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Toolbox CSS
– Agent-based Models I

NSG SR 423, 14/01/2025

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OUTLINE

- Mechanism-based explanations
  - Definition
  - Taking into account time and network structure
- Factors => Actors
  - Schelling (1971) – cellular automata
  - Baldassarri & Bearman (2007) – network
- ABMs – a practical guide
  - ODD protocol

?

Education → Liberalism

NEWS ANALYSIS

How the Democrats Lost the Working Class

A bunch of explanations exist for this phenomenon:

- Exposure – to more diverse cultural phenomena, teachers, ideas, etc.
- Personality traits – more openness
- Liberal people are more curious – pursue more education
- People growing up in more liberal households more likely to pursue education

… etc.

Classic approach: throw this in a regression, look at differences
=> This will tell us (perhaps) that college graduates are, indeed, more liberal
=> But how does this come about?

?

Education → Liberalism

=> All the hypotheses from before might be true
=> But how does this come about? – what is our *MECHANISM*

Social phenomena – like educated people being more liberal – stem from actions by humans; if this action is organized in a certain way, we observe particular phenomena

For a mechanistic explanation, we need to think about

Entities – who (i.e., humans, in this case)
Their **Actions** (e.g., buying, sleeping, talking, …)
How this is **Organized** (i.e., the order of events)

Education → (?) → Liberalism

Here: People talk with each other, might reinforce their liberal values

=> Communication network is structured by education; college students talk to college students, blue collar worker to blue collar workers, etc.
=> Human action is interdependent – again, observations are not independent

=> Prior liberal leanings might get reinforced n discussions
=> Conservative freshmen might become more liberal as they adapt to liberal peers

Consequence: we might overestimate education's impact – the true reason is that people are put together in a shared environment and interact with each other, "accruing" liberal values

Problem: sounds good yet impossible to observe
=> we would need:
- liberal values right before college
- friend network
- values of friend network
- what they're discussing

=> best we can do is a proof of concept *in silico*

typical college students through the eyes of an almost 29-year old

Solution: simulate students with different initial distributions of values and differing settings of social influence

Two groups of agents, educated and non-educated

- Baseline: liberal values are evenly distributed, no opinion change possible
- Independent observations: educated skew liberal, no opinion change possible
- Social influence: liberal values are evenly distributed the beginning, people are influenced by their peers (educated want to be like the educated and distinguish themselves from the non-educated and vice versa)
- Hybrid: social influence and educated lean liberal at the beginning

=> Comparing outcomes allows us to gage whether interactions between students have an effect

Step-wise simulation: each step one agent gets selected and shifts their opinions toward their group mean

Simulation runs until no more shifts occur

Step-wise simulation: each step one agent gets selected and shifts their opinions toward their group mean

Simulation runs until no more shifts occur

Results:

Table 11.1 How peer influence affects the association between education and social liberalism

Peer influence	Proportion of grads with liberal bias	Directed correlation	Undirected correlation
No	0	0.002	0.08
No	0.1	0.052	0.088
No	0.2	0.108	0.122
Yes	0	−0.031	0.709
Yes	0.1	0.292	0.860
Yes	0.2	0.696	0.915

Flache & Macy 2011, p. 259

ABMs are a way to simulate individuals' (agents') behavior to observe macro outcomes.

These actors are:

- *autonomous*
- *interdependent*
- *follow simple rules*
- *adaptive and backward-looking*
- *heterogeneous*

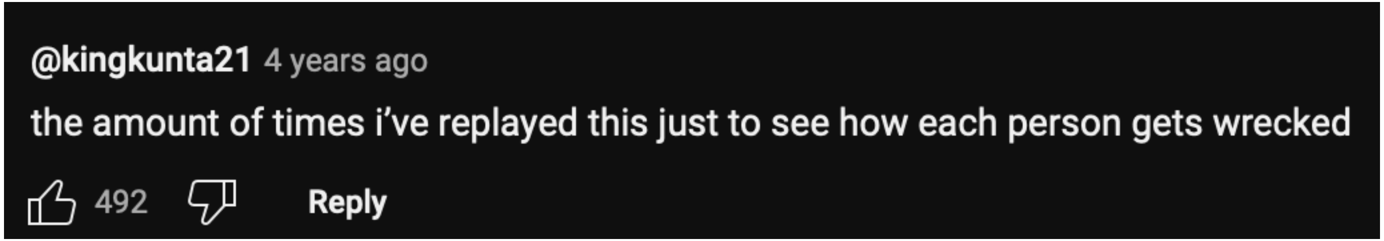
AGENTS

Agents have different properties:

- *autonomous* – single agent's fate matters for the macro outcome
- *interdependent* – one cycler can take out many of them, wreak havoc
- *follow simple rules* – go downhill; crash perhaps
- *adaptive and backward-looking* – crash at t_0 significantly alters speed at t_1; speed accumulates if there's no crash
- *heterogeneous* – different positions in peloton, different skills (probability of crashing)

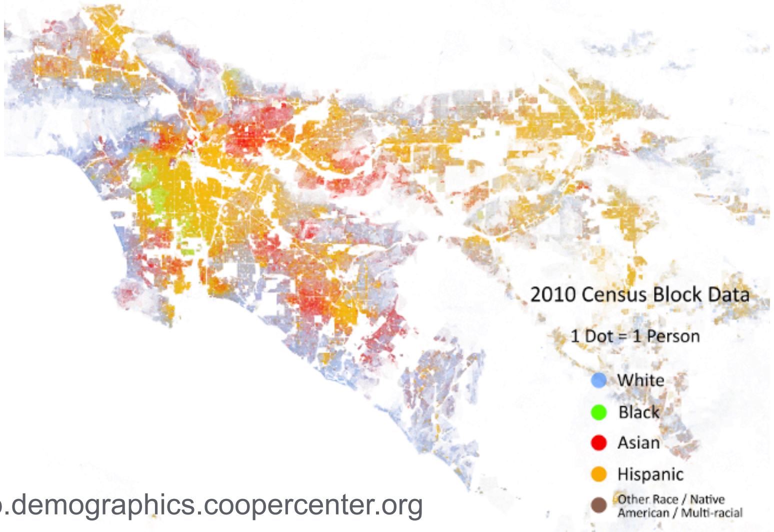
As researchers, we can look at the macro outcome (destroyed peloton)

Or micro outcomes:



SCHELLING (1971)

- Hypothesis (pre-Schelling): people segregate because they are incredible intolerant
- The segregation we see is because people want to leave in homogeneous neighborhoods



http://racialdotmap.demographics.coopercenter.org

“Some of the phenomena of segregation may be similarly complex in relation to the dynamics of individual choice. One might even be tempted to suppose that some 'unseen hand' separates people in a manner that, though foreseen and intended by no one, corresponds to some consensus or collective preference or popular will.” (Schelling 1971: 146)

What extent of individual intolerance is required to see these patterns?

SCHELLING (1971)

- Hypothesis (pre-Schelling): people segregate because they are incredible intolerant
- The segregation we see is because people want to leave in homogeneous neighborhoods

=> Let’s do a simple simulation

Starting point:

0+000++0+00++00+++0++0++00++00++00++0+0+00+++0++00000+++000+00++0+0++0

SCHELLING (1971)

Let’s suppose, that people are mildly intolerant – they don’t want to be the minority group
=> people move if they’re a minority group in their neighborhood (four left, four right)

Starting point:

0+000++0+00++00+++0++0++00++00++00++0+0+00+++0++00000+++000+00++0+0++0

SCHELLING (1971)

Let’s suppose, that people are mildly intolerant – they don’t want to be the minority group
=> people move if they’re a minority group in their neighborhood (four left, four right)

Step 1: minority people in red, they want to move

0+000++0+00++00+++0++0++00++00++00++0+0+00+++0++00000+++000+00++0+0++0

SCHELLING (1971)

Let’s suppose, that people are mildly intolerant – they don’t want to be the minority group
=> people move if they’re a minority group in their neighborhood (four left, four right)

Step 2: Minority people have moved

00000000++++0+++++++++0000++000+0+0+++0+++++++++0000000000000000++++++

SCHELLING (1971)

Let’s suppose, that people are mildly intolerant – they don’t want to be the minority group
=> people move if they’re a minority group in their neighborhood (four left, four right)

Step 3: new situation

00000000++++0+++++++++0000++000+0+0+++0+++++++++0000000000000000++++++

SCHELLING (1971)

Let's suppose, that people are mildly intolerant – they don't want to be the minority group
=> people move if they're a minority group in their neighborhood (four left, four right)

Step 4: others are unhappy now

00000000++++0+++++++++0000++000+0+0+++0+++++++++0000000000000000++++++

SCHELLING (1971)

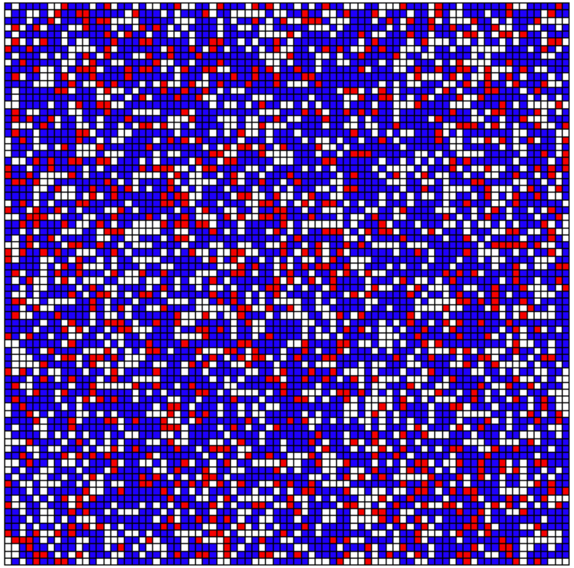
Let’s suppose, that people are mildly intolerant – they don’t want to be the minority group
=> people move if they’re a minority group in their neighborhood (four left, four right)

Step 5: segregation, no-one is unhappy anymore

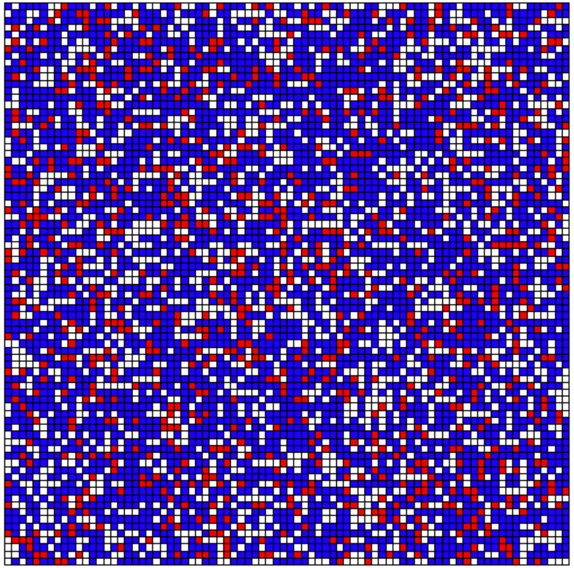
00000000+++++++++++++0000000000+++++++++++++++0000000000000000++++++

SCHELLING (1971)

This is not very realistic (most importantly: no empty spots where people could move to in the first place)
=> we can make this more realistic by using a chess-grid type environment (adding a second dimension)
=> cellular automaton

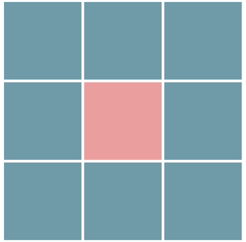


CELLULAR AUTOMATA

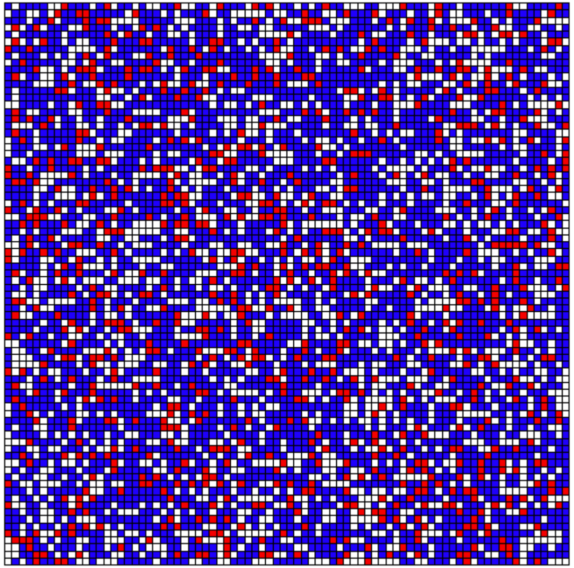


- Dynamic system with discrete states of space, time, and system
- Identical types of cells in multiple dimension
- Cells can change based on their own state and neighboring cells’ states
- Automaton defined by:
  - Size, dimensions, geometry
  - Neighborhood relationships (which cells do we take into account – von Neumann and Moore, typically)
  - Number of states (how many values can cells take)
  - Transition rules

Von Neumann



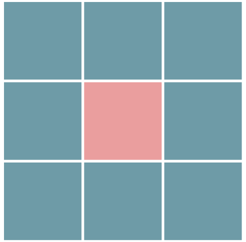
Moore



CELLULAR AUTOMATA

- Automaton defined by:
  - Size, dimensions, geometry
  - Neighborhood relationships (which cells do we take into account – von Neumann and **Moore**, typically)
  - Number of states (how many values can cells take) – color (fixed – either “skin color”, or free plot), happy vs. unhappy (depending on neighborhood)
  - Transition rules (unhappiness threshold)

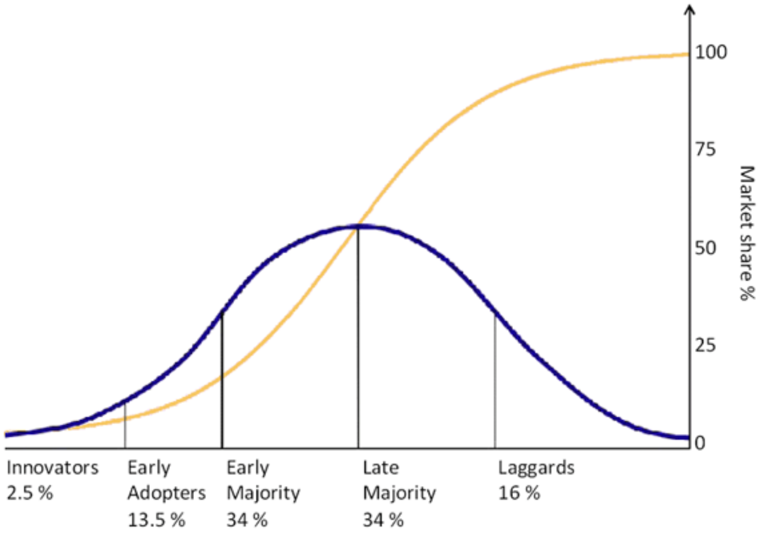
Von Neumann



Moore

CELLULAR AUTOMATA

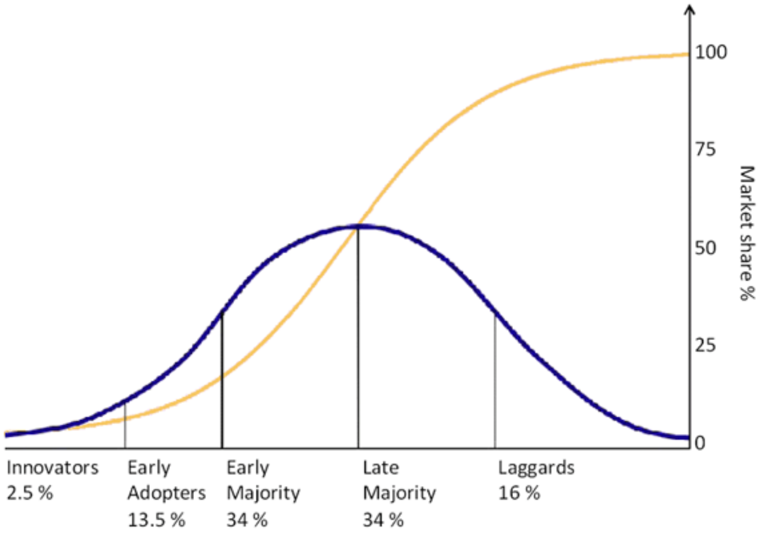
- This can be used to model a bunch of things
- For instance, cultural diffusion (state of cells: adopted a certain thing or not; adopt something once neighbors have adopted it – a bit like a wildfire)
- Or: Rumor Mill



CELLULAR AUTOMATA

- Rumor Mill
- Netlogo sort of replicates the s-curve
- However: is this realistic
  - there might be weak/long ties
  - different ways of communication
  - different types of contagion (Centola 2018)

=> We cannot model this with a cellular automaton
=> We need some sort of **network**



BALDASSARRI & BEARMAN (2007)

“the simultaneous presence and absence of political polarization—the fact that attitudes rarely polarize, even though people believe polarization to be common”

=> elites are polarized – hence this false perception

=> certain issues – “takeoff issues” – are polarized

“the simultaneous presence and absence of social polarization—the fact that while individuals experience attitude homogeneity in their personal networks, these networks retain attitude heterogeneity overall”

=> this is due to homophily – “socially similar individuals are more likely to interact”

=> people discuss politics with others that are similar to themselves, hold similar opinions

“from acquaintances to intimates, individuals’ opinions are shaped by seemingly minor interactions arising from diverse social contexts (Huckfeldt and Sprague 1995; Zuckerman 2005)” => also: strength of others’ influence determined by structural proximity

=> Baldassarri & Bearman (2007) try to investigate how certain views on issues spread based on this

BALDASSARRI & BEARMAN (2007)

Table 1. Outline of the Simulation Algorithm

Initial Conditions:

100 actors
4 issues; issue interest ~ normal (μ = 0, σ = 33.3); interest range (–100; +100)
Initialize perceived ideological distance λ = mean Euclidean distance among actors

Iteration Flow:

Selection of interaction partners
At each iteration for each actor:
Random sample of potential interlocutors ~ to the overall level of interest
Draw from the sample the actual interlocutors with $p = 1 - \lambda$

Process of interpersonal influence
For each pair of actors previously selected:
Select the issue for discussion
Compute the change for each actor based on their interest on the issue
Determine the direction of change according to the sign of the issue
Update actors' level of interest
Update actors' perceived ideological distance with the current/actual distance
Save all necessary information
(Repeat 500 times)

BALDASSARRI & BEARMAN (2007)

Table 2. Directionality of Opinion Change

	a b + +	a b − −	a b + − conflict	a b + − compromise	a b − + conflict	a b − + compromise
Change for a	$+\Delta a_i$	$-\Delta a_i$	$+\Delta a_i$	$-\Delta a_i$	$-\Delta a_i$	$+\Delta a_i$
Change for b	$+\Delta b_i$	$-\Delta b_i$	$-\Delta b_i$	$+\Delta b_i$	$+\Delta b_i$	$-\Delta b_i$
Relative Movement	→ ←	→ ←	← →	→ ←	← →	→ ←

BALDASSARRI & BEARMAN (2007)

Table 2. Directionality of Opinion Change

	a b + +	a b − −	a b + −		a b − +	
			conflict	compromise	conflict	compromise
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Change for b	$+\Delta b_i$	$-\Delta b_i$	$-\Delta b_i$	$+\Delta b_i$	$+\Delta b_i$	$-\Delta b_i$
Relative Movement	→ ←	→ ←	← →	→ ←	← →	→ ←

- If disagreement w.r.t. other topics – opinions on focal topic become more dissimilar
- If agreement w.r.t. other topics – opinions converge

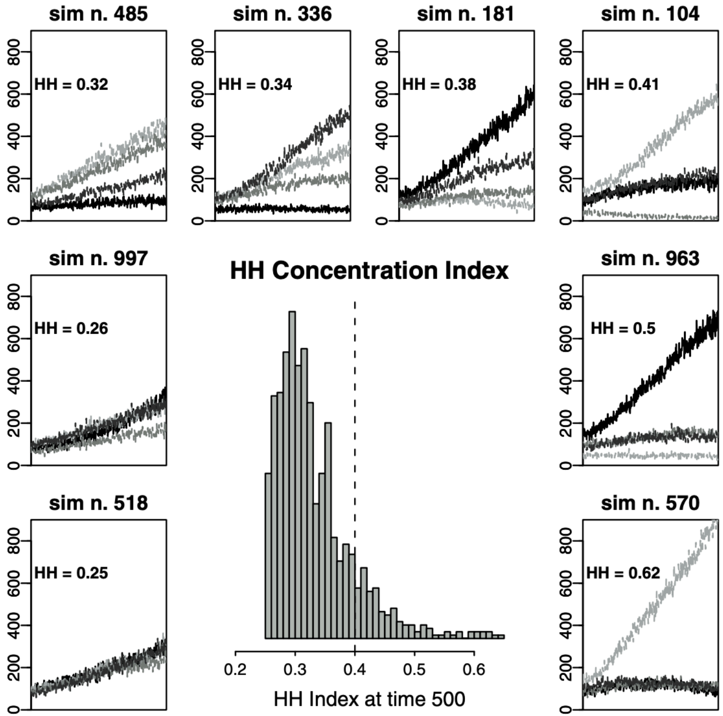
$$\Delta a_i^{(t)} = \mu \times \frac{\left| a_i^{(t)} \right| - \left| b_i^{(t)} \right|}{\left| a_i^{(t)} \right|} \text{ for } a_i^{(t)} \neq 0$$

BALDASSARRI & BEARMAN (2007)

- Finally: Herfindahl-Hirschmann index to see whether a topic dominates public discourse (HH>0.4)

$$HH = \sum_{i=1}^{4} P_i^2$$

- Another finding: if issue dominates, it also polarizes more and shapes network – like-minded people are communicating more with other like-minded people



BALDASSARRI & BEARMAN (2007)

- But: “takeoff is rare”
  - But if so, then a topic dominates the discussion
  - People divide in camps
  - Other topics are the “glue” that connects these camps
- Society appears divided because we perceive it in a biased way – not “everything is polarized” but rather “certain issues are”; there is common ground
- However: see DellaPosta (2020) for an empirical account

ABMS – CONCLUSION

- Important toolbox to test theories sans data
- Build a model from the ground up where people behave according to how you think they behave
  - Observe macro- and micro-outcomes
  - Run multiple models in parallel where you include varying conditions (e.g., varying starting conditions, policies, etc.) – look at the differing outcomes
  - The “multiple worlds” can serve as counterfactuals, allowing to single out the individual effects particular variables/interventions might have
- Important principle: KISS (keep it simple, stupid)
  - Include as little variation as necessary – easier to understand
  - Helps with transparency w.r.t. assumptions and mechanisms
  - Reveals fundamental dynamics/mechanisms – find the simplest representation possible
  - Less prone to implementation errors

BUILDING ABMS FROM SCRATCH – THE ODD PROTOCOL (GRIMM ET AL. 2006, 2010, 2020)

- A standardized way of reporting ABMs
- Easy for the reader/reviewer
- But also very helpful as a schema to construct ABMs from scratch

BUILDING ABMS FROM SCRATCH – THE ODD PROTOCOL (GRIMM ET AL. 2006, 2010, 2020)

Overview	O	1. Purpose and patterns
		2. Entities, state variables and scales
		3. Process overview and scheduling *Submodel A* *Submodel B ...*
	D	4. Design concepts
Details	D	5. Initialization
		6. Input data
		7. Submodels *Submodel A (Details)* *Submodel B (Details) ...*

Design concepts:

Basic principles
Emergence
Adaptation
Objectives
Learning
Prediction
Sensing
Interaction
Stochasticity
Collectives
Observation

Overview	
	1. Purpose and patterns
	2. Entities, state variables and scales
	3. Process overview and scheduling

Purpose and patterns:
- What is the model supposed to show – which patterns or phenomena

Entities, state variables, and scales
- Description of model entities (agents, environment)
- Definition of state variables and attributes
- Specification of temporal and spatial scales

Process overview and scheduling (make a flow chart or table, e.g., Baldassarri & Bearman (2007), Table 1)
- List of model processes
- Order of execution
- Time stepping

D	4. Design concepts

Basic principles
Emergence
Adaptation
Objectives
Learning
Prediction
Sensing
Interaction
Stochasticity
Collectives
Observation

basic principles – are there existing, similar models? What are the differences?

emergence – how do results come about

adaptation – how do actors adapt

sensing – how much do actors know about the state of other agents?

learning – does new knowledge lead to new decisions in actors?

prediction – are actors trying to predict the future?

interactions – how do actors interact?

stochasticity – are there any “random numbers” involved?

collectives – do we see groups of actors?

observation – how do you collect and summarize information?

Details		
	D	**5. Initialization**
		6. Input data
		7. Submodels *Submodel A (Details)* *Submodel B (Details) ...*

Initialization:

- How’s the world set up
- How are the actors initialized
- How are the state variables set up?

Input data:

- Particular input parameters (e.g., empirical calibration, GIS data, etc.)

Submodels:

- Report all processes (formulas, parameters and how they change, algorithms),
- Justify them
- Robustness checks – how do parameters change behavior

=> Align this with “Process overview and scheduling”

NEXT WEEK

- I have a visa interview scheduled in the morning, so I might be a tad late – I'll send you an update from the road before class, so monitor your email inbox
- We'll extend today's models with some empirical data – shorter session
- And then I'm done – then it's your turn with papers etc.

- Also: regarding presentations – keep them shorter, maybe 5-7 minutes of you talking, 5 minutes feedback from opponent, 3-5 minutes feedback from audience
  => I'll cut you off, ruthlessly

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