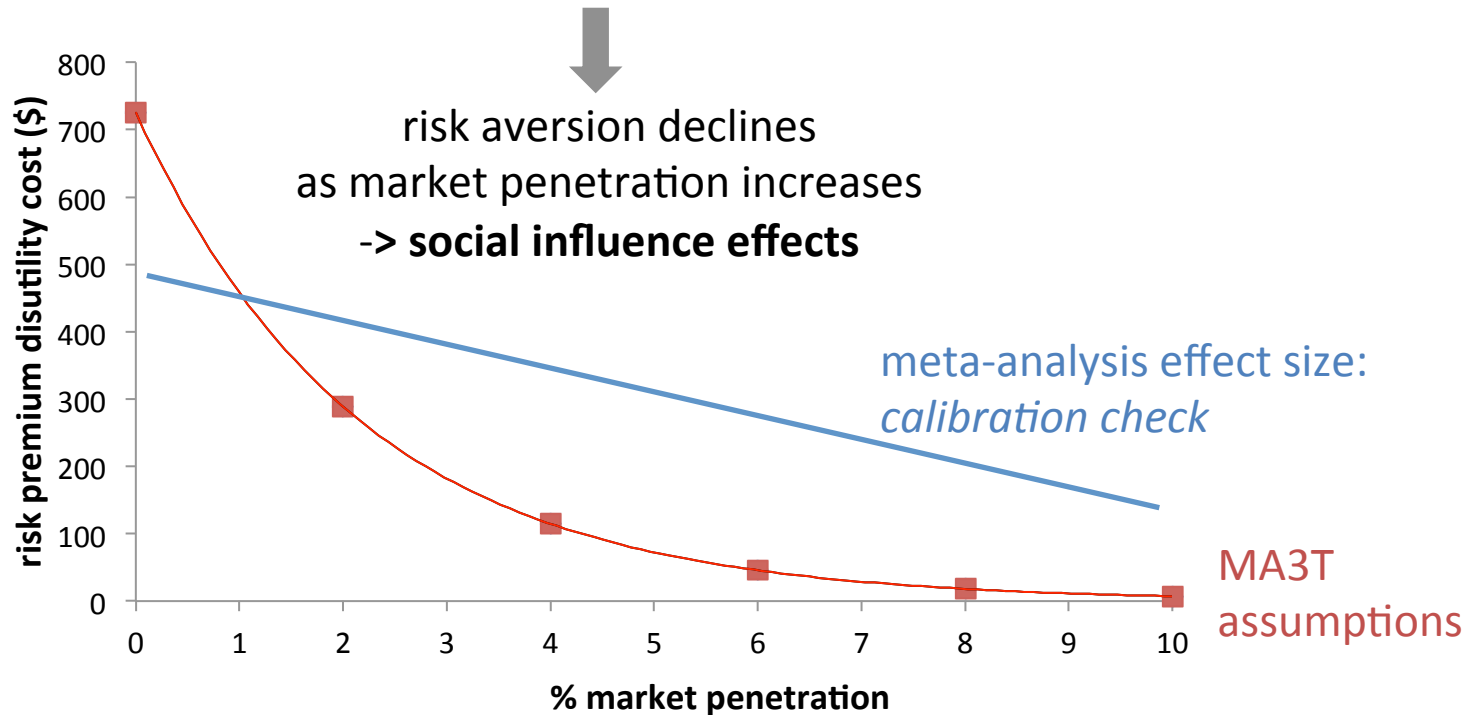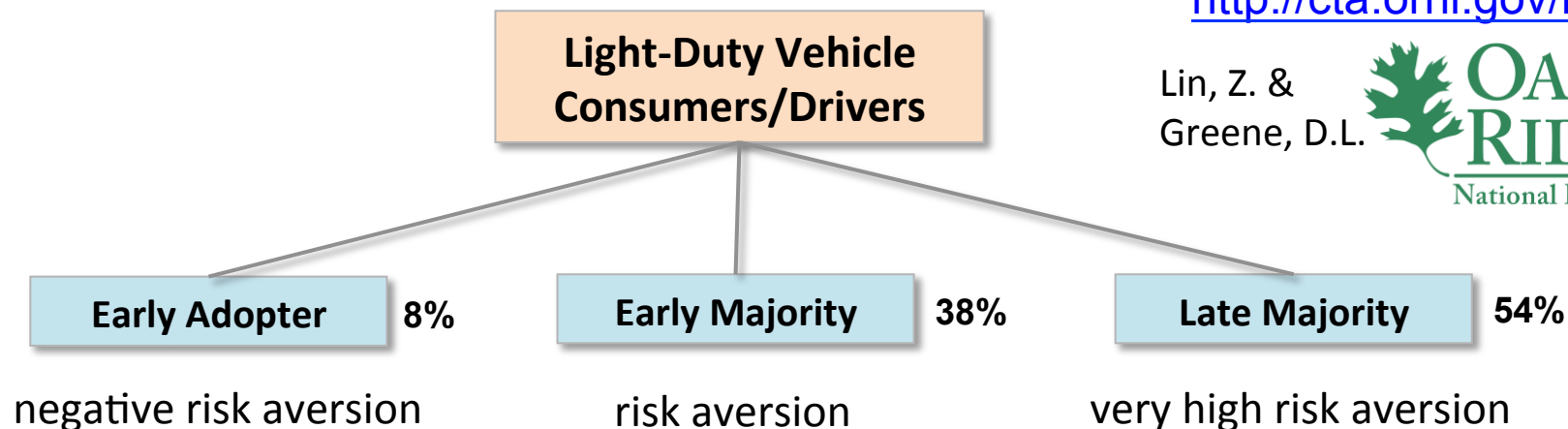
observed behaviour   - - - - >   model

Social influence is captured in declining **risk premiums** of risk-averse vehicle purchasers (MA3T / MESSAGE)

Attitude toward technology / risk

Light-Duty Vehicle Consumers/Drivers

Early Adopter	8%
Early Majority	38%
Late Majority	54%

negative risk aversion

risk aversion

very high risk aversion

risk aversion declines
as market penetration increases
-> **social influence effects**

risk premium disutility cost ($) vs *% market penetration*

meta-analysis effect size: *calibration check*

MA3T assumptions
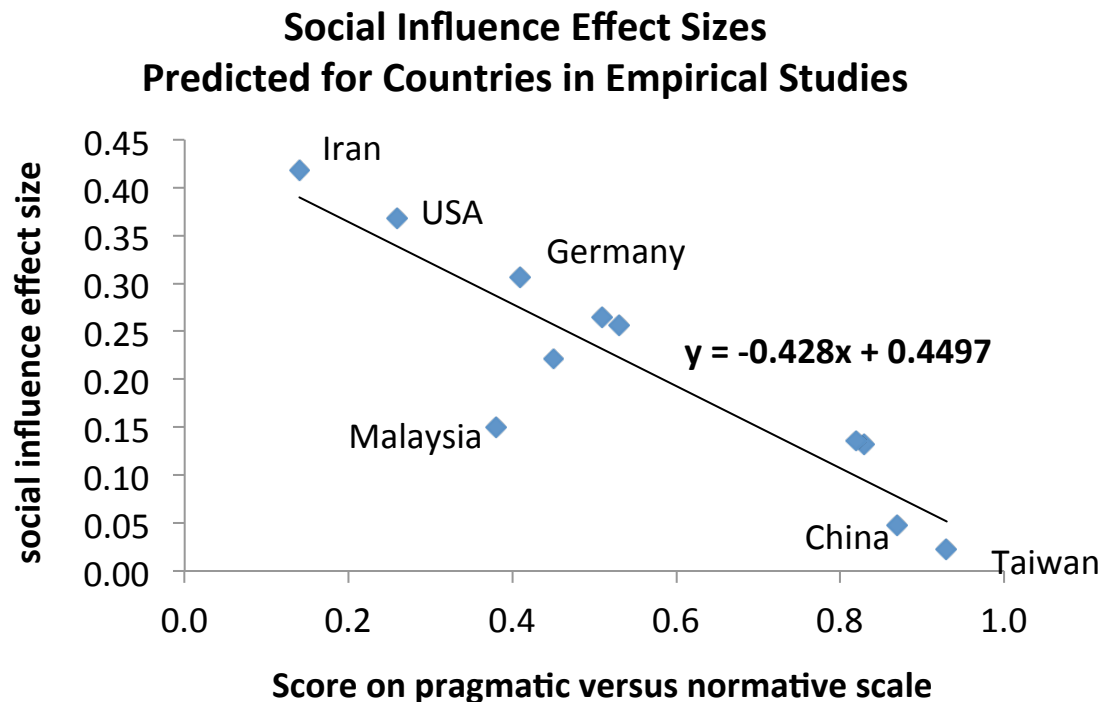
Relationship between social influence effect and cultural values enables **regional parameterisations**

use of empirical relationship → to rescale US data

Social Influence Effect Sizes
Predicted for Countries in Empirical Studies

$y = -0.428x + 0.4497$

(y-axis: social influence effect size; x-axis: Score on pragmatic versus normative scale; data points labelled Iran, USA, Germany, Malaysia, China, Taiwan)

MESSAGE regions	Social influence effect 'multiplier'
North America **US**	**1.00**
Latin America *Mexico*	*0.94*
Centrally Planned Asia *China*	*0.13*
Western Europe *Germany*	*0.36*

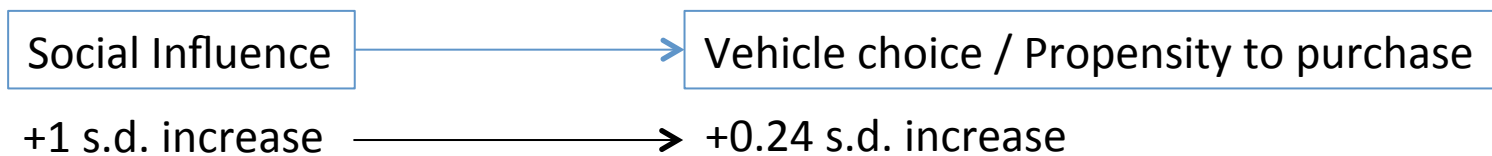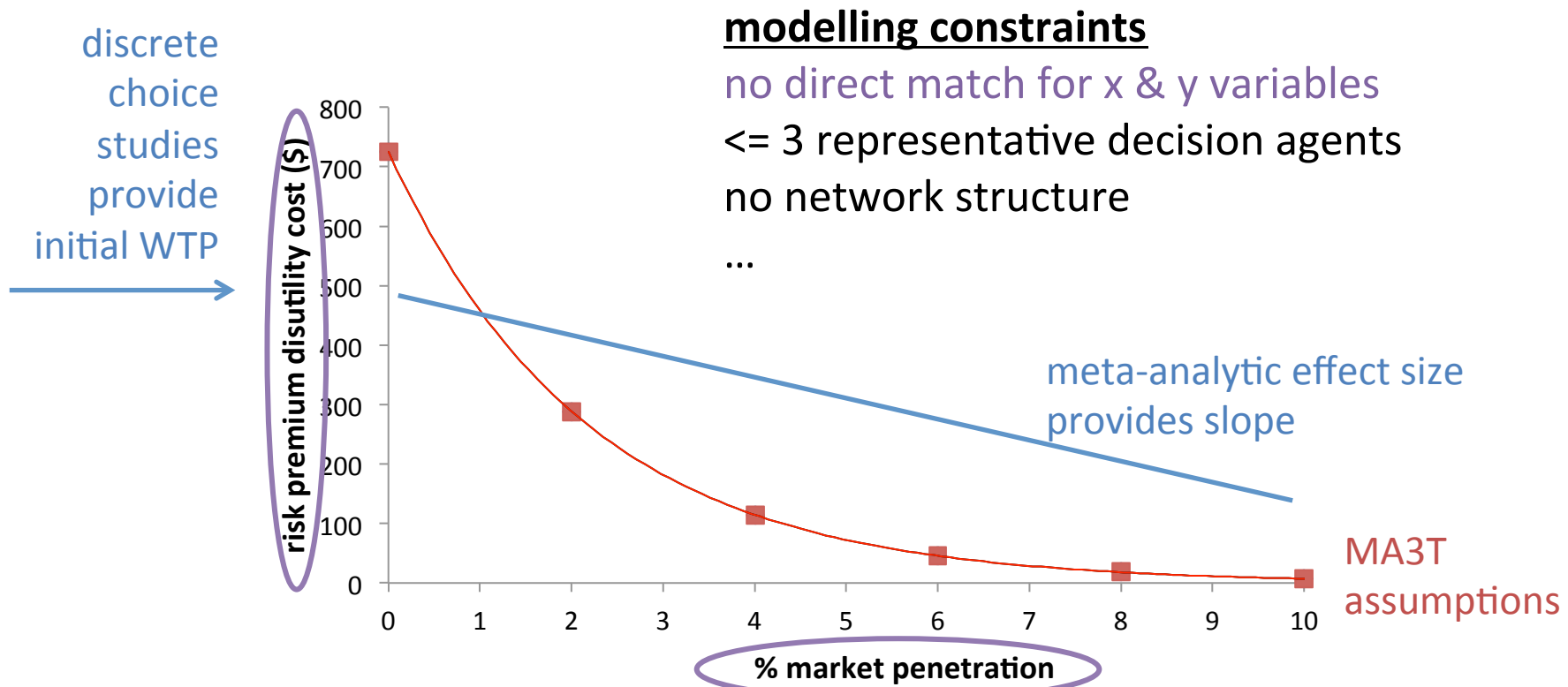generalisable approach to global modelling

Can empirical evidence also determine direction of model development ... **in existing models**?

model　　　< - - - - -　　observed behaviour

observed behaviour　　　- - - - >　　model

Implementing a meta-analytic effect size in global energy-economy models is … **problematic**

discrete choice studies provide initial WTP

modelling constraints

no direct match for x & y variables

<= 3 representative decision agents
no network structure

…

meta-analytic effect size provides slope

MA3T assumptions

risk premium disutility cost ($)

% market penetration

| Social Influence | → | Vehicle choice / Propensity to purchase |

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- **model-pull**: modified, improved <-> complicated, assumed
- **evidence-push**: bespoke, unconstrained <-> usefulness

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