Date: 2nd July 2014

# Households as adopters of smart grid technology using Agent-Based Modelling (ABM)


Built with: CASCADE — Complex Adaptive Systems, Cognitive Agents and Distributed Energy

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**Venue:** Room 0.14, Queen's Building, De Montfort University, Leicester

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- Summary and Questions

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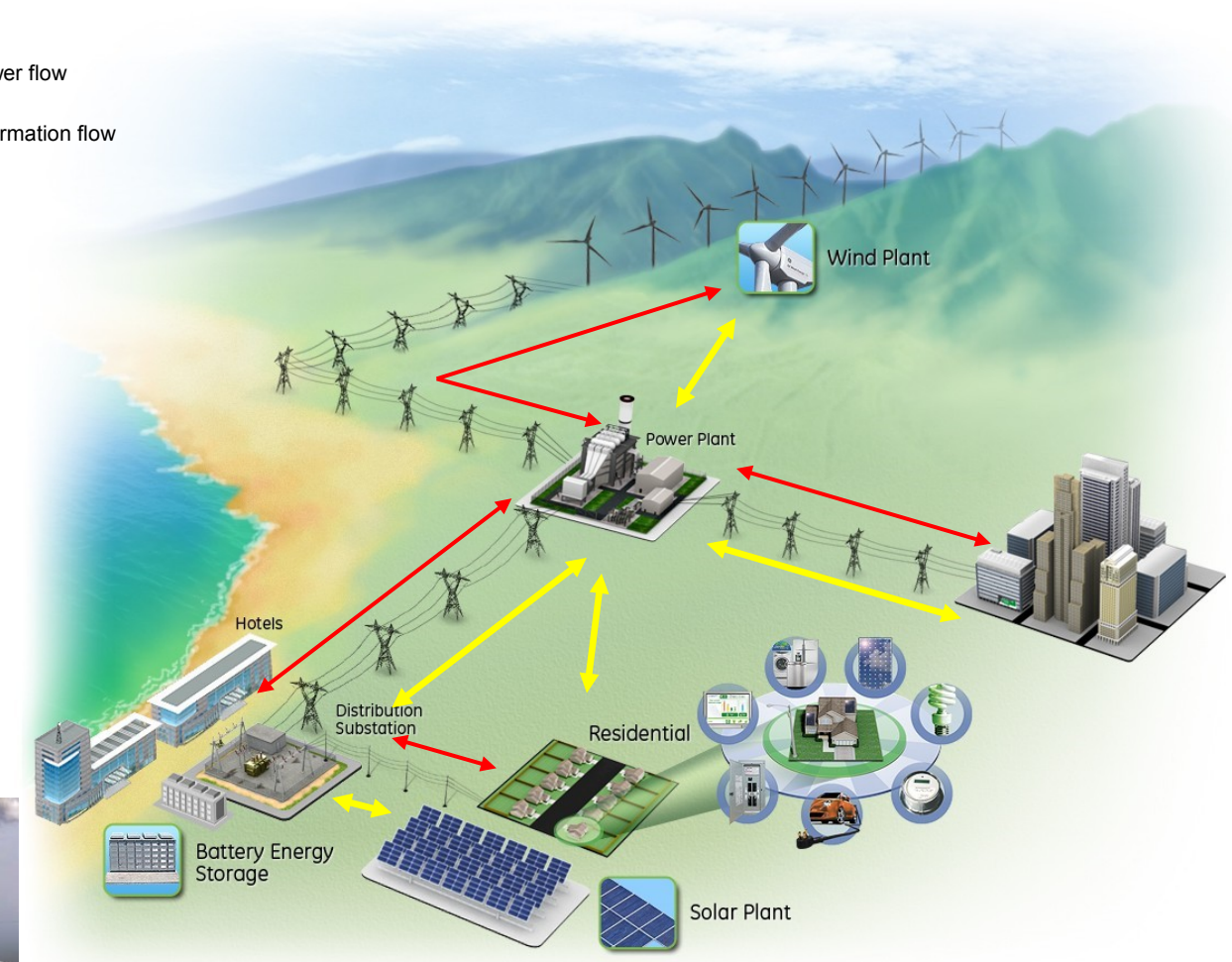
# Adoption in Smart Grid context

Bidirectional power flow

Bidirectional information flow

€, £, $







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# PV adoption - numbers

- Considering Feed in Tariff (FiT) registered installations only – excludes commercial farms registered for ROCs

**As of May 2014**

- 554,186 PV installations on FiT
- 2.4 GW registered capacity (comparison – large CCGT power station ~ 1GW, Drax ~ 4GW, London array offshore wind ~ 0.6GW, Eaglesham onshore ~ 0.5)
- 99% of registered FiT installations are PV, representing 86% of FiT registered capacity.

Source: DECC (2014)

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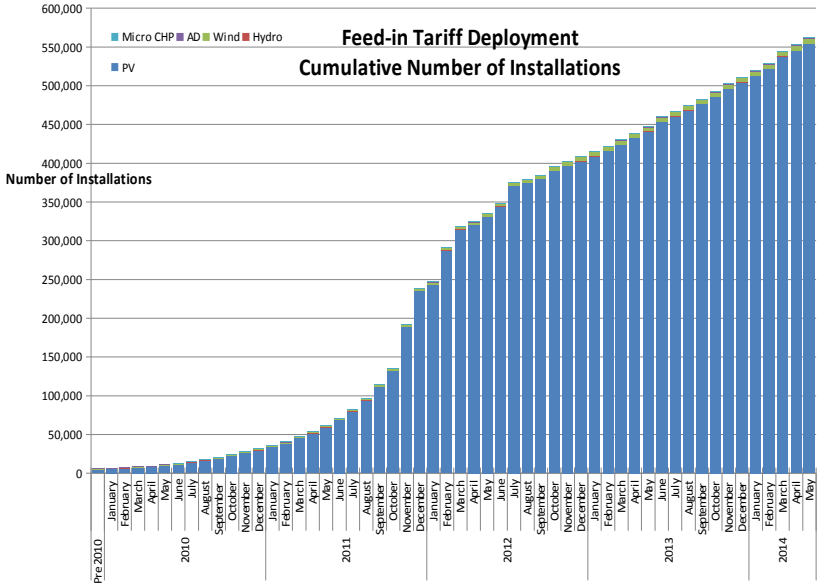
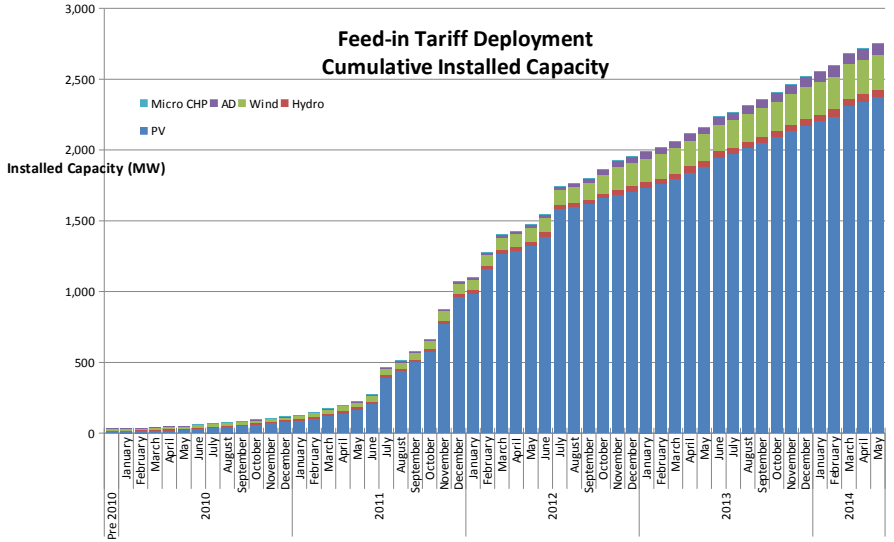
# PV adoption - graphs




Source: DECC (2014)

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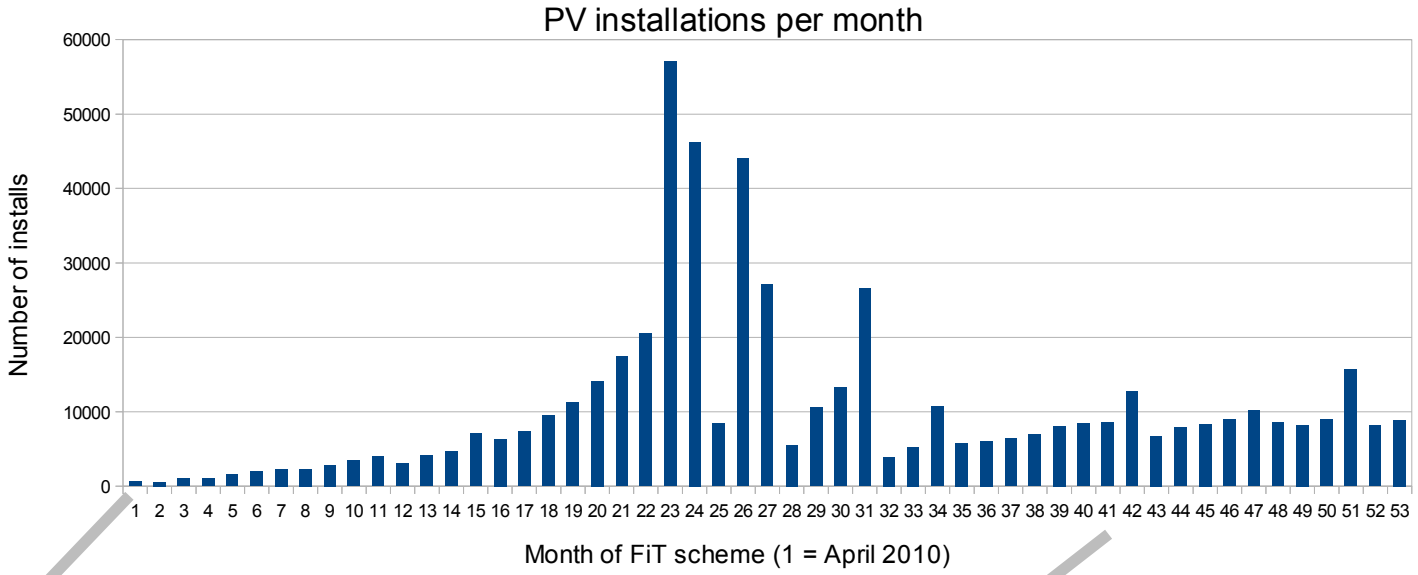
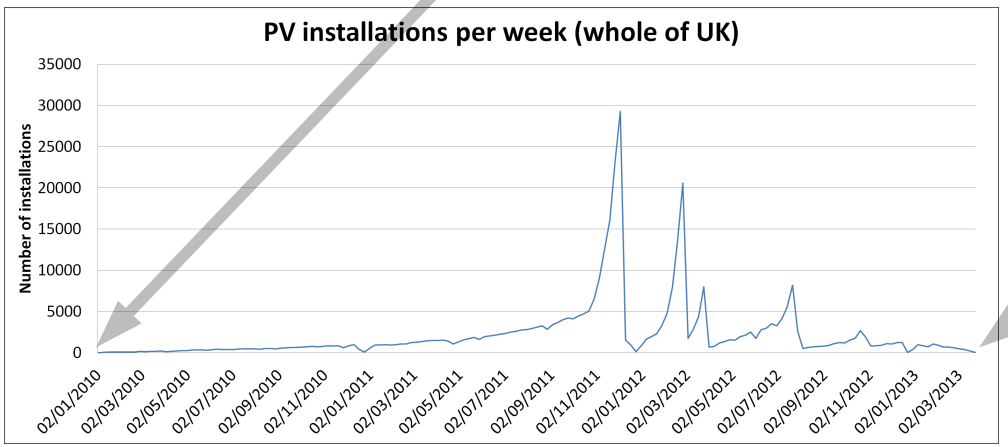
# PV adoption - graphs




Source: DECC (2014)

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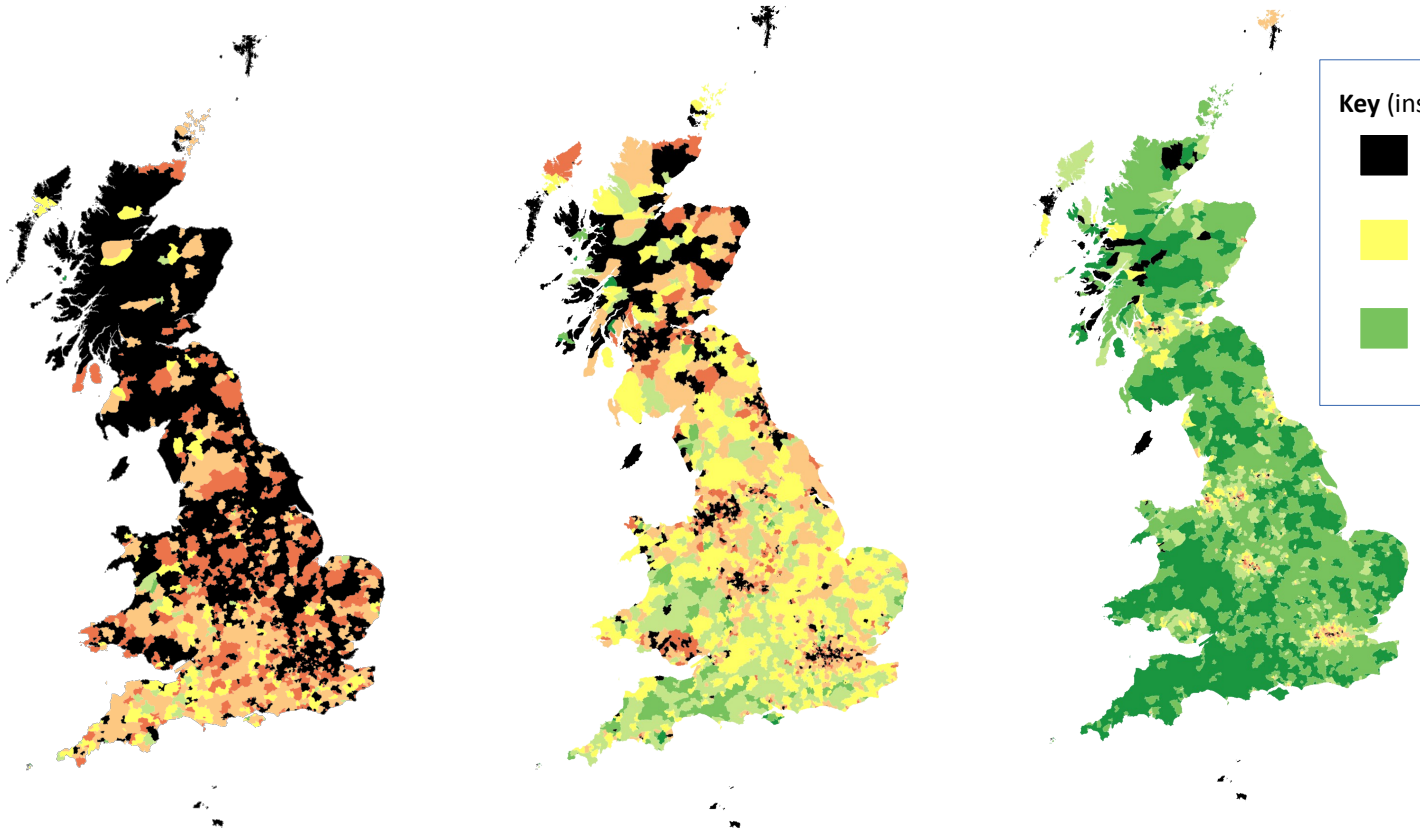
# PV adoption - maps

## Pre FiT

## End 2010

## End 2011

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# PV adoption – the movie... :)

LInk to video of PV adoption by week in each PCD

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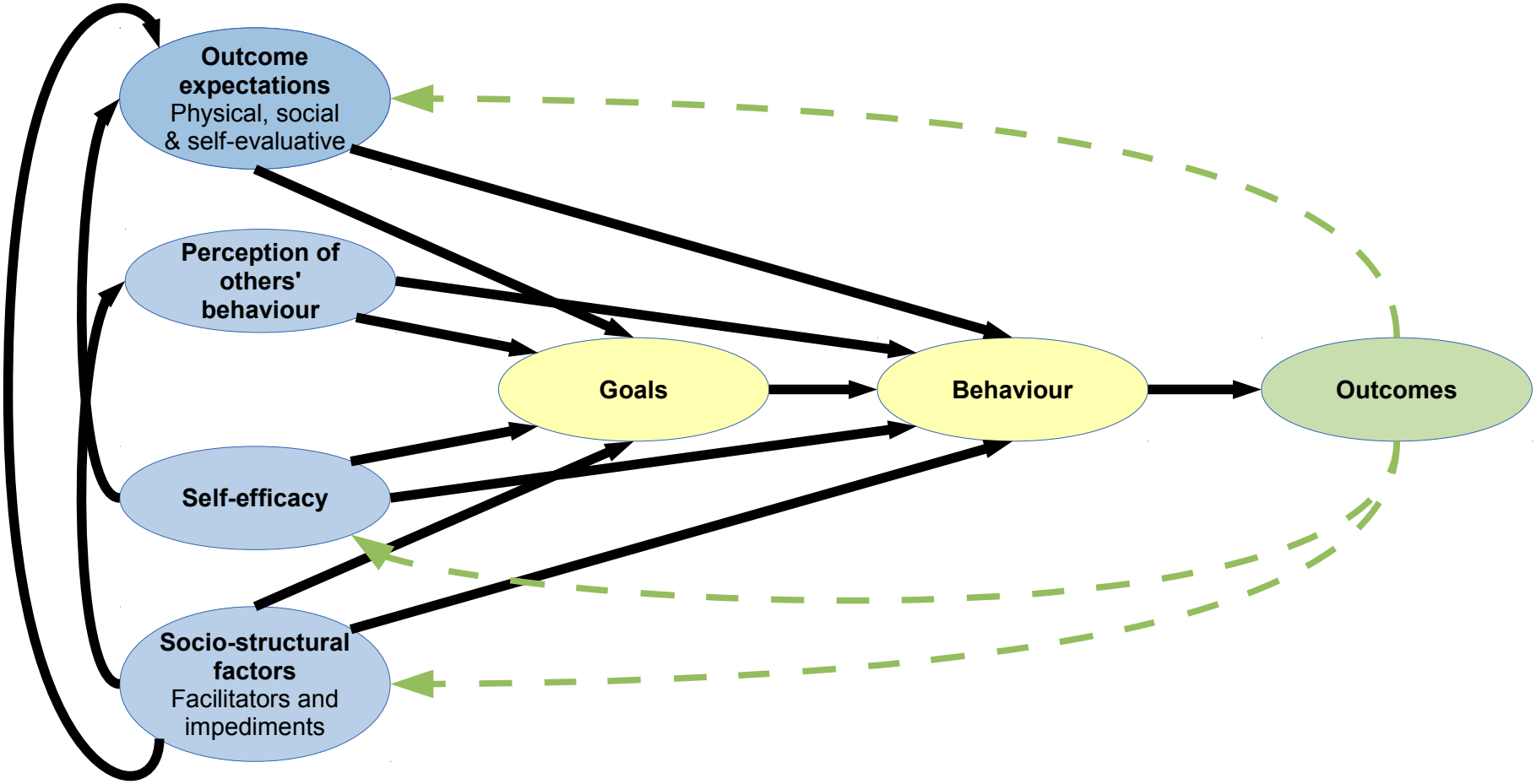
# My ABM model – decision making

Social Cognitive Theory model (Bandura 1986)

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# My ABM model – decision making

| Construct | Contributing factors | Modelled as |
|---|---|---|
| **Outcome expectations** | Expectation that installing the technology will contribute to avoiding climate change. | (noisy) calculation by agent of expected moentary benefits (gets quote, works out previous bill and therefore montyly benefit & payback period) |
| | Expectation that installing the technology will save money on electricity bill | |
| | Expectation that the investment outlay will quickly be offset by savings on electricity bill (i.e. perception of payback period) | |
| **Perceptions of others' behaviour** | Perception of number of people having solar panels installed | **Fraction of neighbours with PV panels installed** |
| | Perception that people are having solar panels installed because of the money they will be paid for the electricity they generate | |
| | Perception that people are having solar panels installed because they care about reducing climate change | |
| **Self-efficacy** | Internal belief in the ability to have the technology installed | Pro-environmental behaviour category. |
| | Perception of the ease with which others have installed the technology. | |
| **Socio-structural factors** | Household size (is there enough space to install a viable PV system) | House physical size position / orientation etc from OS map. Tenancy all assumed owner occupied for this study. Income bracket and occupancy assigned to agents drawn from distribution matching national stats. |
| | Household orientation (is there a roof facing between SE and SW). | |
| | Tenancy – owner occupier / private rented / social housing etc. | |
| | Household income bracket | |

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# My ABM model – decision making

| Construct | Contributing factors | Modelled as |
|---|---|---|
| **Goal** | adoping a particular piece of technology (i.e. a PV panel, or in the further exploratory study a smart controller) | - |
| **Behaviour** | Procuring the technology and having it installed. | Agents have a threshold based on pro-environmental category. If this is exceeded, the agent will get a price and, if sufficient funds, procure. |
| **Outcomes** | Money saved on electricity – | measured as the difference between total energy bought from the grid 2 months before adoption and 2 months after. |
| | Perceived ease of installation | Installation time is drawn from a Poisson distriution following the time of the behavioural decision to install. |
| | Perceived functioning of the panel. | Facility to give some agents defective equipment (not used as yet) |

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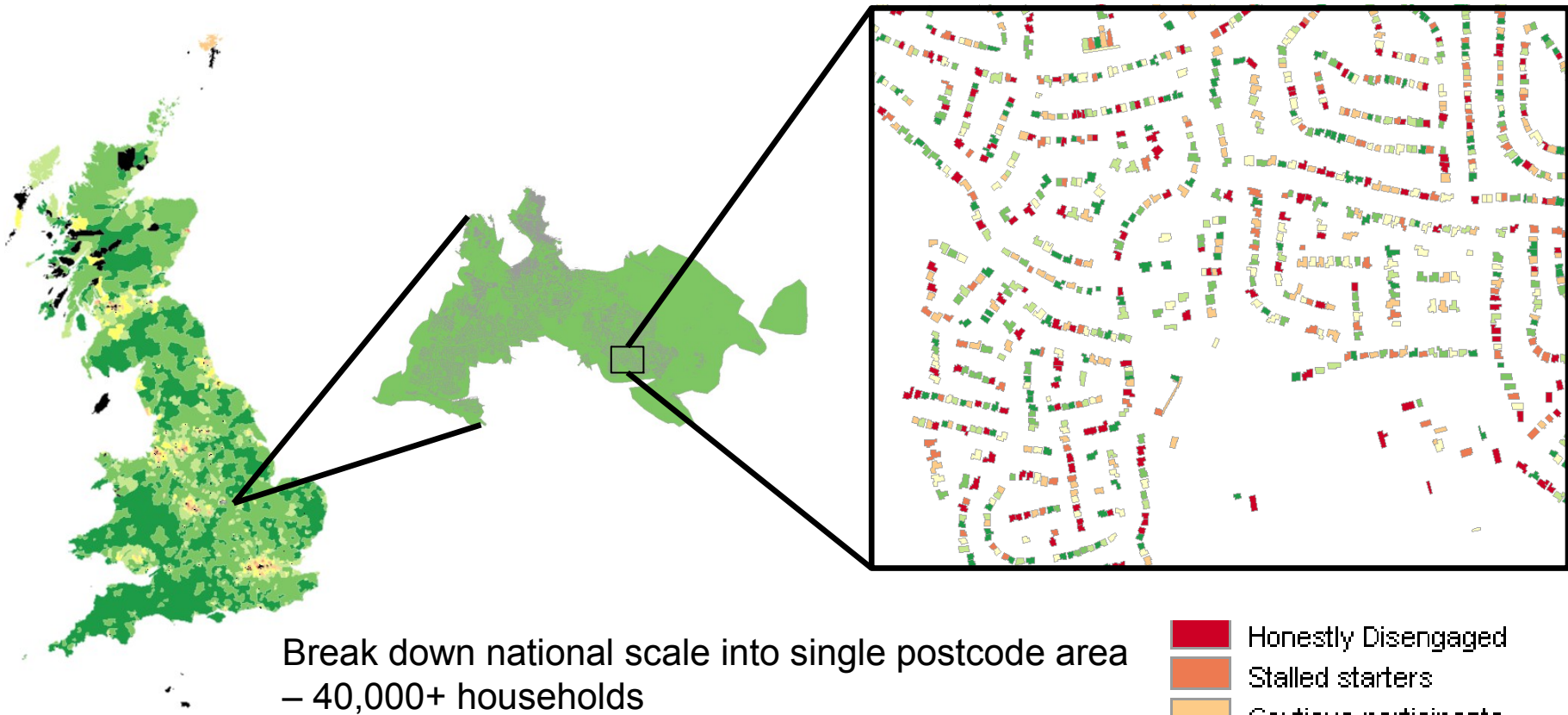
# ABM model – start condition



Break down national scale into single postcode area – 40,000+ households

Geographical data incorporated

Simulation assigns predisposition from empirical distribution of attitudes (DEFRA)

- Honestly Disengaged
- Stalled starters
- Cautious participants
- Sideline supporters
- Concerned consumers
- Waste watchers
- Positive Greens

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# Example results

- Varying ***only*** the area over which agents observe neighbours
- Affects perception of others' behaviour construct in psychological model
- Illustrates need for many ABM runs when stochastic
- Illustrates range of possible outcomes
- Illustrates dependence on only two parameters...

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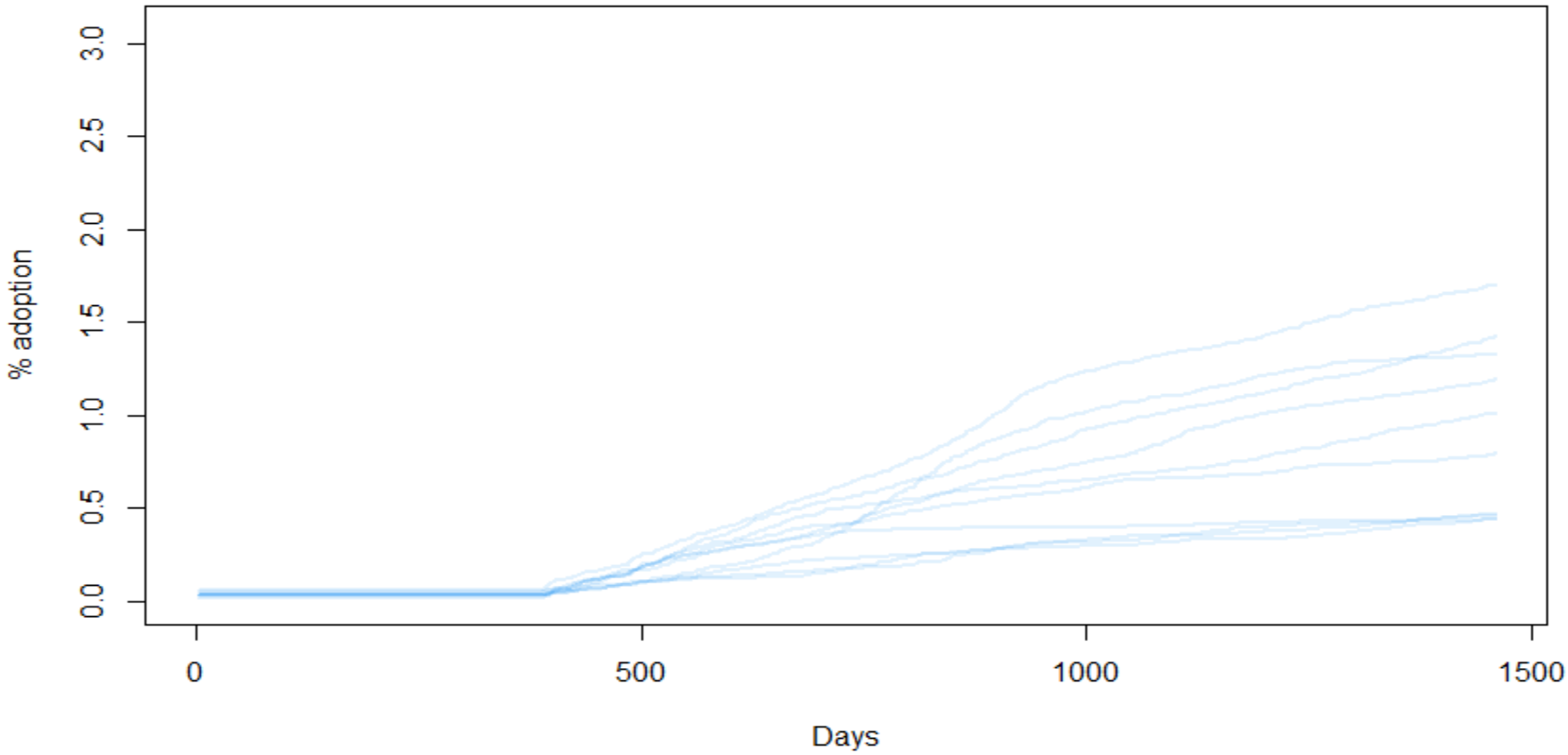
# Stochasticity and uncertainty

Observed radius picked from Normal(10,5): 10 model random seeds

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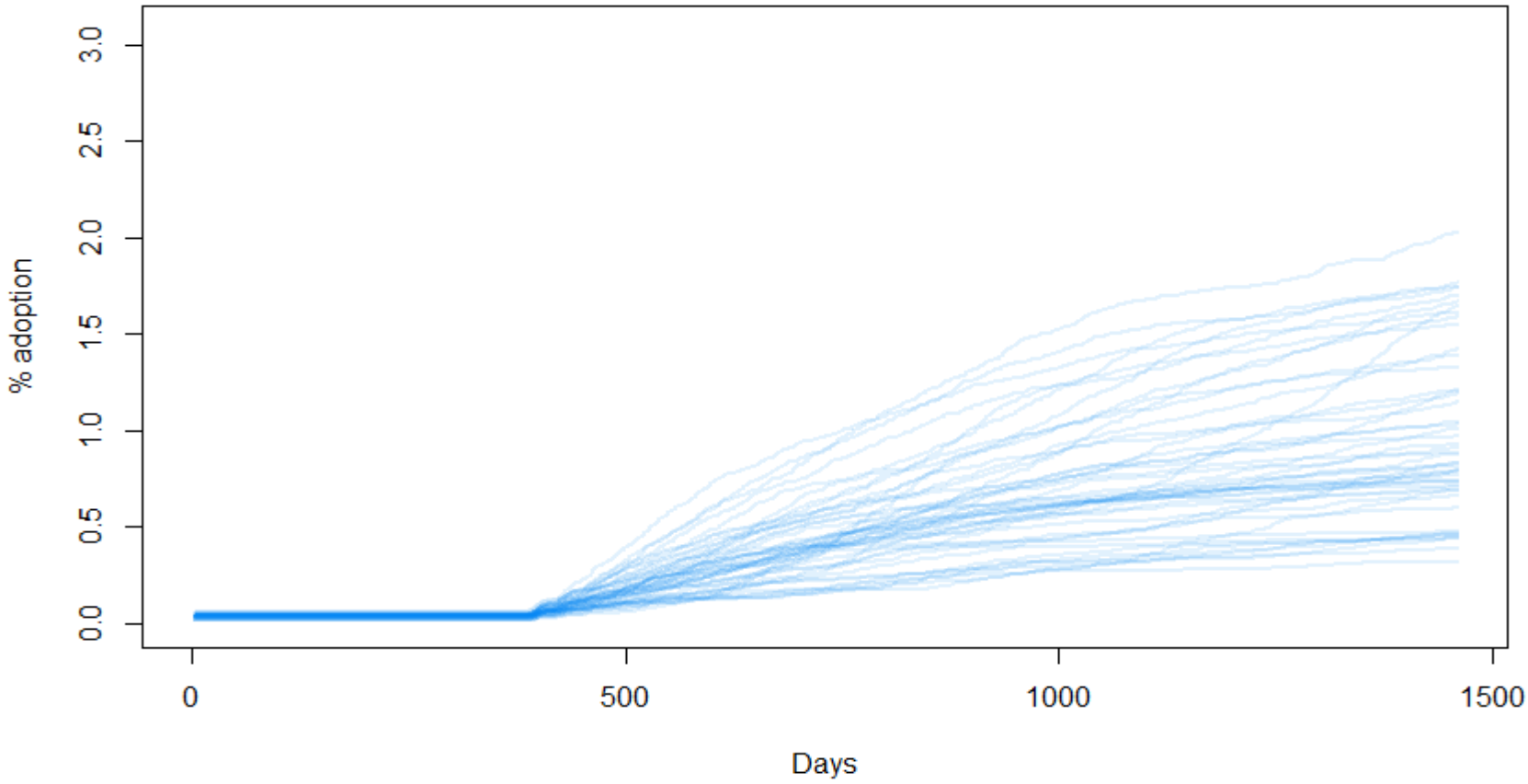
# Stochasticity and uncertainty

Observed radius picked from Normal(10,5): 50 model random seeds

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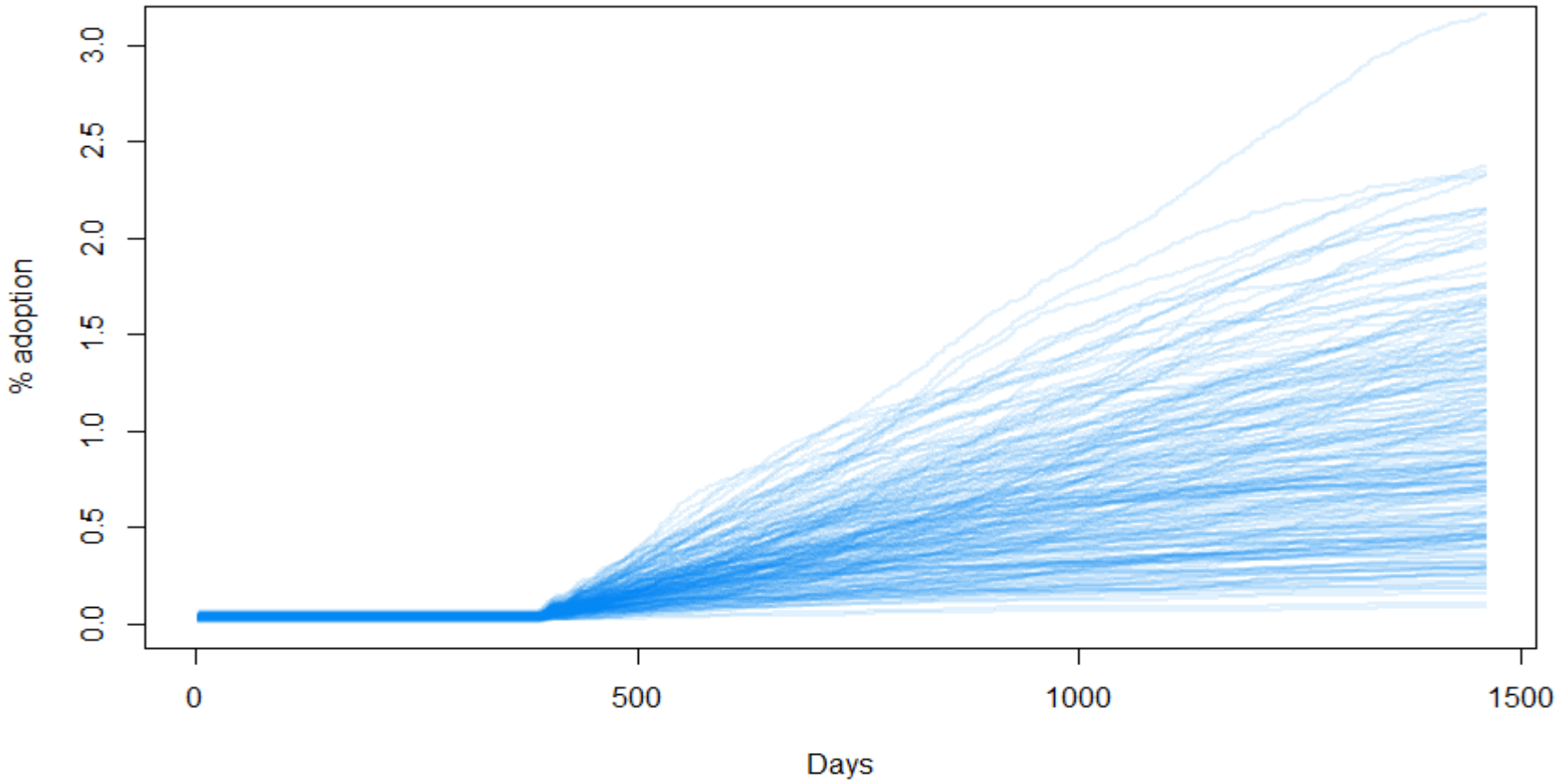
# Stochasticity and uncertainty

Observed radius picked from Normal(10,5): 200 model random seeds

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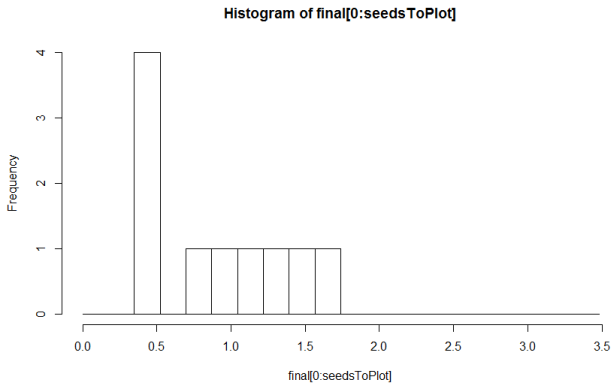
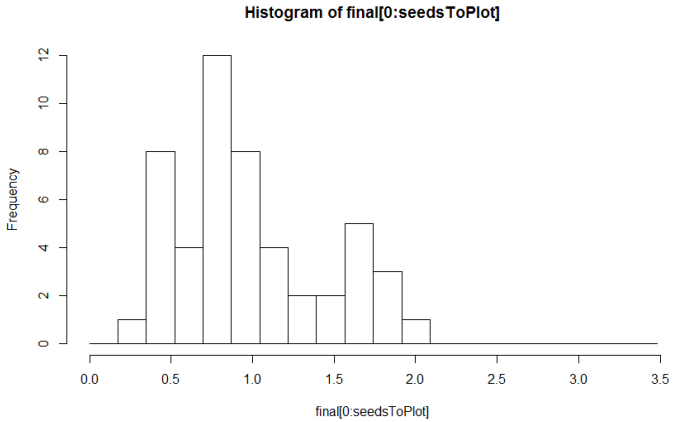
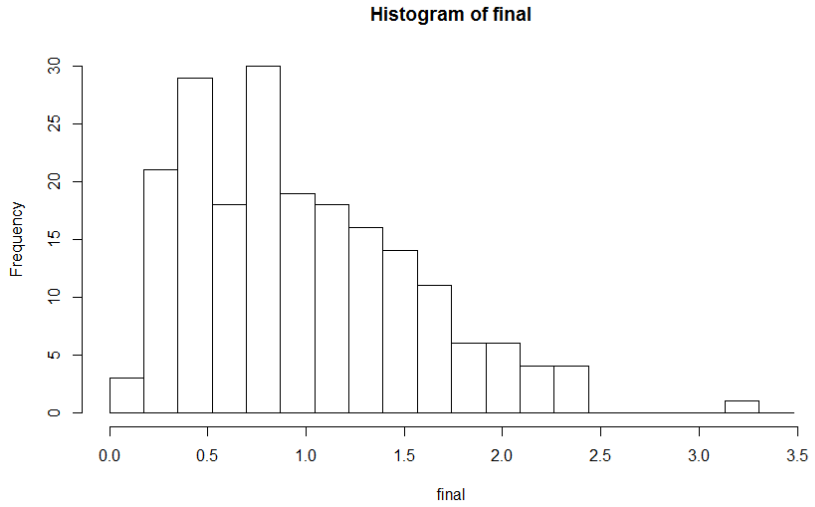
# Stochasticity and uncertainty

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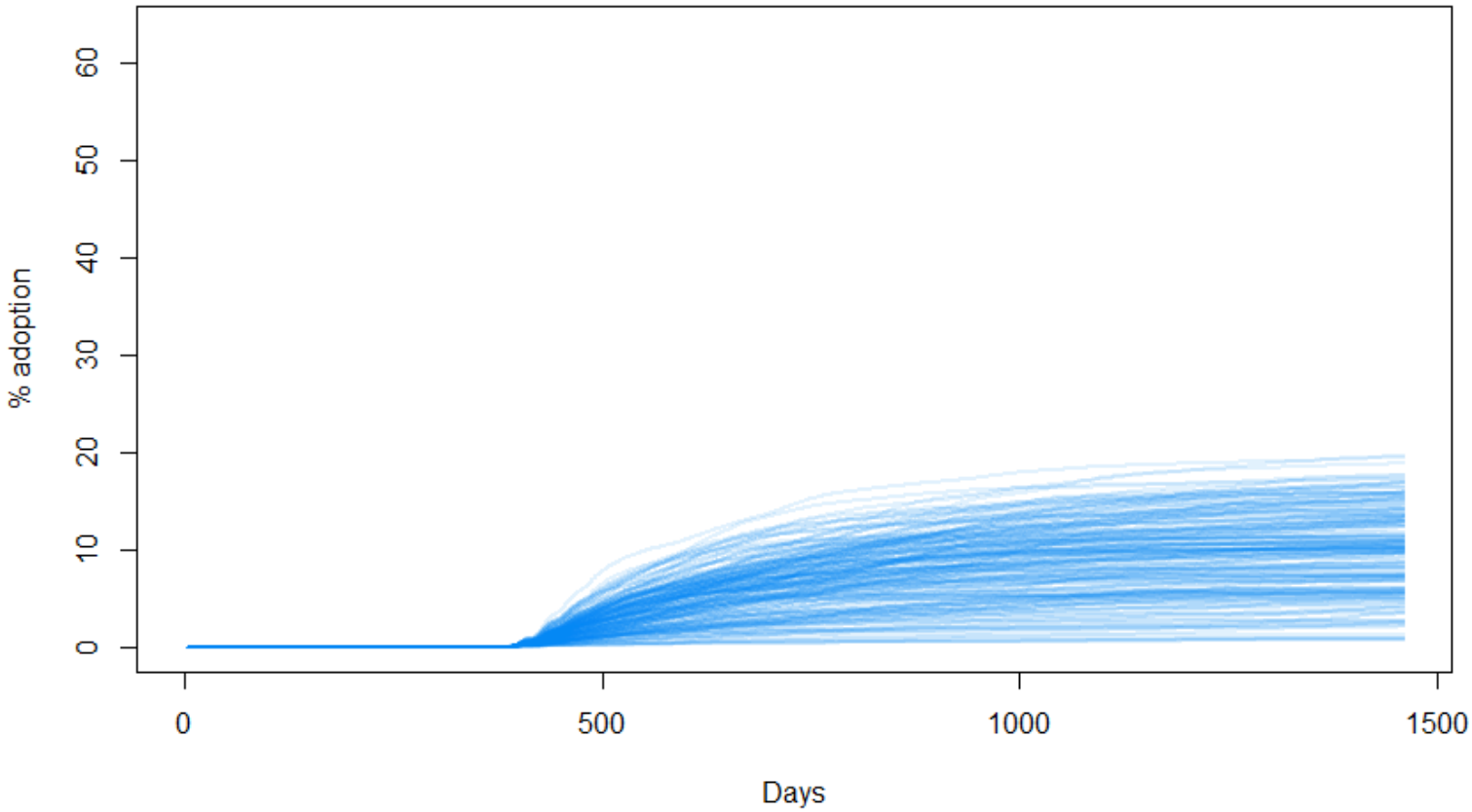
# Magnitude of observation radius

Agent observation radius drawn from Normal(20,0)

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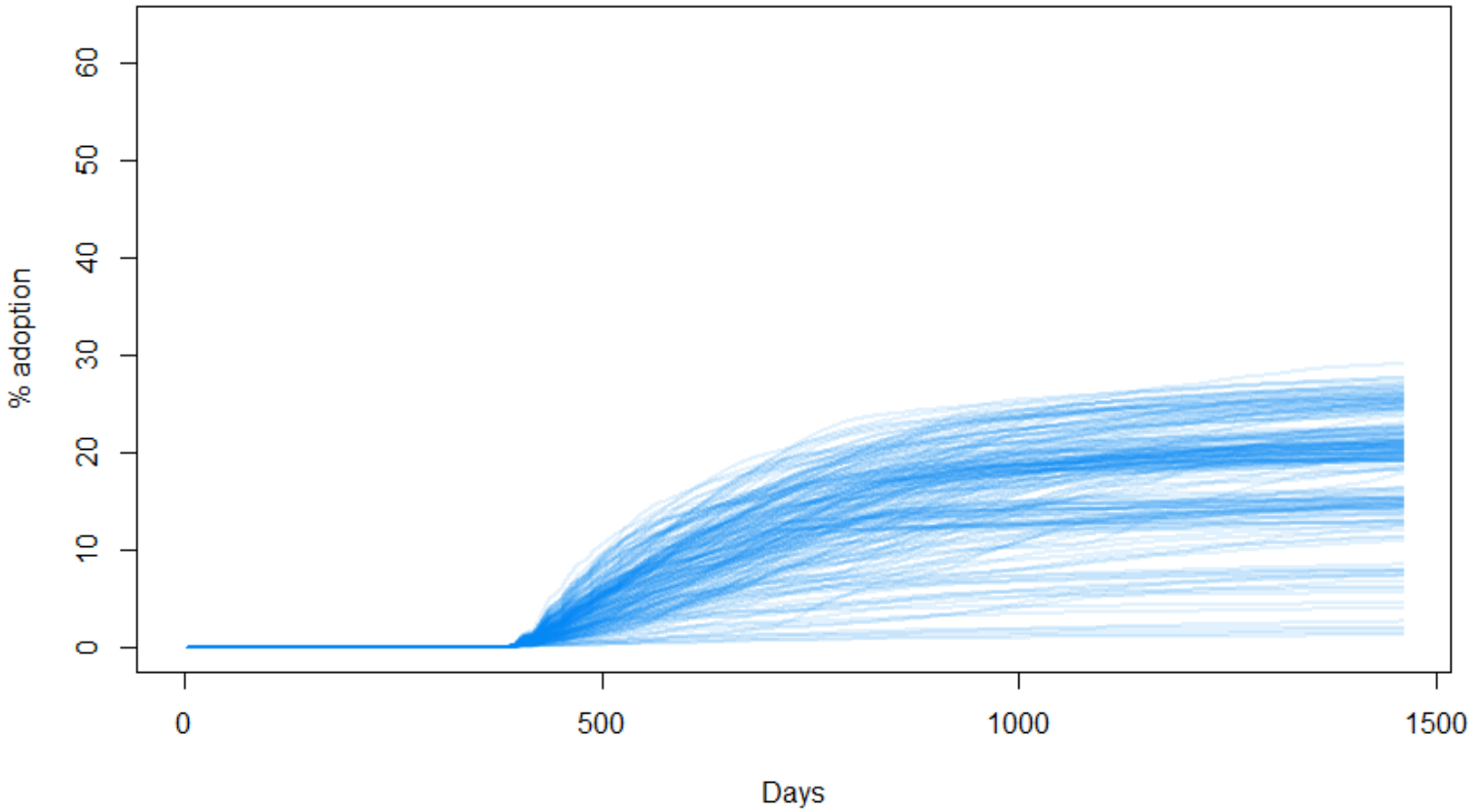
# Magnitude of observation radius

Agent observation radius drawn from Normal(22.5,0)

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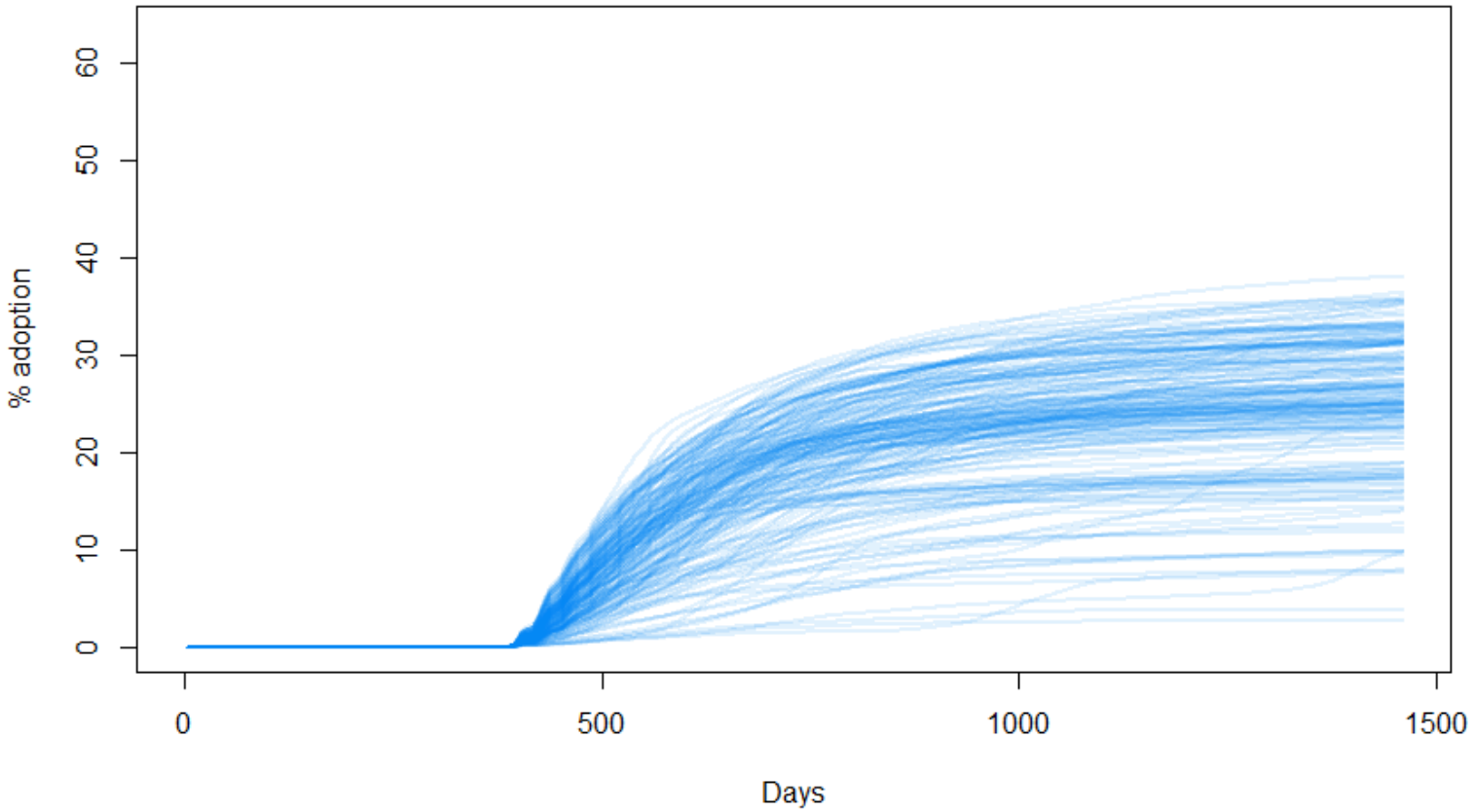
# Magnitude of observed radius

Agent observation radius drawn from Normal(25,0)

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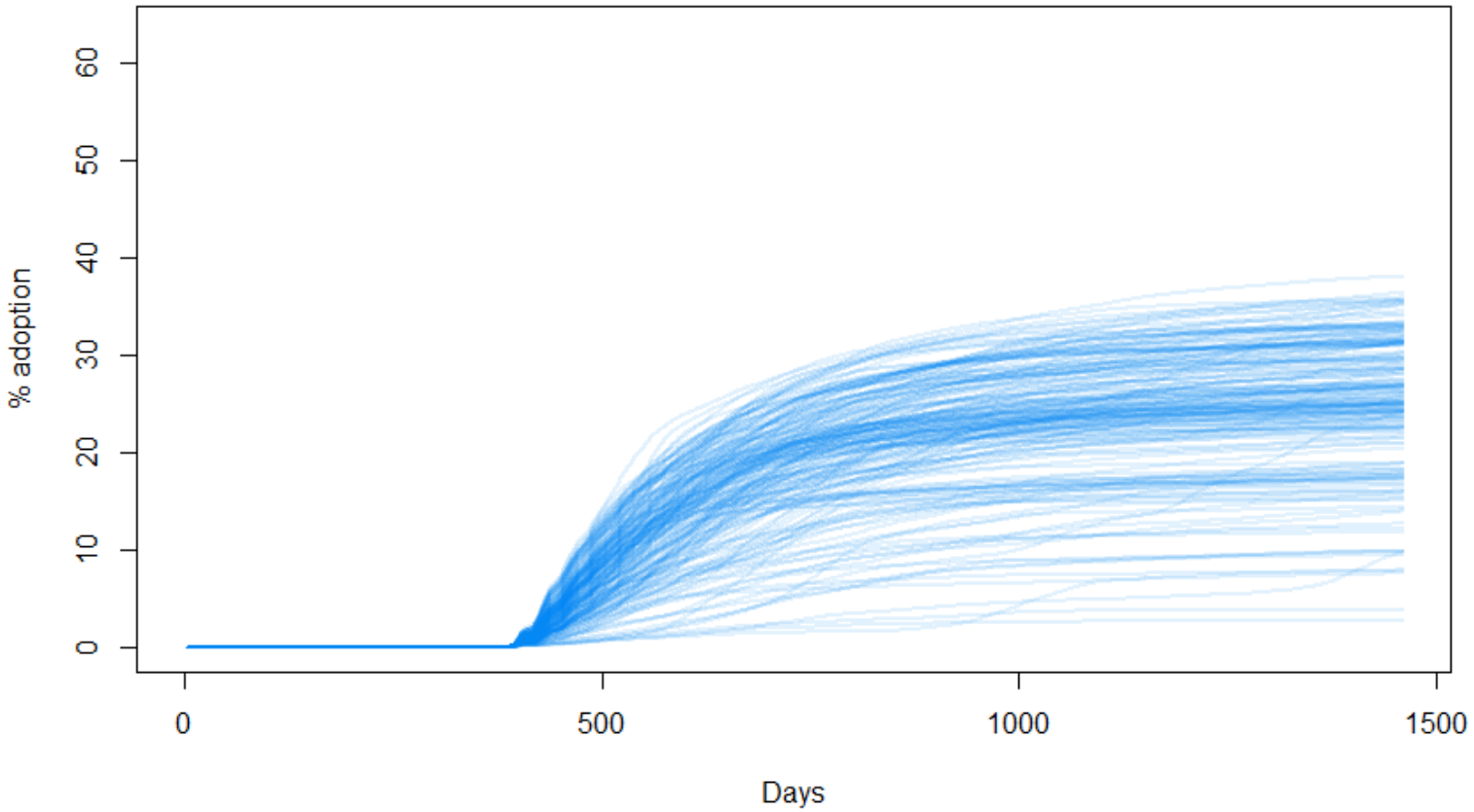
# Observation radius heterogeneity

Agent observation radius drawn from Normal(25,0)

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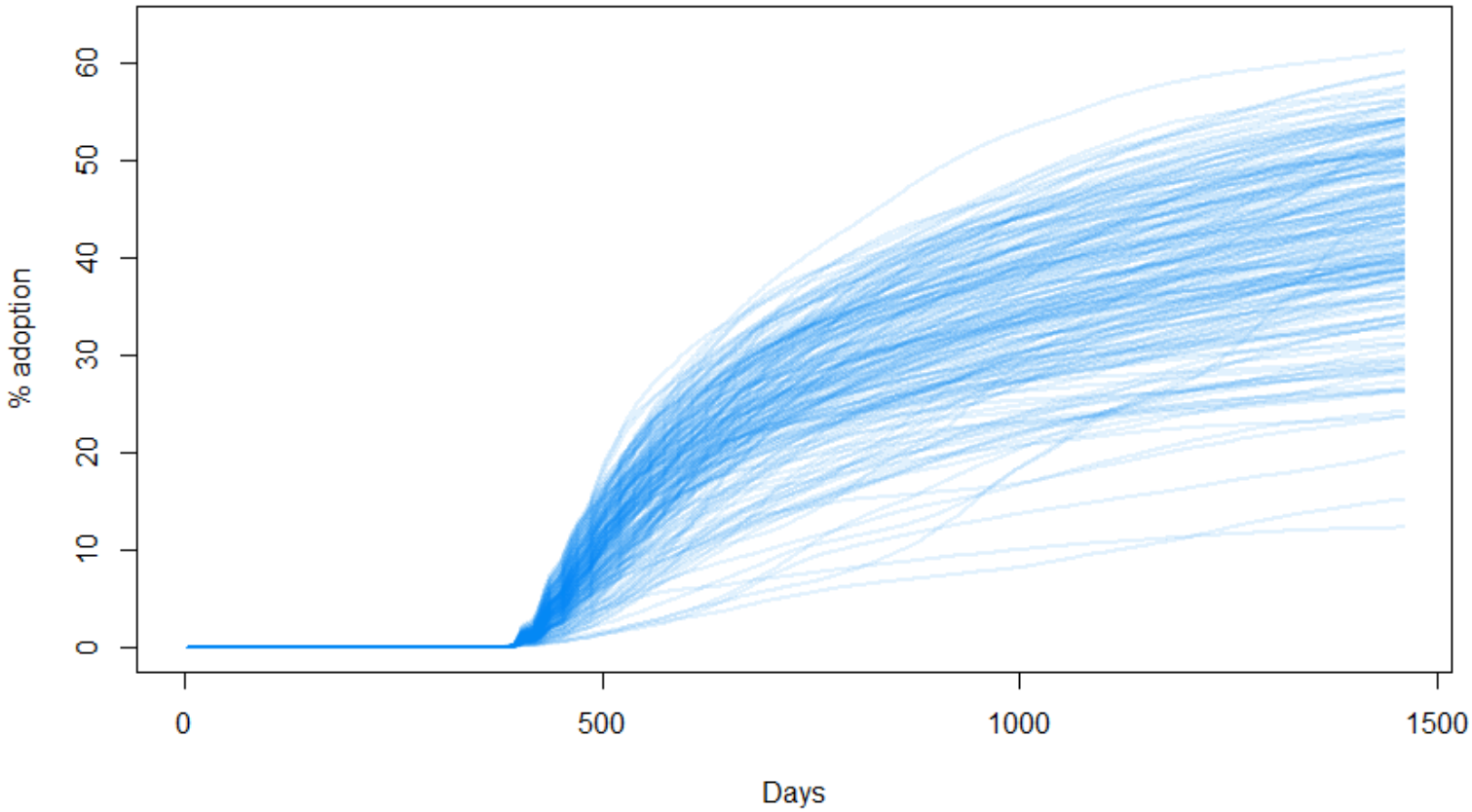
# Observation radius heterogeneity

Agent observation radius drawn from Normal(25,10)

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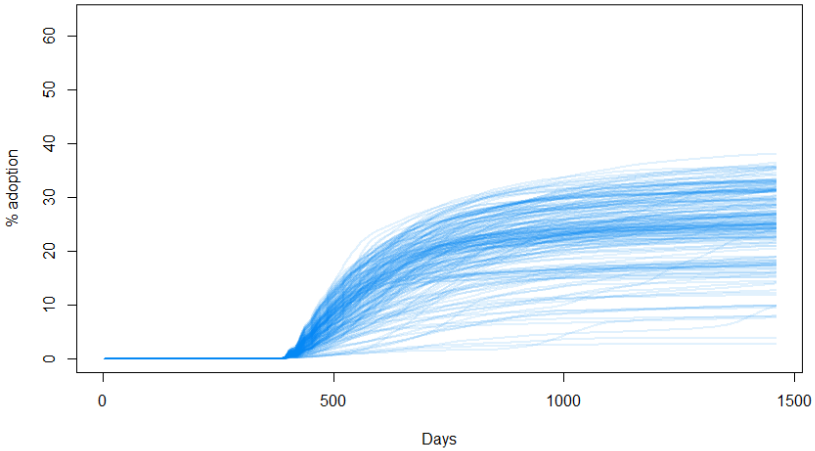
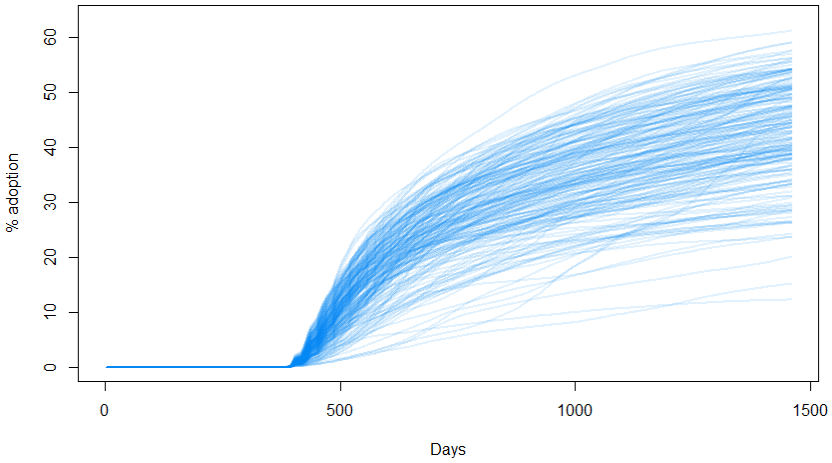
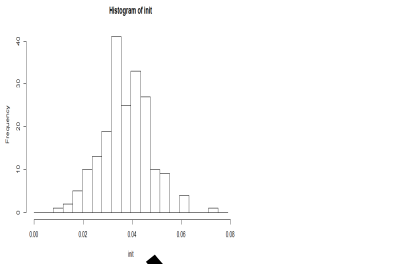
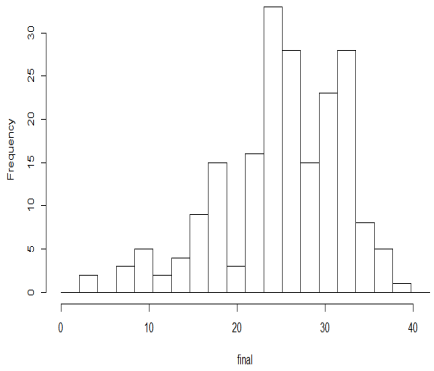
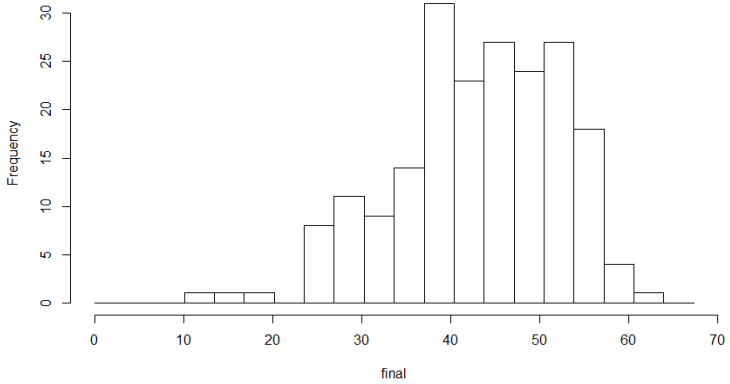
# Observation radius heterogeneity

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# Interaction of multiple green / smart tech

- Subject of final part of PhD (forthcoming!!) and Snape & Boait (2013)
- Adoption of technology can influence propensity to adopt another:

| Increase likelihood | Decrease likelihood |
|---|---|
| • Adopter has "taken the plunge" into green technologies<br>• Money saved<br>• Interest of others<br>• Increased normalisation of owning / using green tech | • Less money to spend<br>• Worse than expected outcomes |

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# Current work - RHI

- Renewable Heat Incentive introduced to incentivise renewable heat generation as FiT incentivised renewable electricity
- Should make adoption tempting, especially in some circumstances (e.g. heat pumps to replace oil heating in off gas grid locations)

**Unlike FiT...**

- Technologies generally replacing existing system rather than pure add-on
- Hassle of installation may be greater (removal of old boiler etc...)
  - Tariffs not quite so generous
  - Mainstream media coverage generally minimal so far.

**But....**

  - Degression mechanism built in and may “kick” the process as reducing the FiT did.

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# Summary and questions

- Adoption influenced by multiple factors
  - Incentive stimulus
  - Shock effect of incentive change
  - Social normalisation
  - Individual propensities
- ABM useful to model adoption highly heterogeneous actors in smart grid scenarios
- ABM reveals variability and responses that may not have been apparent from aggregate modelling techniques.
- Models sensitive to initial conditions
- Models sensitive to heterogeneity in agent parameters
- ABM useful to smart grid scenario investigation
- More work needed...

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# References

DECC (2014) Monthly Feed in Tariff statistics https://www.gov.uk/government/collections/feed-in-tariff-statistics

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