Large Scale Models
and
Other Modelling Paradigms

THE UNIVERSITY of EDINBURGH
informatics

Modelling of Systems for Sustainability
INFR10088

Overview

- SGS model of sand, gravel and stone resources
- The World6 world model
- The Locomotion Integrated Assessment Project
- Other Modelling Paradigms
  - Economics
    - Computable General Equilibrium - CGE
    - Dynamic Stochastic General Equilibrium - DSGE
  - Discrete Event Simulation
  - Grid/cell Models

Sand, Gravel and Stone (2012)

- Construction – 50 billion tons/year
- Concrete – 30 billion tons/year
- Last 20 years
  - 400% increase in China, 60% increase elsewhere
- Most used to be mined from riverbanks and local pits
  - Now a lot of sand from marine/beach sources, desert sand not suitable
  - Sand / gravel increasingly from industrial crushing
- Sustainability of supply concern

SGS Model Structure

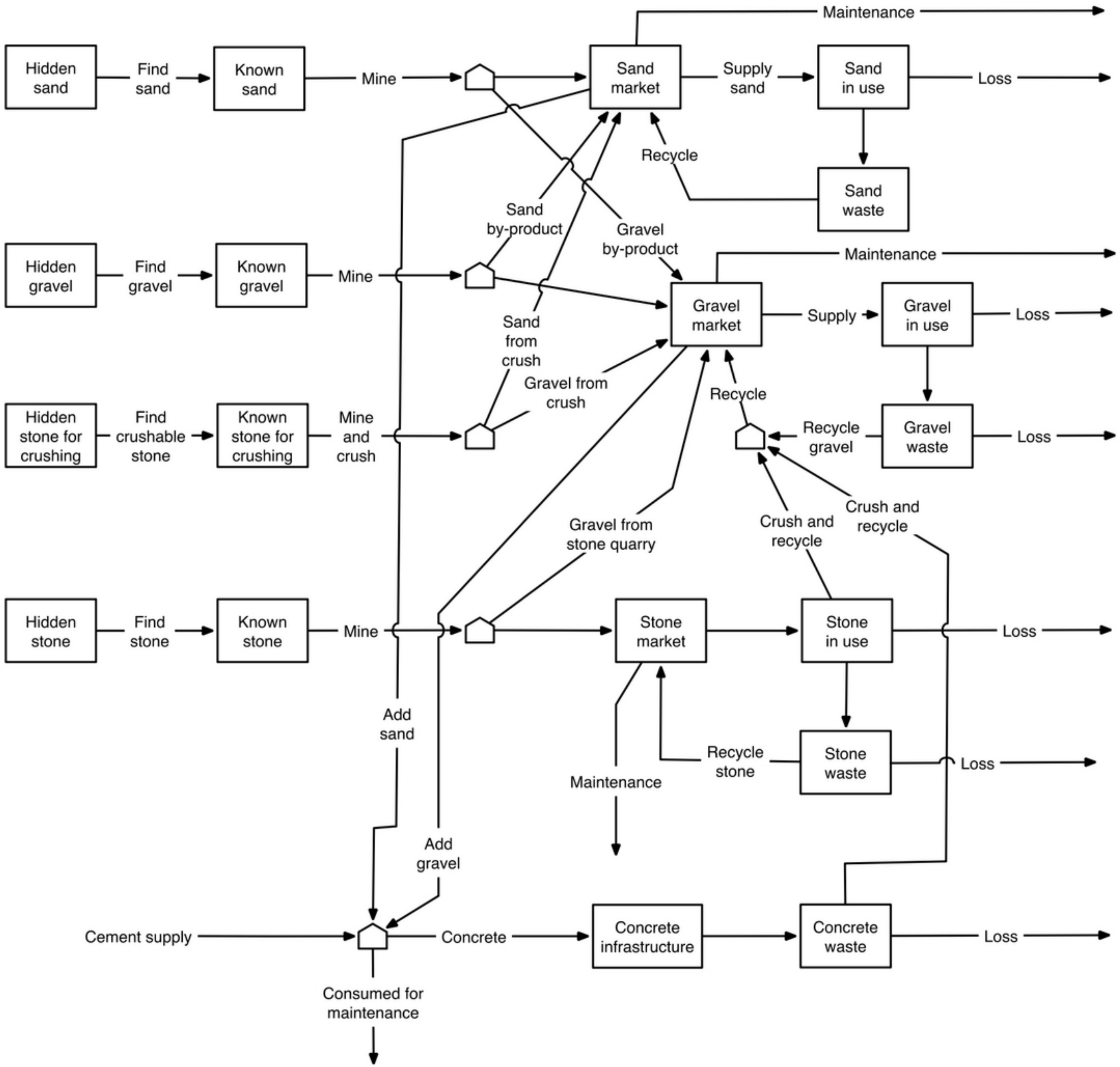


Fig. 1 The flowchart for the sand-gravel-stone (SGS) model. Maintenance flow is assumed to be the replacement for lost material and thus do not add to stock-in-use. Known corresponds to known reserves. All known plus all hidden corresponds to total resources

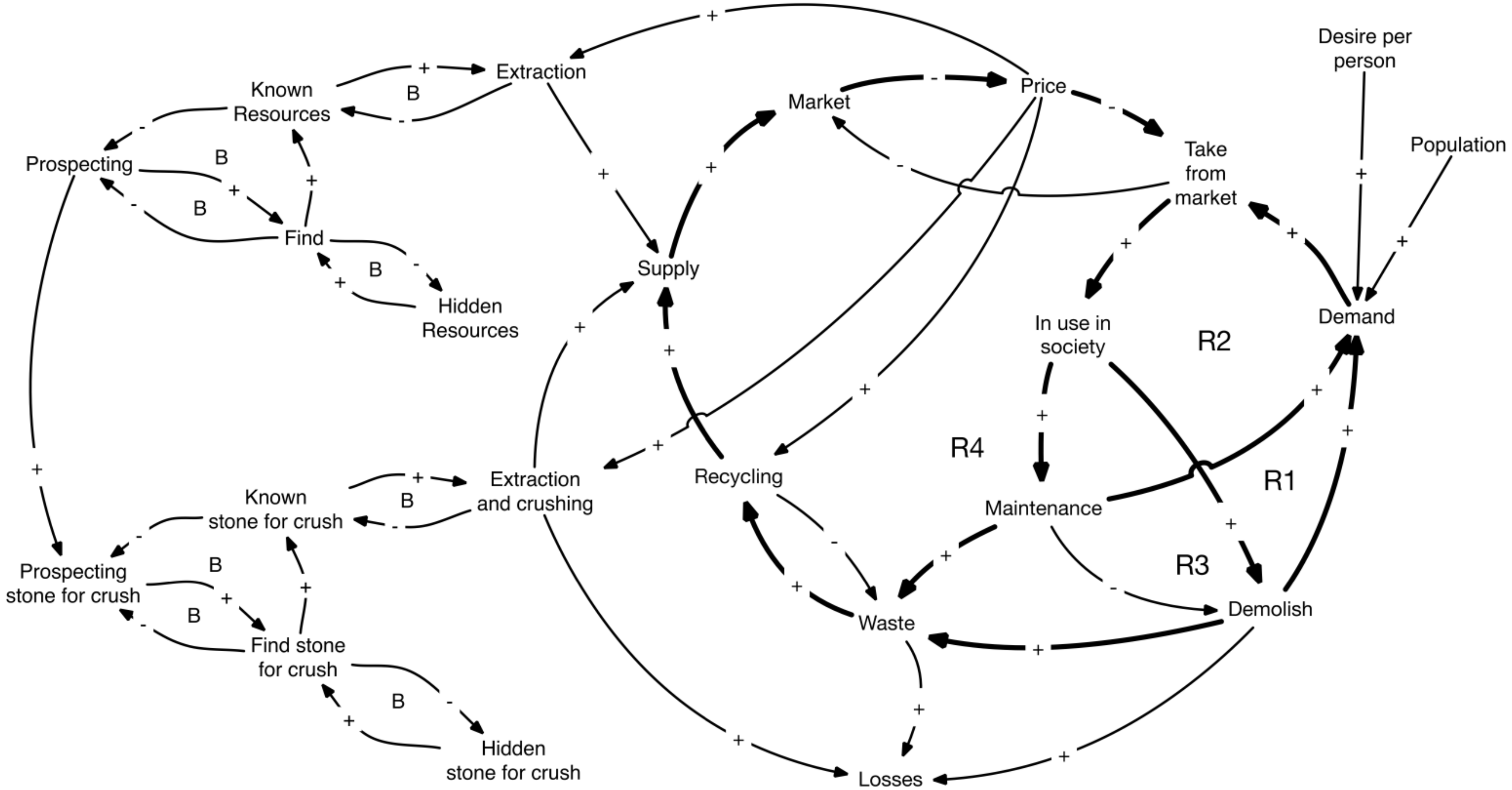
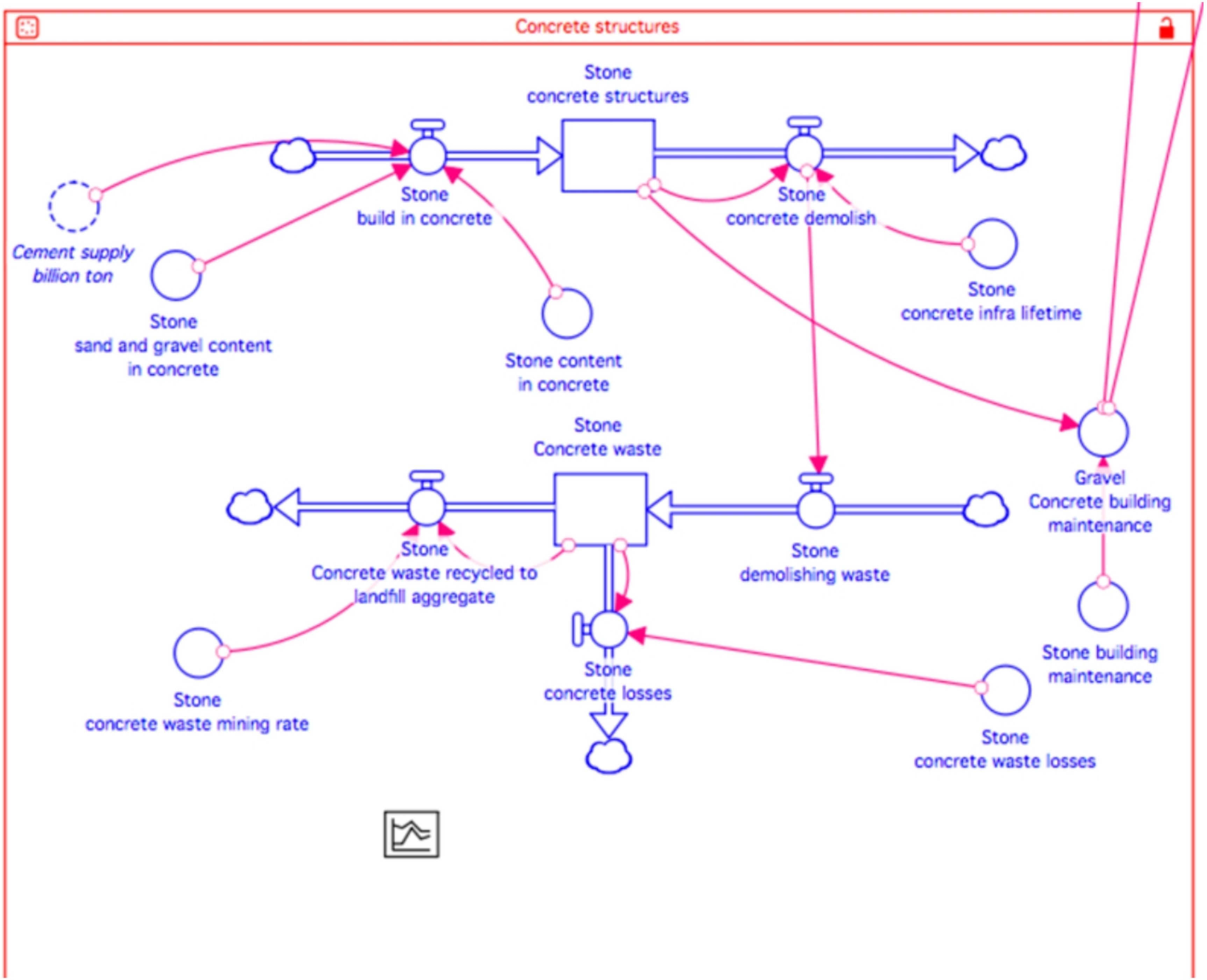
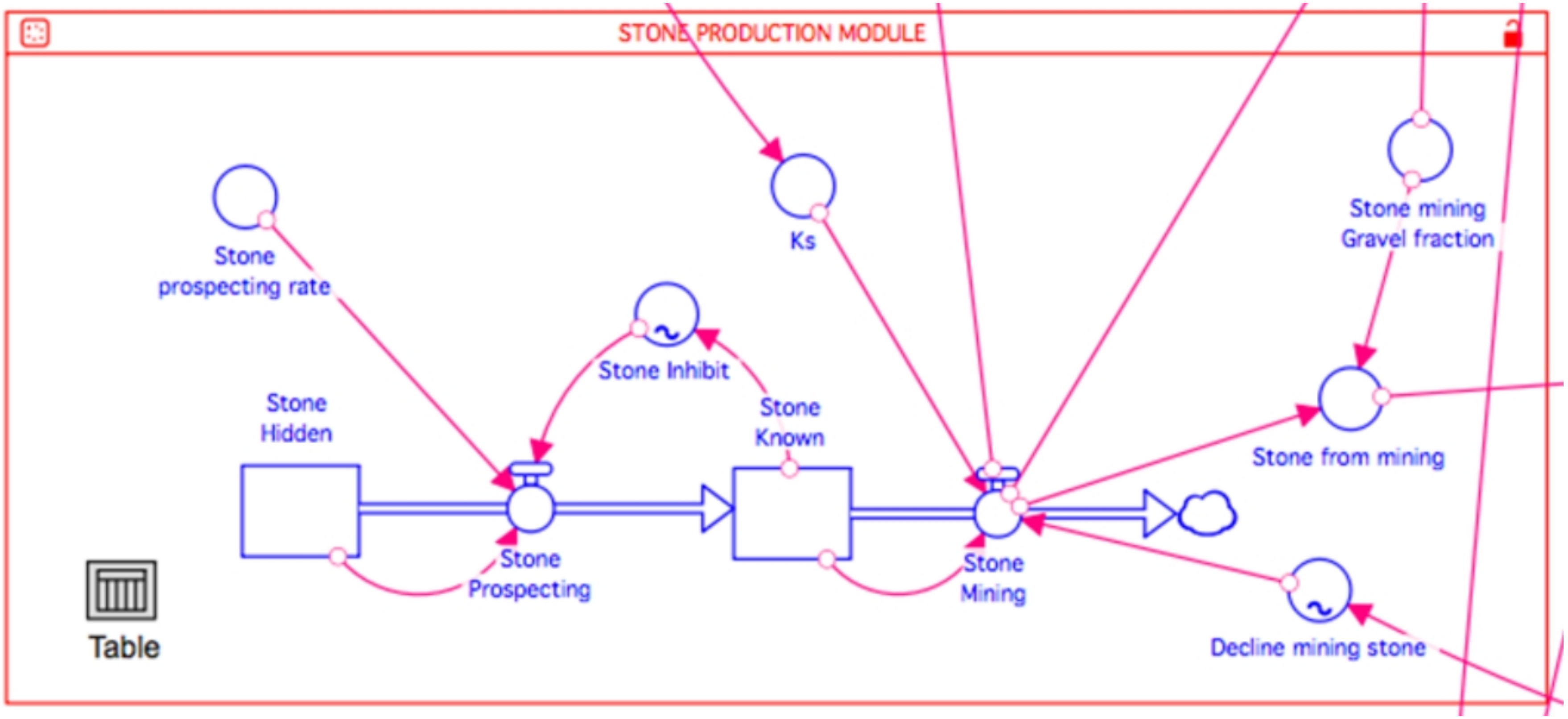


Fig. 3 The basic causal loop diagram applied for the simplified SGS model. The causal loop diagrams for sand, gravel, stone for crushing and cut stone were linked as shown in the flow chart of Fig. 1. The actual model consists of four such coupled causal loop diagrams for sand, gravel, crushed stone and cut stone as Fig. 1 will demand (Fig. S3 in the supplementary material). The *bold arrows* show the reinforcing. The reinforcing loops (*R*) keep the system running. The balancing loops (*B*) act as brakes in the system. The system is driven by demand from general consumption, demolition and maintenance (*R*1–*R*2) and income through price and pushed by demand (*R*3–*R*4)

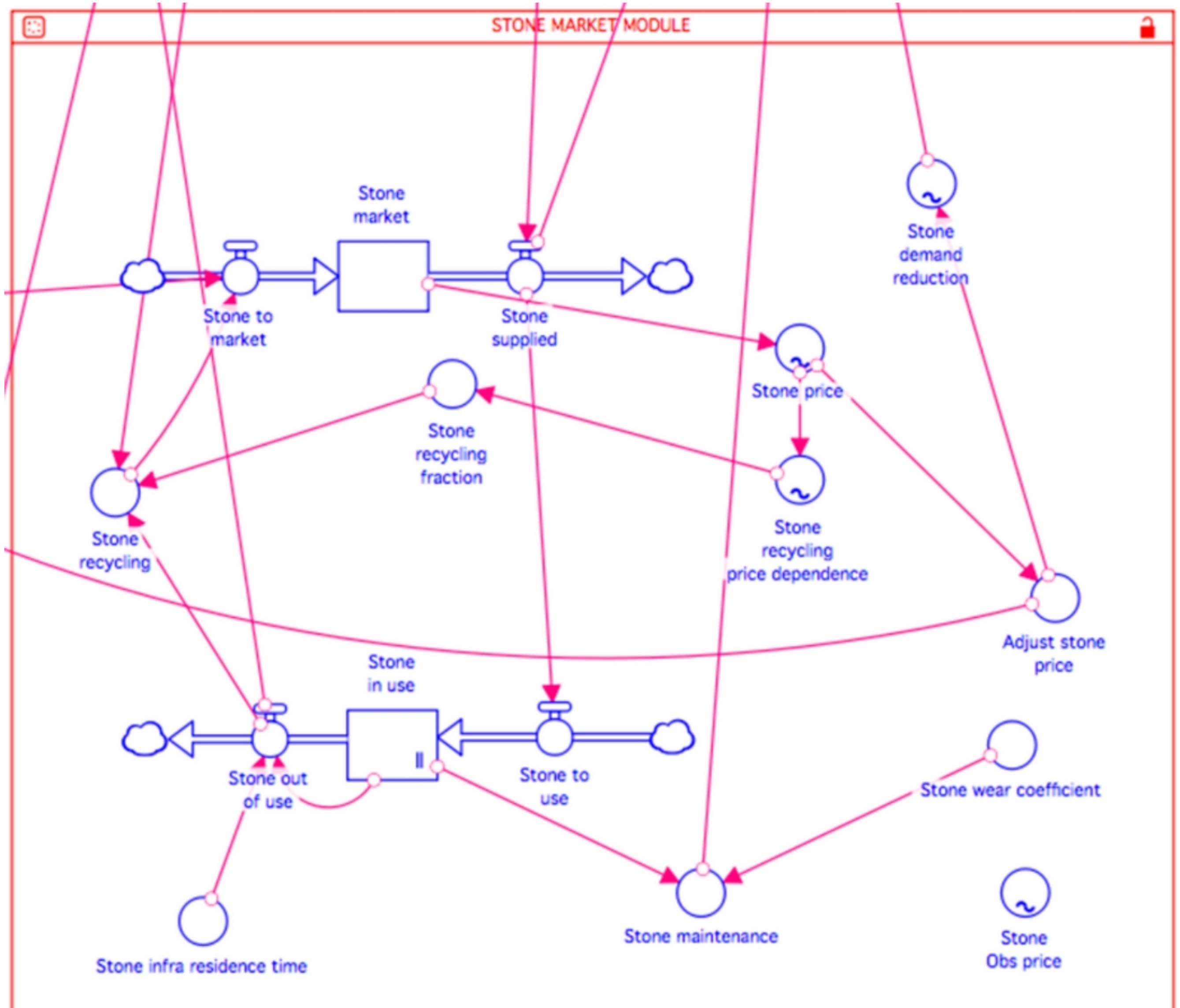
SGS Concrete Stock and Flow



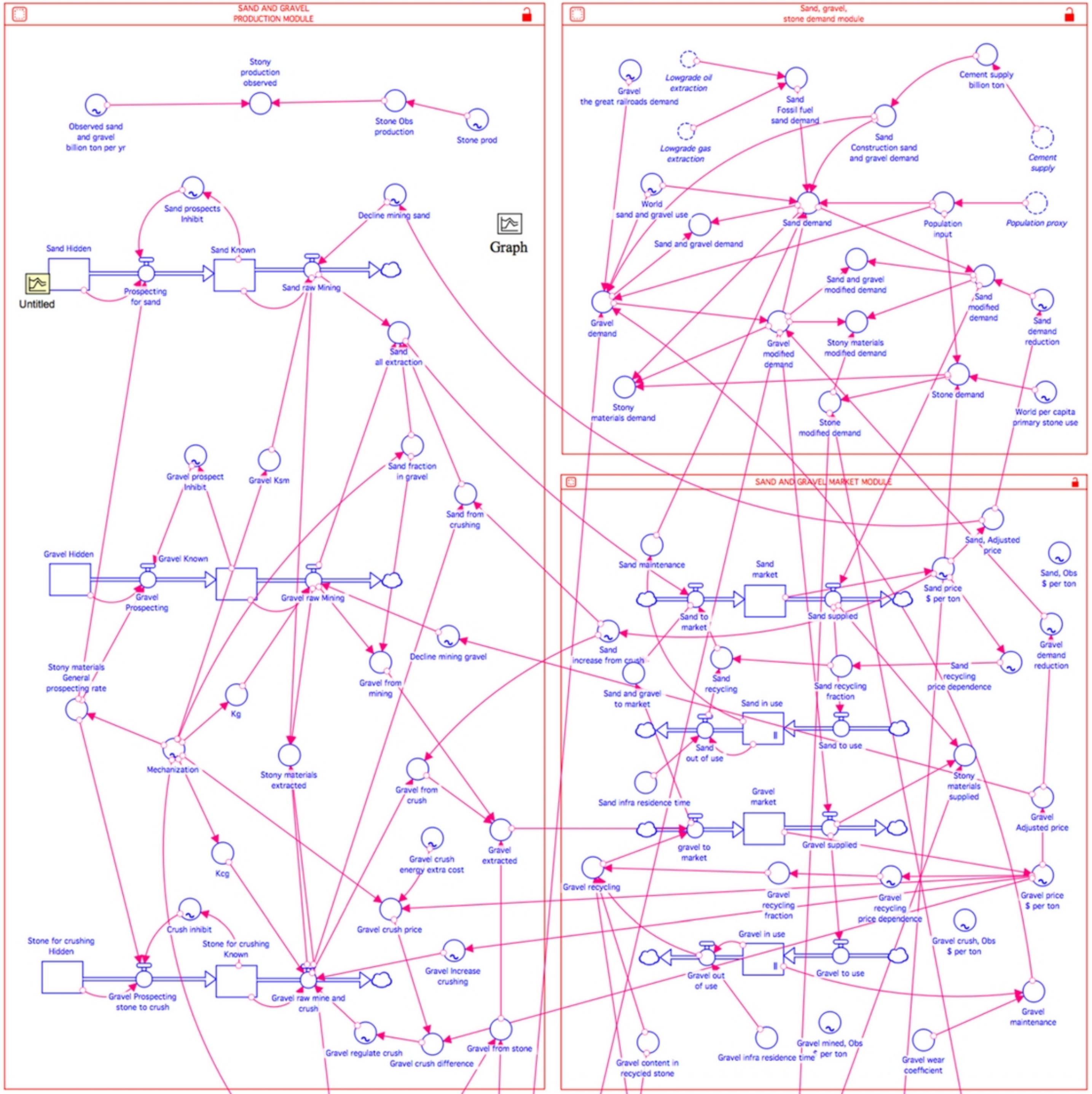
SGS Stone Stock and Flow



Stone Market stock and flow



Sand and Gravel Production and Consumption



SGS Input Data and Calibration

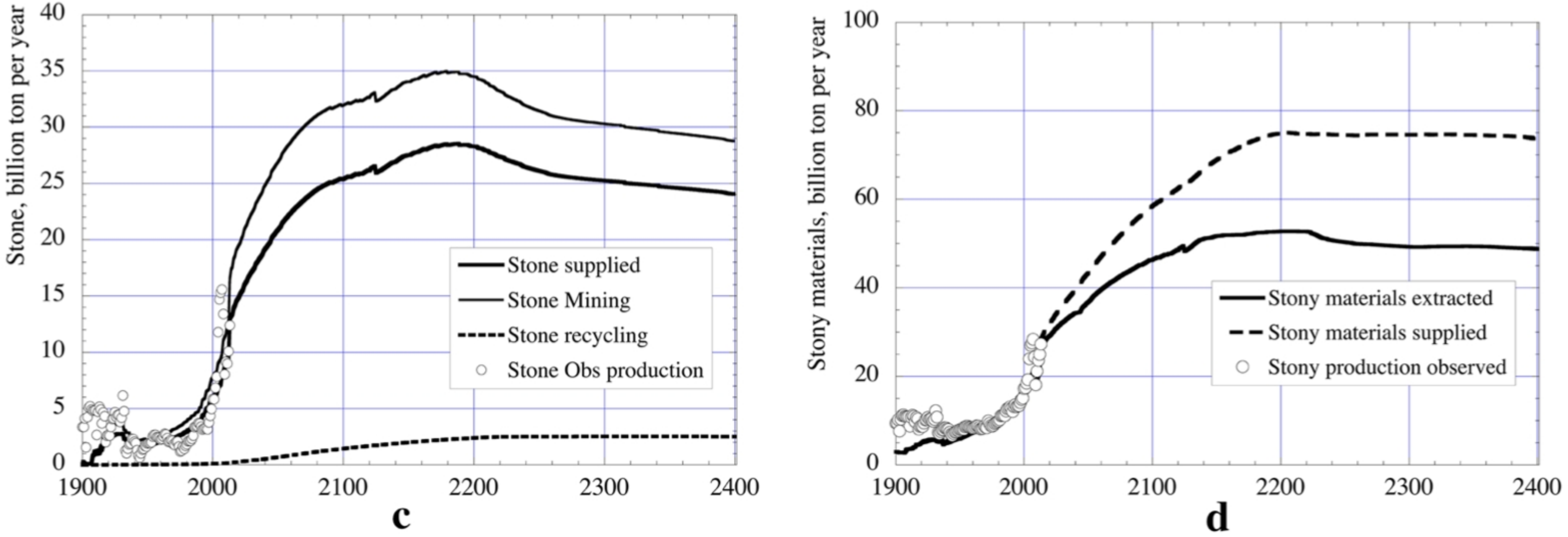
- Estimates from national statistics, company documents, knowledge of the industry
  - Time series projected forward
- Calibration against 1900-2015 historical data
- Scenarios to 2300

SGS Parameter Settings

Parameter	Sand	Gravel	Stone for crushing to sand and gravel	Stone for building
Mining rate coefficient, fraction (k_{mining})	0.025	0.02	0.02	0.015
Mining rate order (n)	1	1	1	1
Prospecting coefficient, fraction ($k_{prospecting}$)	0.005	0.005	0.03	0.035
Base recycling fraction, ($x_{recycling}$)	0.05	0.05	–	0.1
Society retention time, years, ($t_{society}$)	100	100	–	100
Yield gravel in product, fraction, (Y_{sand})	0	0.85	0.9	0.5
Yield sand in product, fraction, (Y_{gravel})	0.85	0.15	0.1	0
Yield stone in product, fraction, (Y_{stone})	0	0	0.25	0.75
Yield in stone recycling	0	0.5	0	0.5

The values were taken from estimates in the available scientific literature

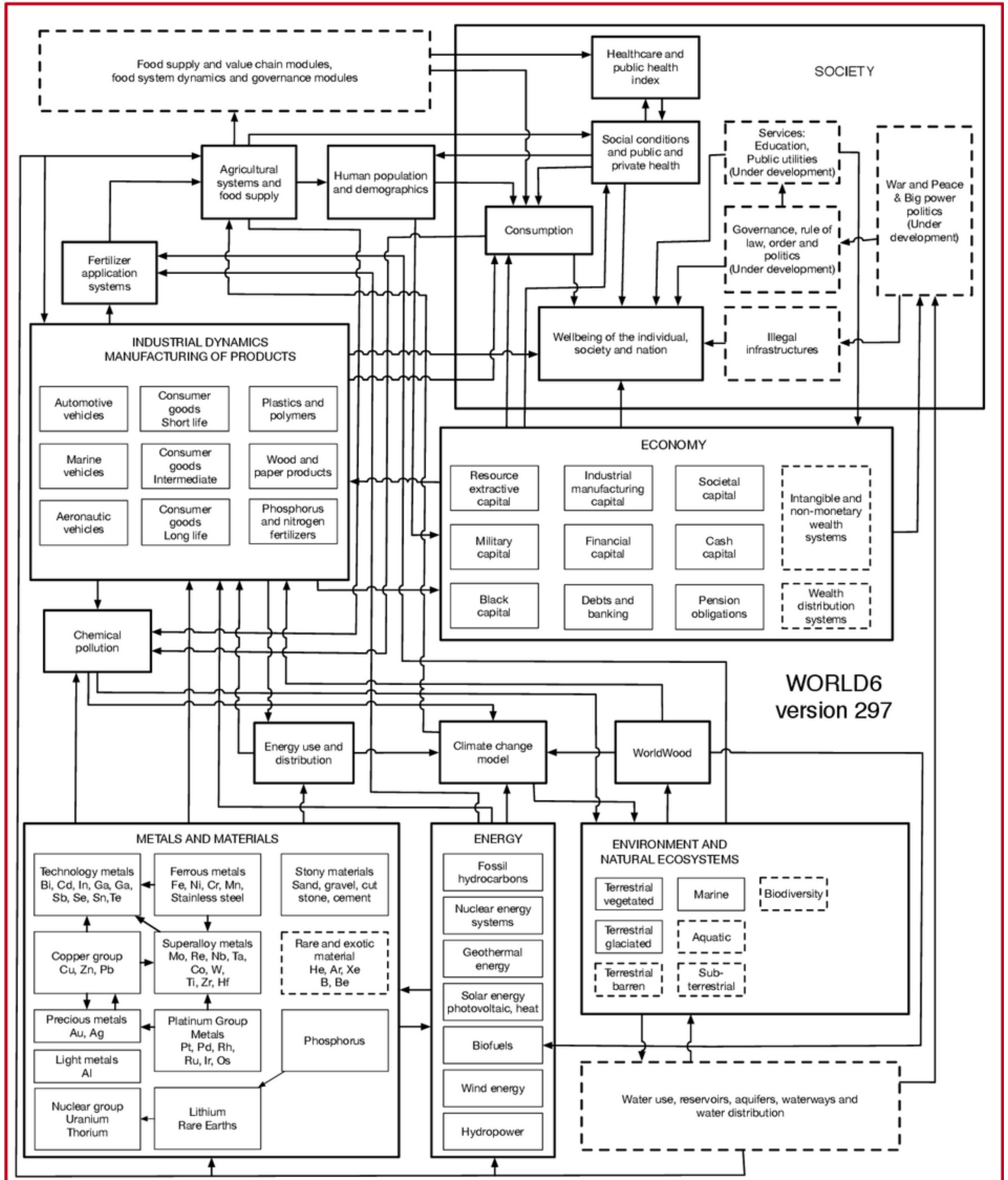
SGS Results Example



World6

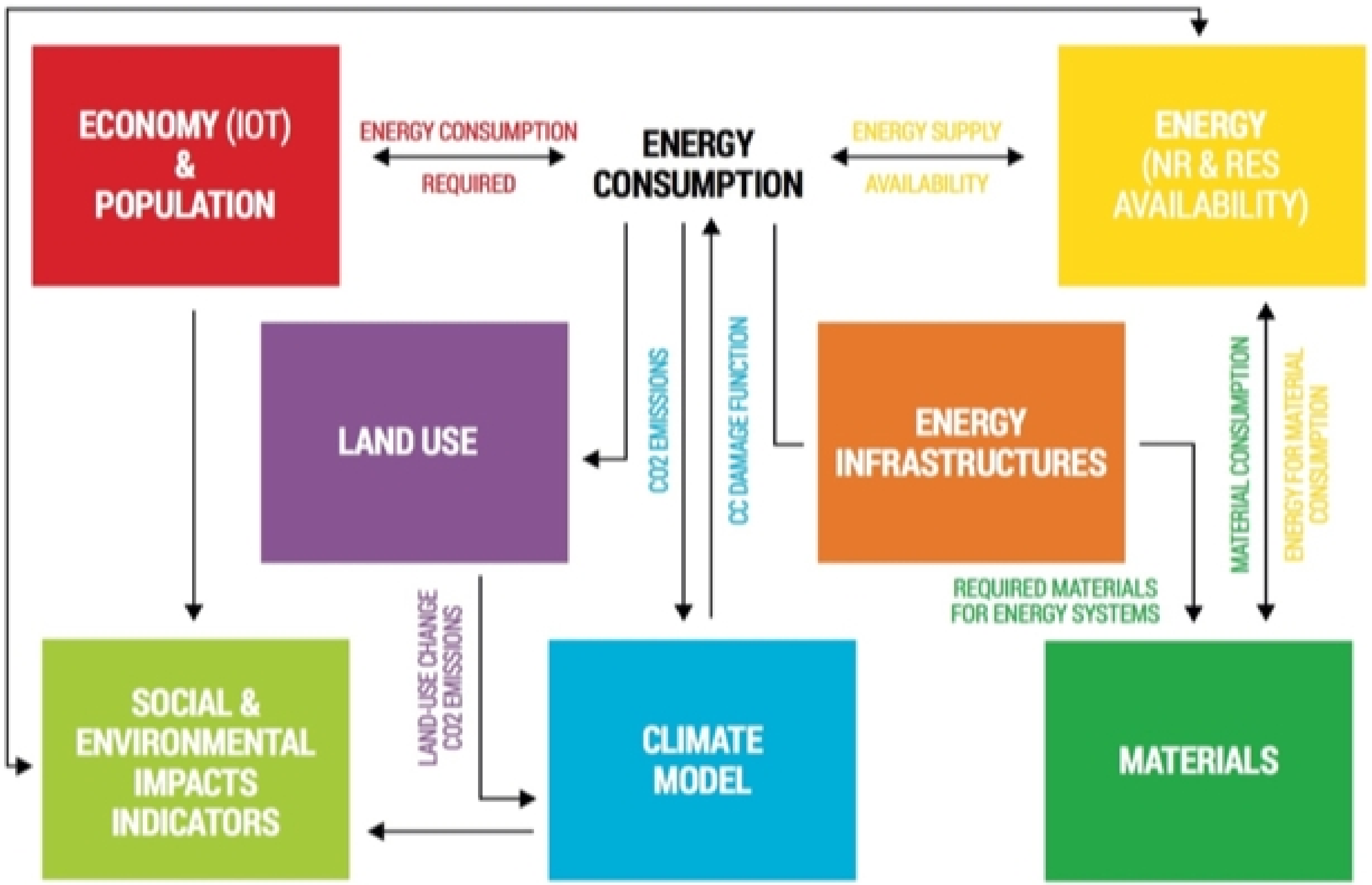
- Builds on *Limits to Growth*, 1972, 1992, 2004
- These integrate models of
  - Society
  - Economy
  - Industrial production
  - Resource flows
  - Energy flows
  - Climate syste
  - Ecosystems

World6 Model components



Sverdrup et al, 2018

Locomotion Integrated Assessment Model



An overview of MEDEAS-World by the modules and modelled linkages between them.

Locomotion website

Locomotion Focus

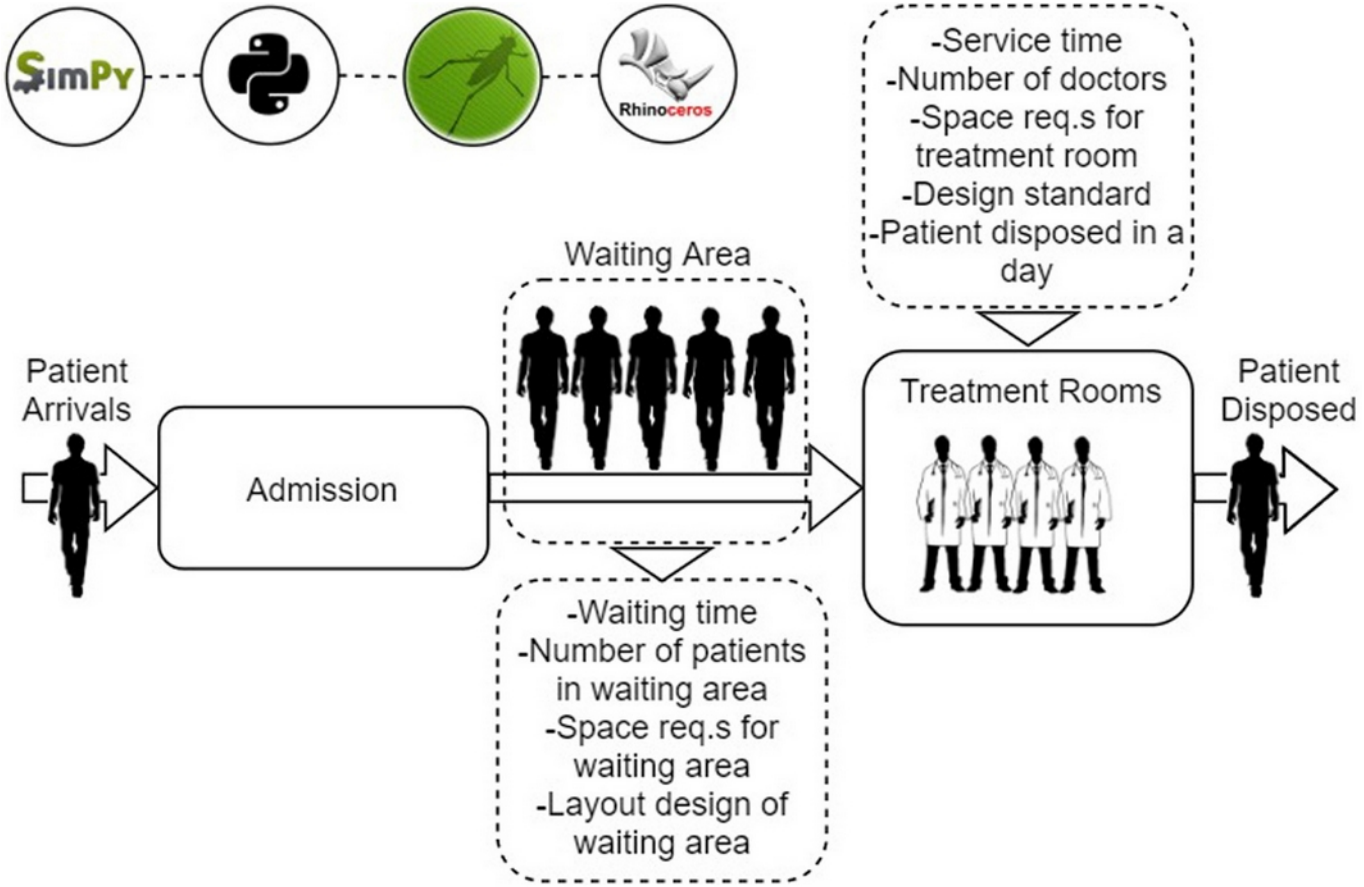
- the careful modelling of the complex human-nature system that is governed by dynamic, tightly coupled, nonlinear, self-organising, adaptive and evolving feedbacks
- the proper representation of biophysical and temporal constraints to renewable and non-renewable energy production
- the declining Energy Return on Energy Investment (EROI) with increasing shares of renewable energy
- the consistent integration of climate change damage feedbacks
- the dominance of conventional economic equilibrium and optimisation approaches, which suffer significant limitations when it comes to capturing socioeconomic system dynamics and the role of macroeconomic policies for sustainability governance

Locomotion Methods

- The endogenous and dynamic integration of economic, financial, energy-related, social, demographic and environmental variables into the models.
- The use of a wide array of methods, such as System Dynamics, Input-Output Analysis, Energy Return On Energy Investment (EROEI) calculations, Life Cycle Analysis (LCA), land and carbon footprinting, microsimulation, etc.;
- The adoption of relevant functionalities from other models (World6, TIMES, LEAP, GCAM, C-Roads, …
- The consistent quantification and representation of uncertainty in model results.

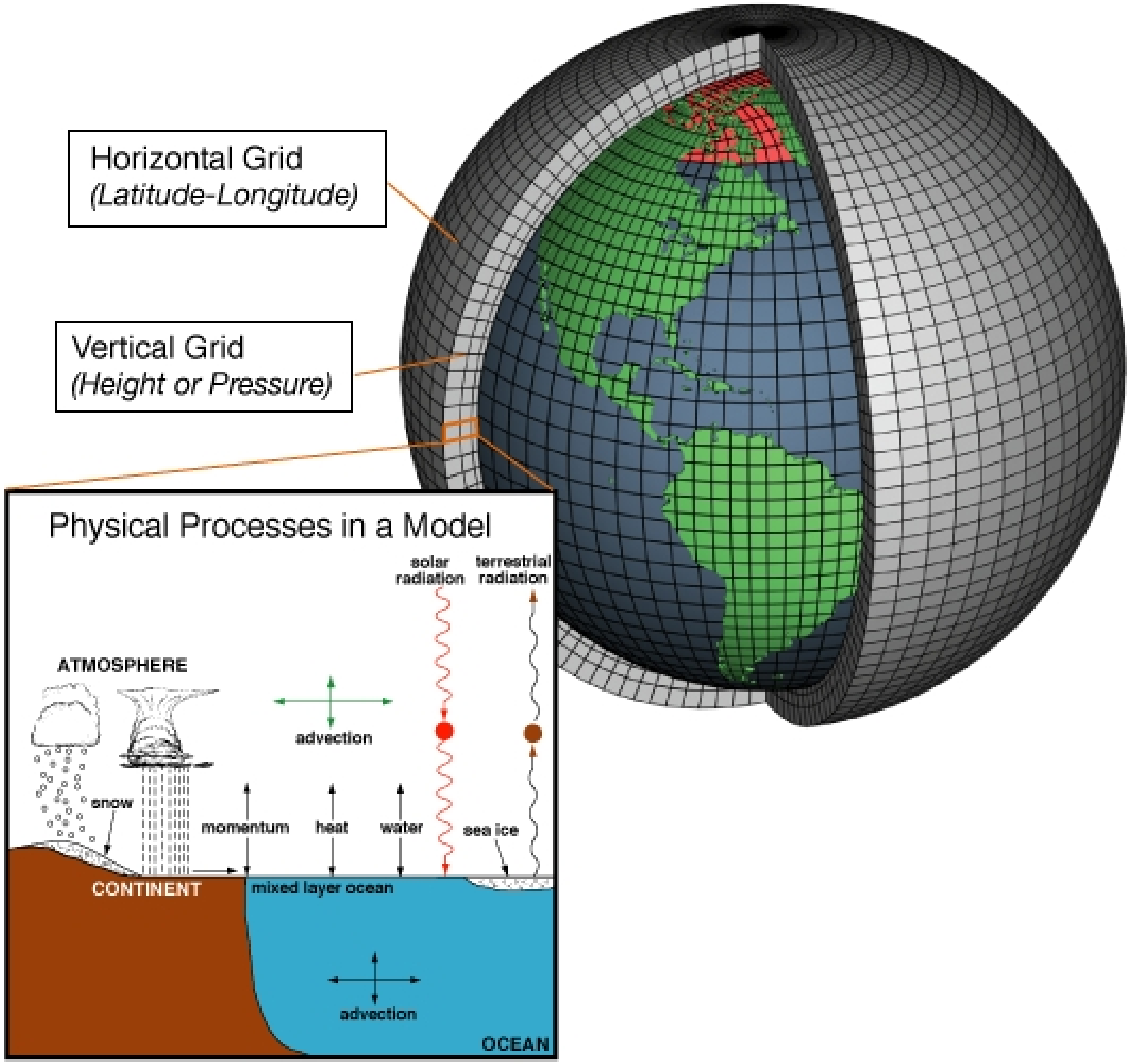
Discrete Event Simulation

- Entities post events for other entities
- Global queue of events
- Parallelisable
- *Time* extension in NetLogo



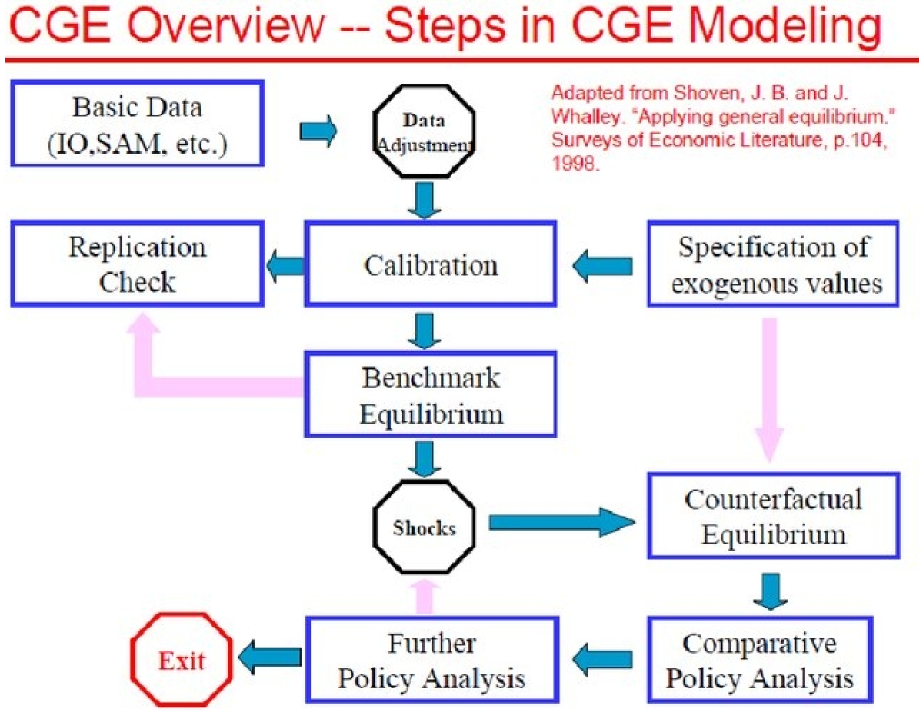
Grid/Cell Models

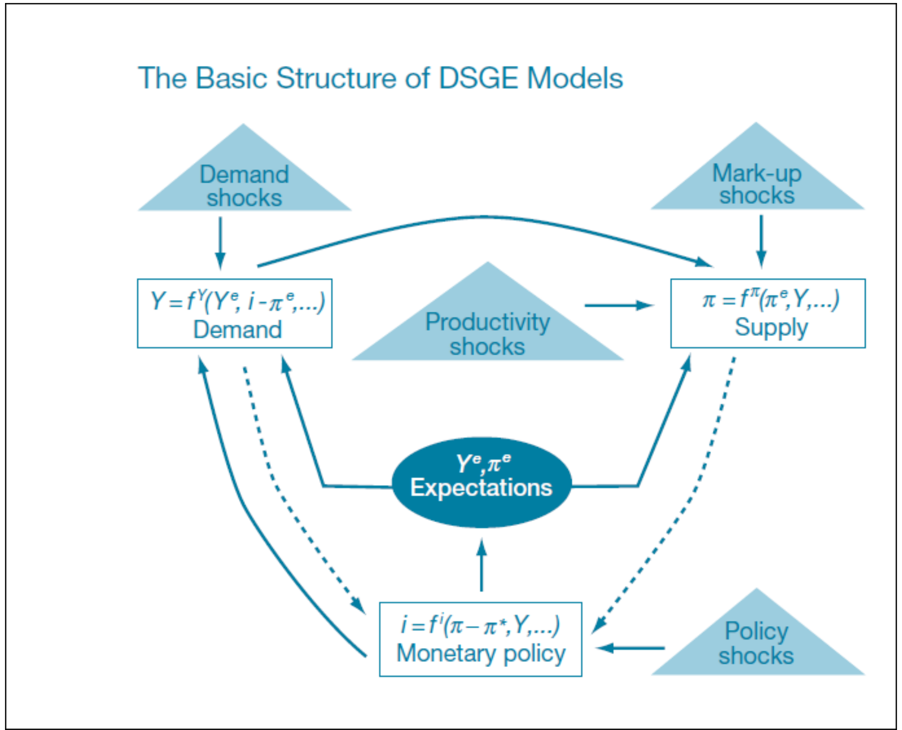
- Climate models
- Each cell modeled with differential equations (typically)
- Cells exchange info
- Surface cells exchange with surface processes



Standard Economic Models

- No stocks or flows, just variables
- Differential equation optimising
- Equilibrium is key
  - 'Shock' → new equilibrium
  - DSGE → dynamic (limit cycle)





Summary

- SGS model
- Integrated Assessment Models
- Other Modelling Paradigms
- Next: Project kickoff