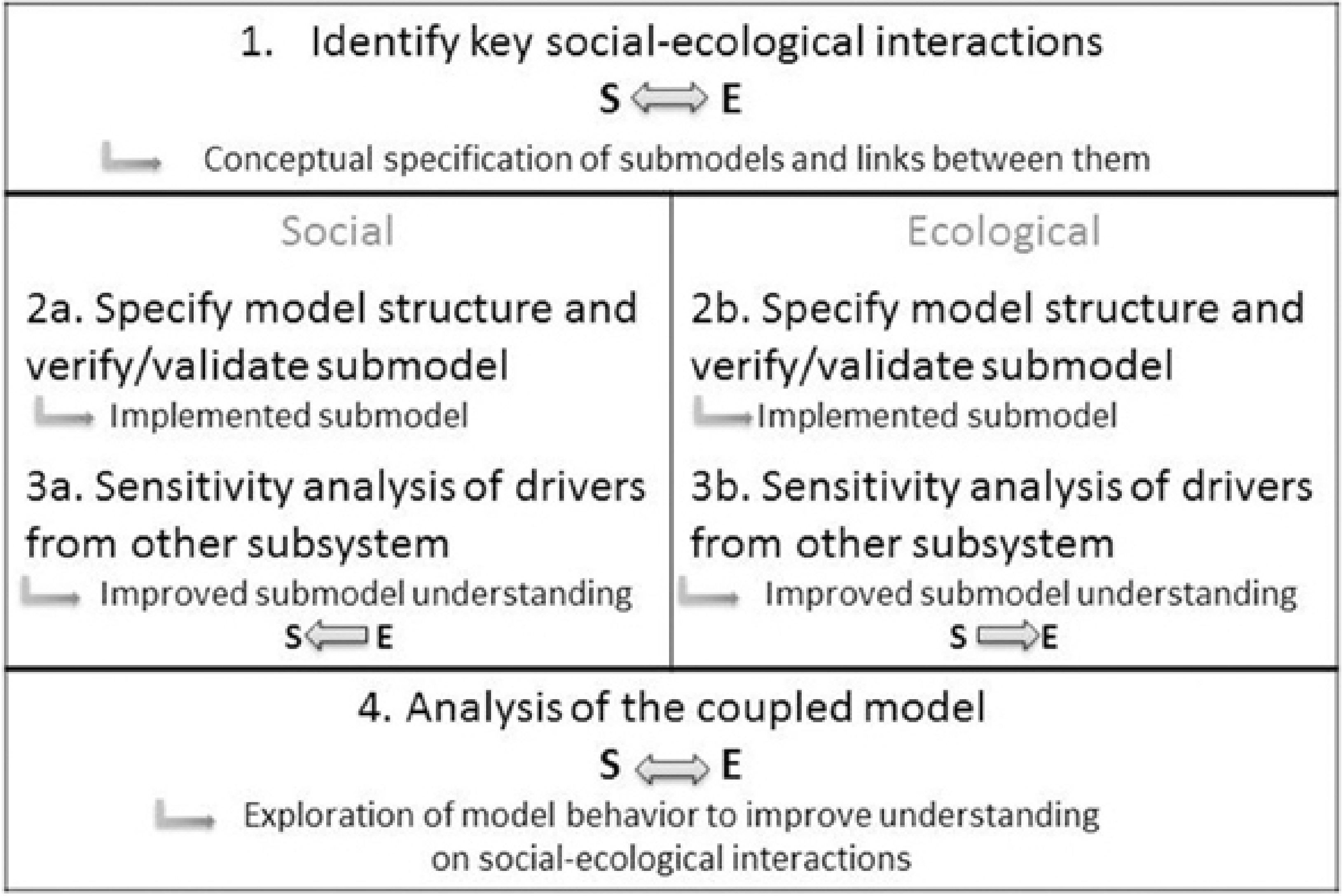
Social System Models

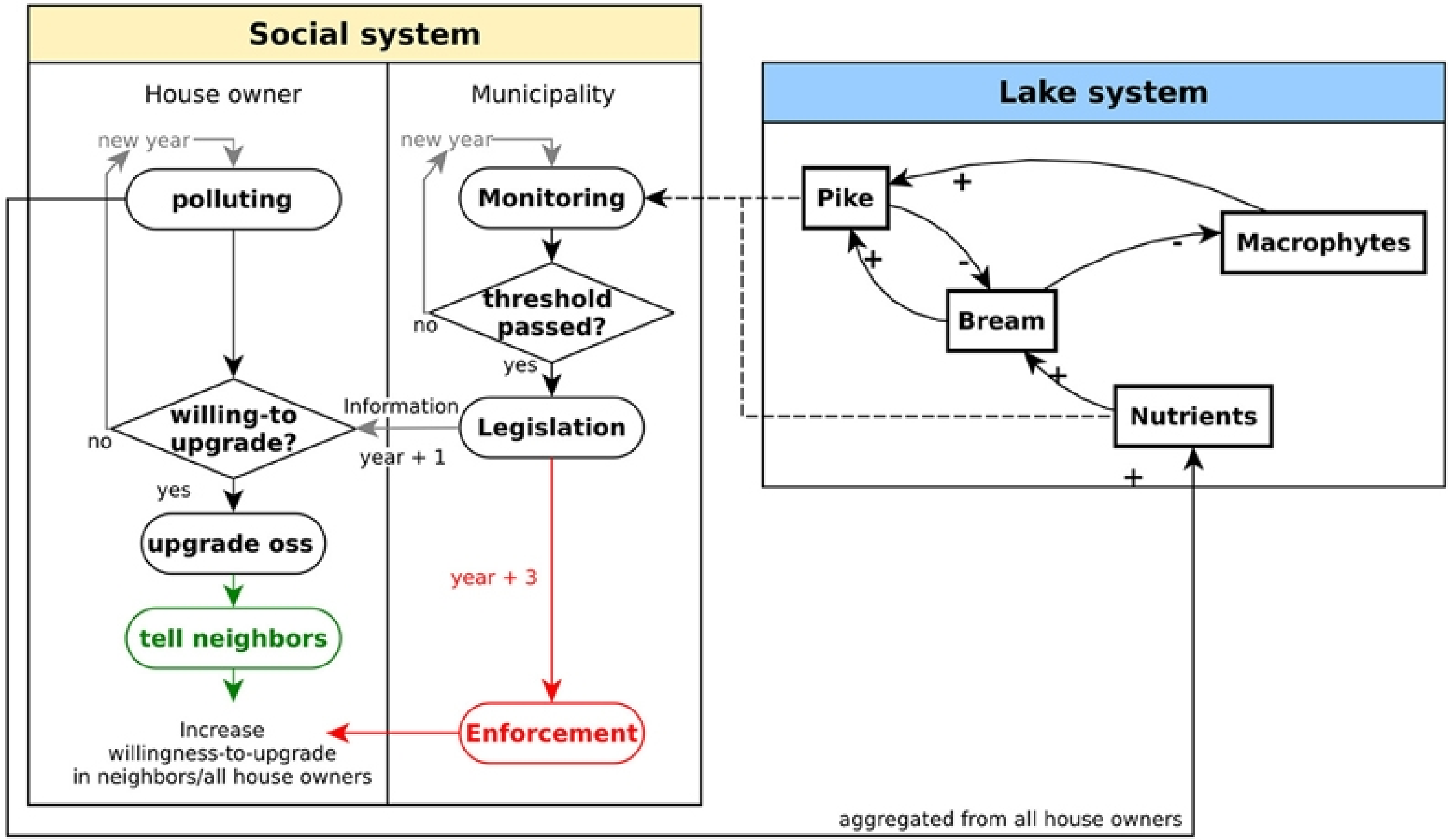
Outline

- LIMNOSES social submodel in hybrid social/ecosystem model
- ECCO/4See – energy-based modelling of the economy
- NHS / economy modeling for campaigning

LIMNOSES 4-step modelling process



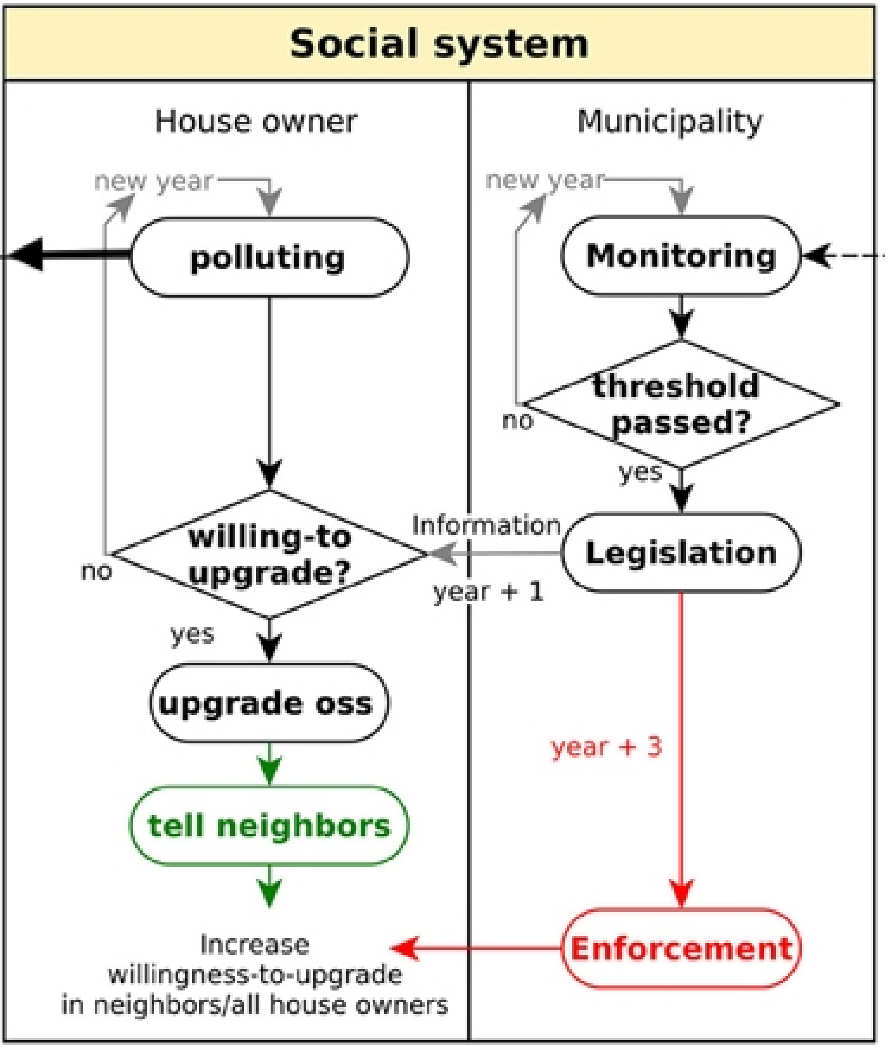
LIMNOSES hybrid AB+SD model



- Motivation – Swedish wetlands
- Ecosystem SD model – last time
- Social model
  - Municipality
    - Monitors wetland health
    - Issues regulations
    - Monitors compliance
  - House owners
    - Produce nutrient pollution
    - Can upgrade on-site sewage system
    - Talk to neighbours

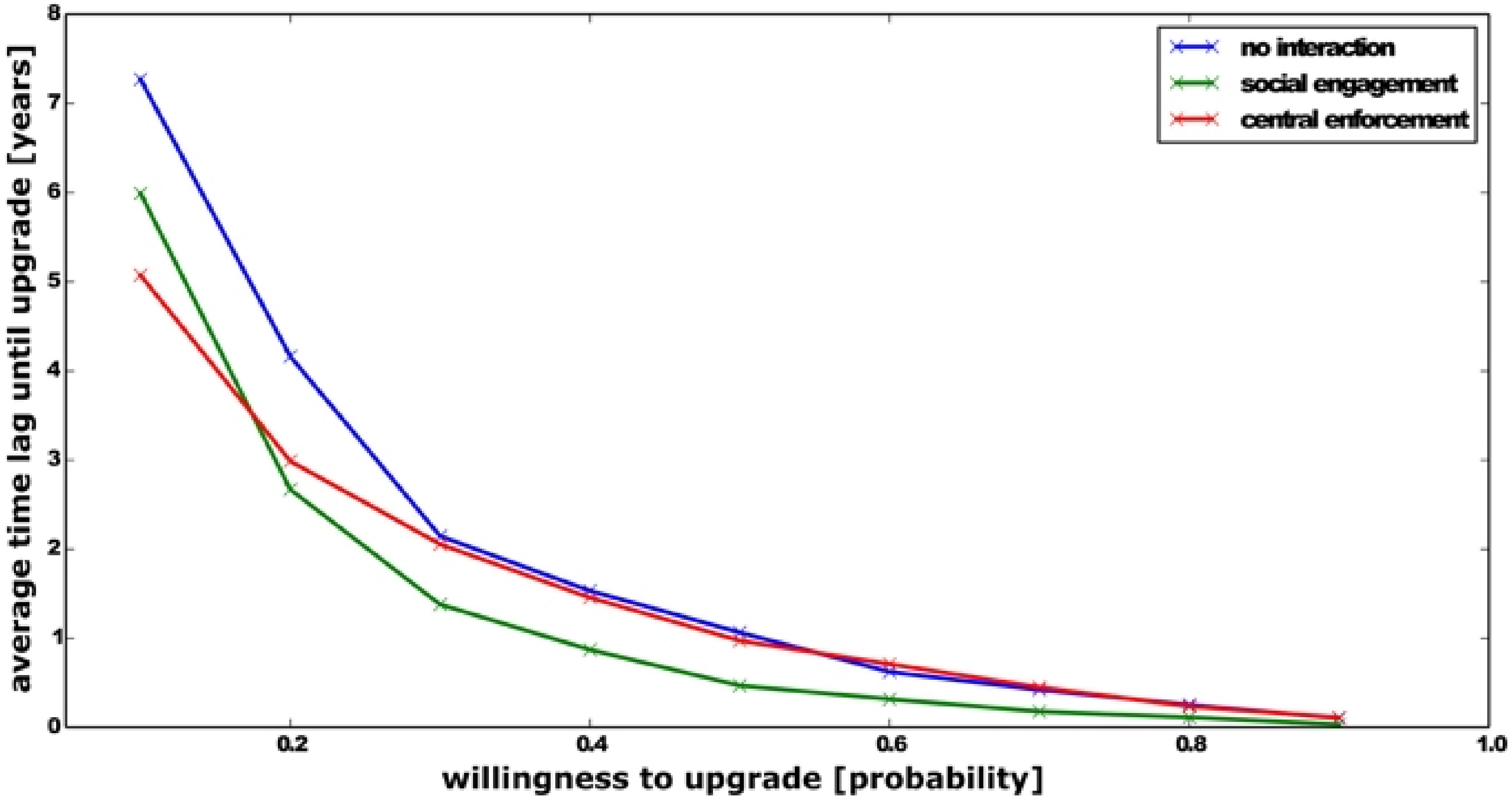
From R. Martin & M. Schlüter, *Frontiers in Environmental Science,* 2015

LIMNOSES Social Model



- Based on research by others on norms and cooperation
- Municipality
  - Annual monitoring of fish (pike) and nutrients
  - If threshold exceeded
    - Legislation for on-site sewage (OSS) upgrade
    - Communicate to house-owners
    - Enforce regulation
- House-owner
  - Annually decides whether to upgrade OSS
  - If so, talks to neighbours about it, increasing their likelihood of upgrading (norms).

LIMNOSES social model steps 2a, 3a



- 2a) Specification / validation based on research in the literature
- 3a) Sensitivity analysis of how ecosystem submodel drives social model
  - Social most effective
  - Enforcement somewhat

LIMNOSES coupled model analysis

- Hypothesise:
  - Lowest social lag if:
    - Low willingness → enforcement
    - High willingness → social engagement
  - Ecological lag increases non-linearly with social lag due to ecosystem reinforcements

Scenario	Willingness-to-upgrade	Social lag [years]	Ecological lag [years]
No Interaction	0.1	9.6 ± 0.9	34.6 ± 2.8
	0.2	4.2 ± 0.4	9.7 ± 4.8
Social engagement	0.1	5.7 ± 0.4	21.4 ± 2.5
	0.2	**2.5 ± 0.3**	**3.9 ± 0.3**
Central enforcement	0.1	**4.9 ± 0.3**	**19.9 ± 2.1**
	0.2	3 ± 0.3	4.8 ± 1.9

Bold entries mark the minimal time lag compared to the alternative interaction scenarios tested.

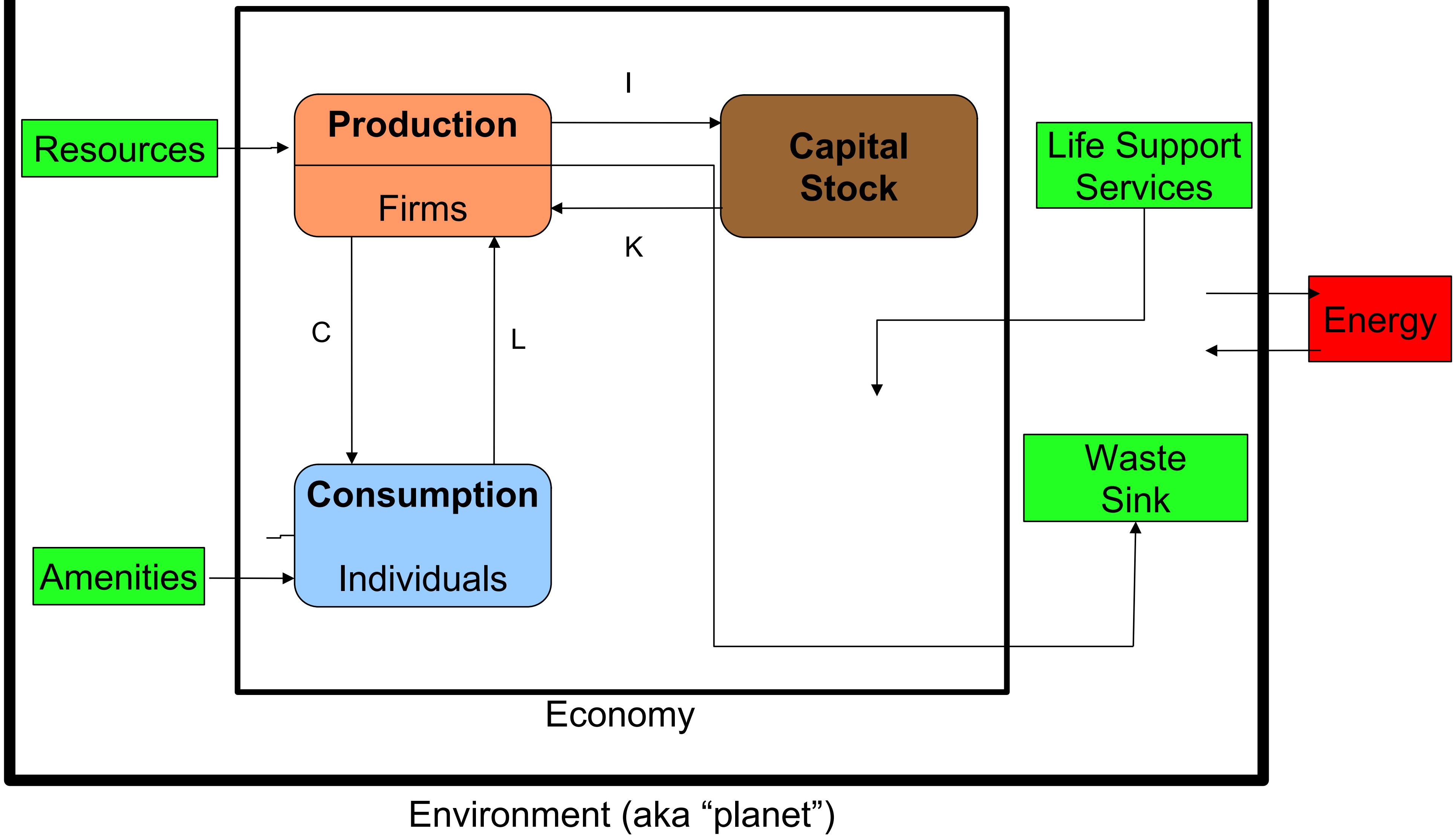
LIMNOSES – Why hybrid?

- All agent-based: why not AB for ecosystem?
  - Key patterns reproducible with simple SD model
  - Computationally less complex / intensive
- All system dynamics: why not SD for social system?
  - What would the stocks be?
  - How to represent decisions as flows?
- Organisational/spatial/temporal scales
  - Organisation, individual home-owners, fish / plants
  - Temporal scale: ecosystem daily, social yearly

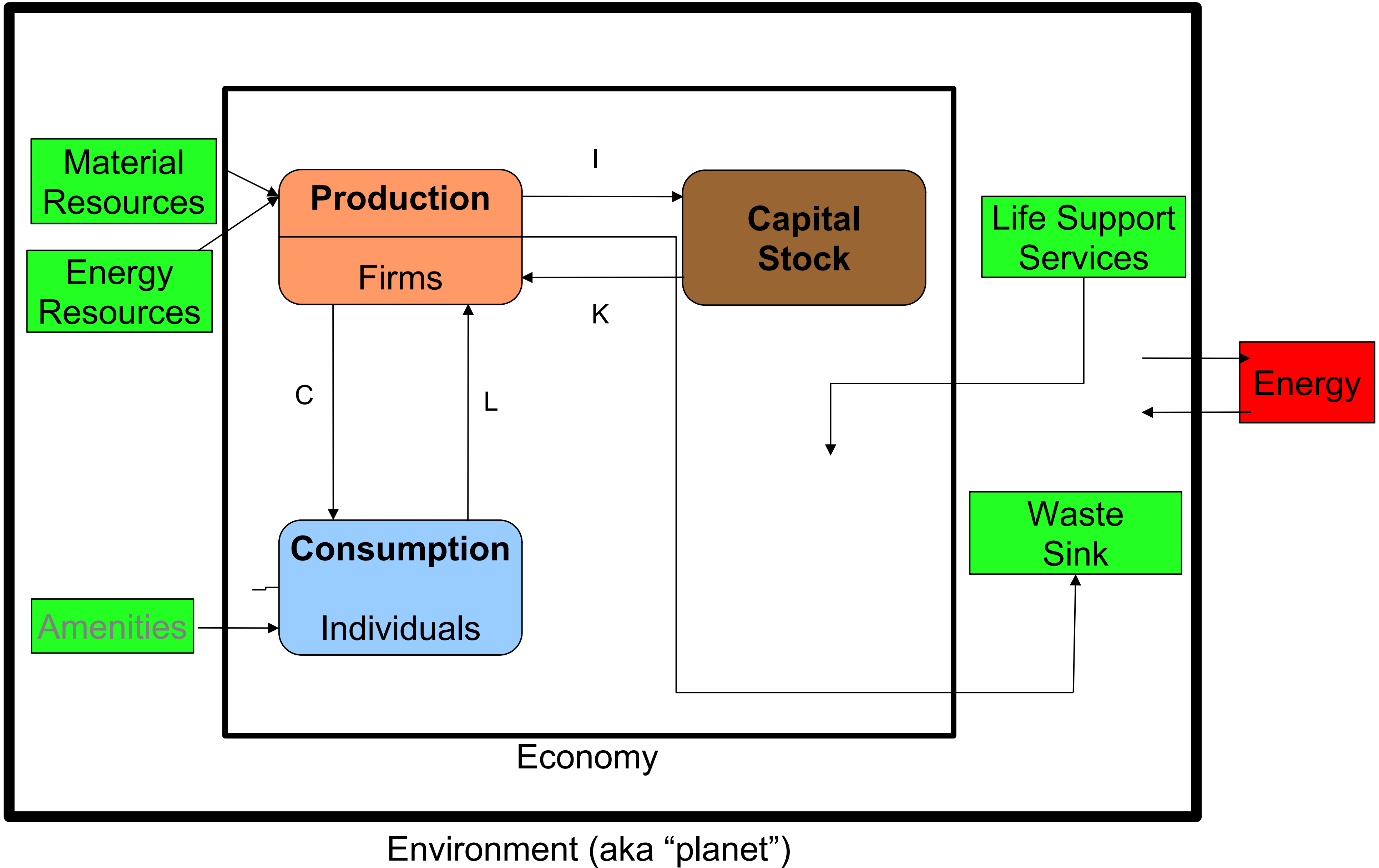
ECCO Modelling Approach (1990s)

Using the principles of energy flows, the ECCO model helps users to identify the underlying physical limits operating on an economic system, in terms of that economy's ability to extract natural resources and process them into capital and consumer goods and services. Its aim is to provide a tool for examining the overall impact of specific policies upon an economy (usually a national economy).

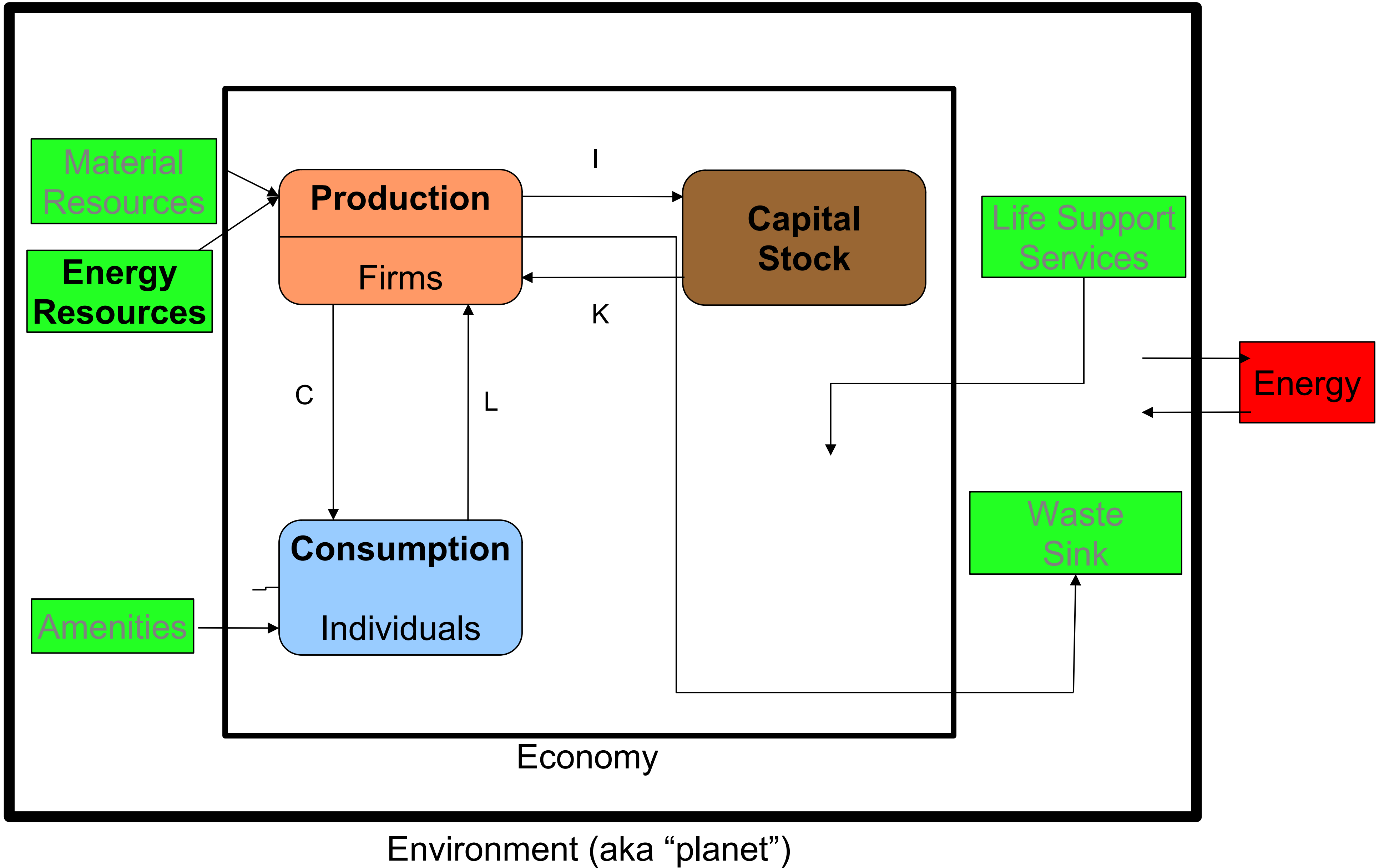
(Ecological) Economics



Physical Economics



Energy Economics



Money in Energy Economics

The money price of something is the sum of all the labour value that went into producing it (including the labour of entrepreneurs), recursively applied

Labour today is decision-making

Therefore money represents accumulated decision-making

So what actually drives the physical economy?

Work

Work drives the economy

- scientific sense: effort expended to get something done

Human ability to produce *work*

- 12 hours a day, 7 days a week is about 6 KwH

Economic development is the process of replacement of human *work* with *work* from animals and then *work* from energy resources

- EU – 30 energy slaves per capita
- US – 60 energy slaves per capita

Human Made Capital (Capital Stock)

Machines require *work* to be built, and require that *work* be done to operate – need energy!

Carnot: heat-to-work fraction = $(T-T_0)/T$

e.g., diesel engine (773-373)/773 = 52%

average efficiency economy wide ~ 20%

Work required is huge: building 1 tractor takes about 28,000 days (a lifetime) of human *work*

Human *work* is of low value (low temperature)

Fossil fuel *work* is high value (high temperature)

Human Made Capital

All the physical infrastructure we have

- housing
- factories
- energy services
- transport services

Life-cycle analysis

- gives amount of *work* embodied in HMC
- account for in primary energy terms (gigajoules)
  - one barrel oil ~ 5.7 GJ

Energy and Money

Production combines *work* with decision-making

- cf. production function involves capital and labour

Money economy is the story of decision value

Energy economy is the story of *work*

Can relate them:

- Energy (*work*) resource is managed by decision
- Energy intensity is the amount of energy managed per unit of decision value (£)

Natural Resources

Natural Capital

- flow resources (e.g., fresh water)
- stock resources
  - renewable (wood)
  - non-renewable (fossil fuels)

Assume free and unlimited (!)

- but... embodied energy increases as easily accessible sources are depleted/degraded
  - e.g., fresh water

Thermodynamics

First law: can't win (order cannot increase)

- can't increase order in one place without decreasing it at least as much somewhere else

Second law: can't break even (order decreases)

Production is generating order from disorder

- e.g., iron-ore to car
- compensating disorder provided by energy source
  - e.g., tree to carbon dioxide and ash

Energy is not like other natural resources!

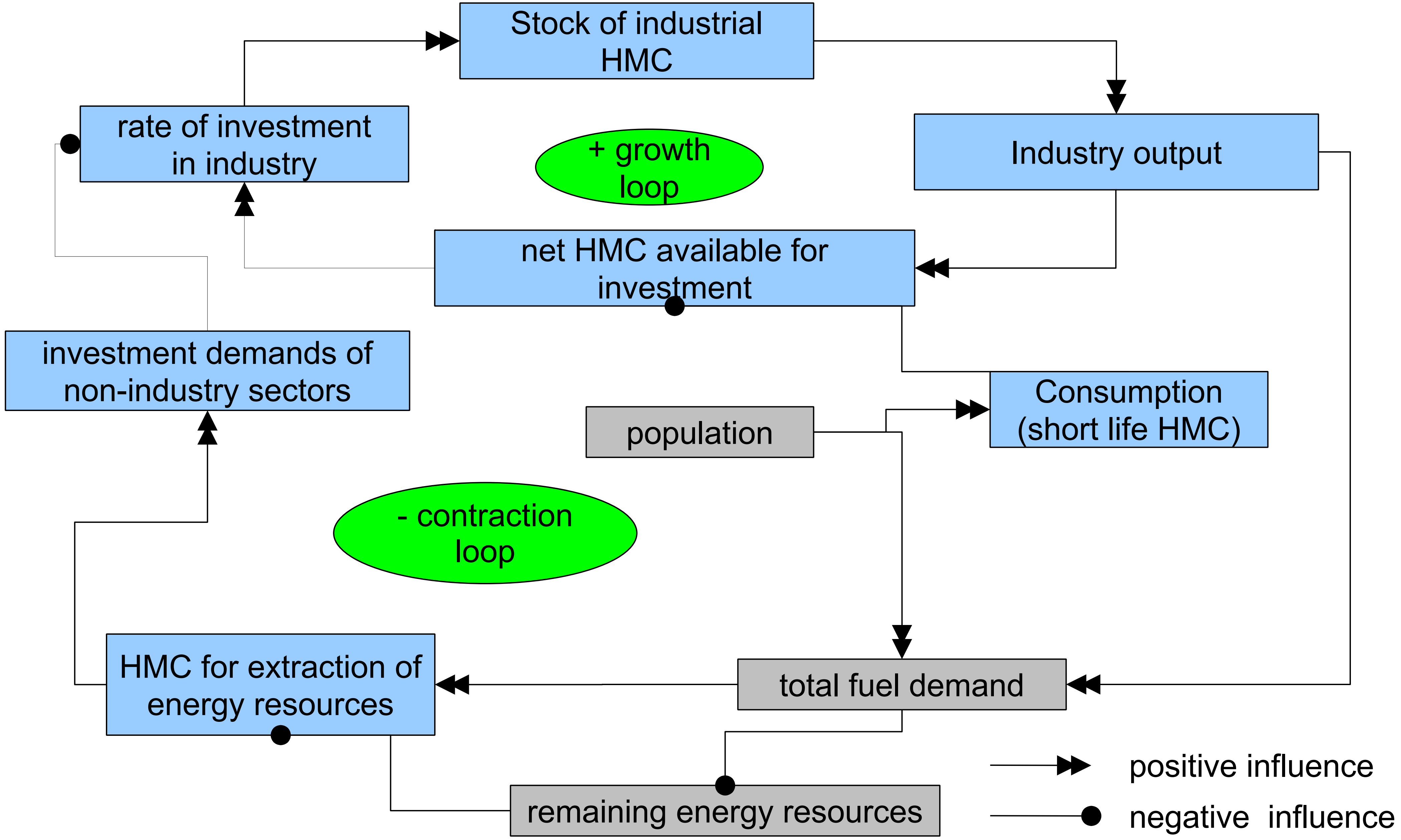
Question

Can we increase energy supply fast enough?

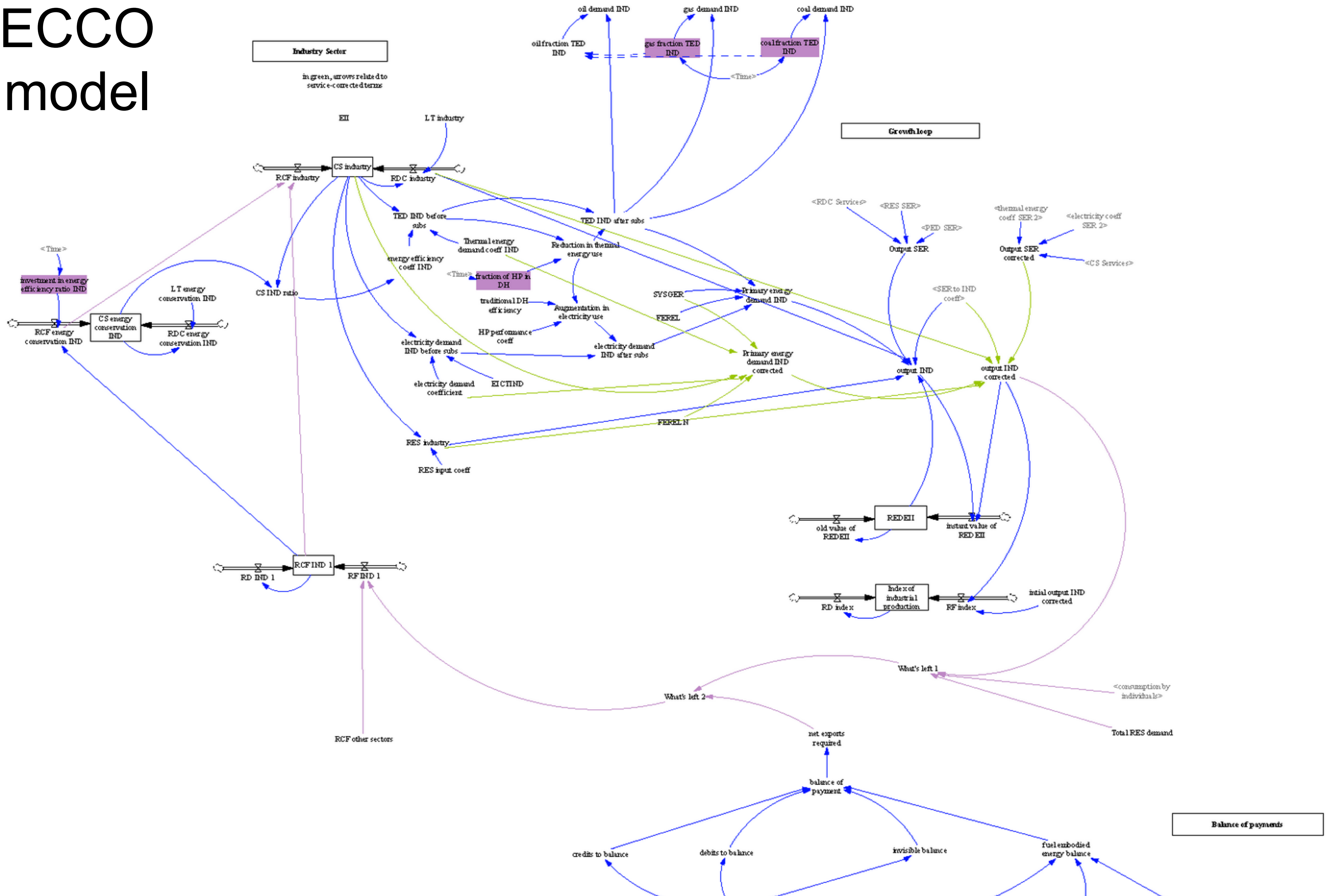
- to make the transition to new infrastructure
- to maintain/increase energy per capita for consumption
- in a way that avoids dangerous climate change
- in the context of growing population (6B to 9B)
- in the context of rapid increase in per-capita energy consumption in developing countries

Results so far: not clear!

Basic ECCO model

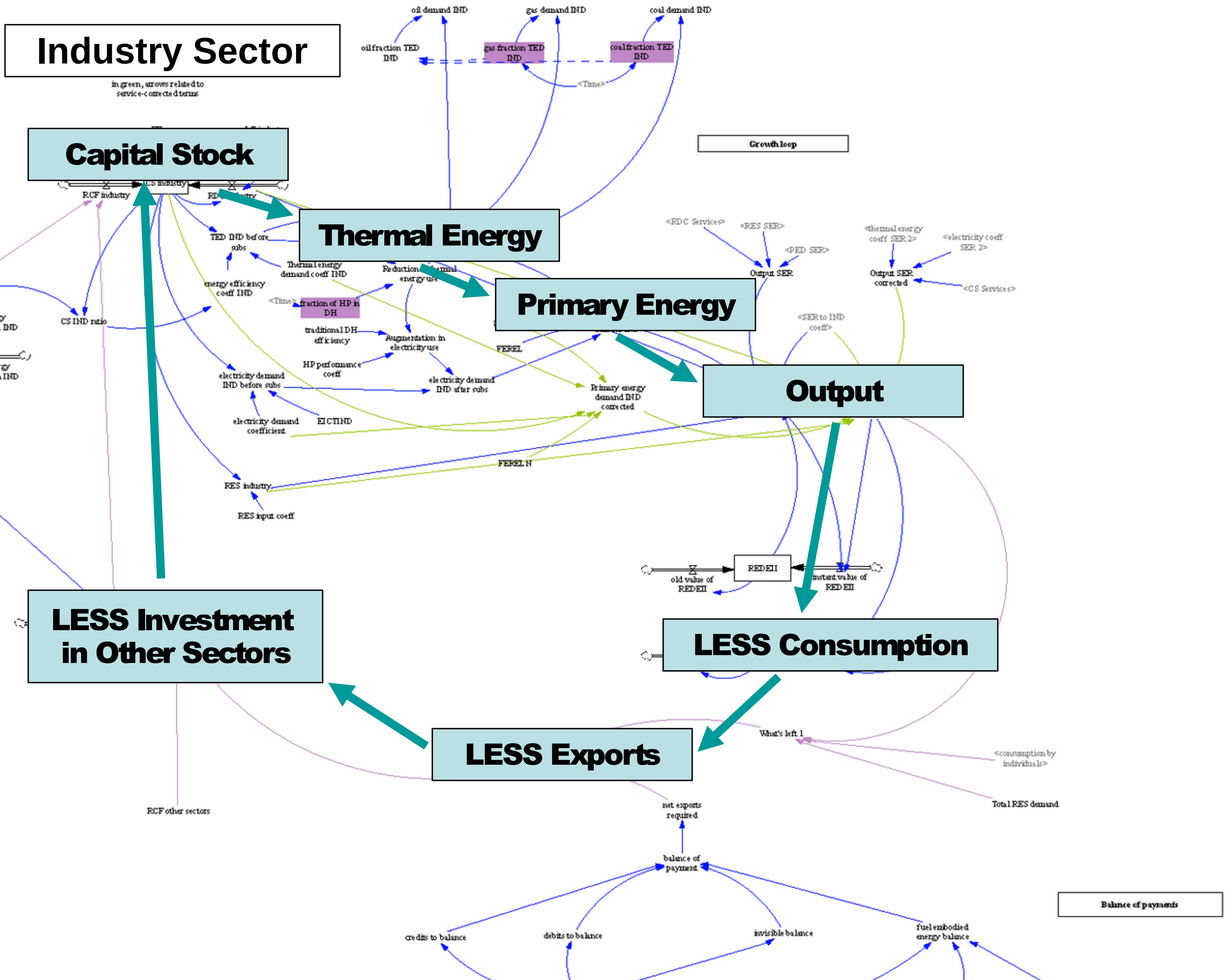


ECCO model



Industry Sector
in green, arrows related to service-corrected terms
oil demand IND
gas demand IND
coal demand IND
oil fraction TED IND
gas fraction TED IND
coal fraction TED IND
<Time>
EII
LT industry
Growth loop
CS industry
RCF industry
RDC industry
TED IND before subs
TED IND after subs
<RDC Services>
<RES SER>
<PED SER>
<thermal energy coeff SER 2>
<electricity coeff SER 2>
Output SER
Output SER corrected
<CS Services>
<Time>
investment in energy efficiency ratio IND
Thermal energy demand coeff IND
Reduction in thermal energy use
energy efficiency coeff IND
LT energy conservation IND
CS IND ratio
<Time>
fraction of HP in DH
SYSGER
Primary energy demand IND
FEREL
<SER to IND coeff>
CS energy conservation IND
RCF energy conservation IND
RDC energy conservation IND
traditional DH efficiency
Augmentation in electricity use
HP performance coeff
electricity demand IND before subs
electricity demand IND after subs
Primary energy demand IND corrected
output IND
output IND corrected
electricity demand coefficient
EICTIND
FERELN
RES industry
RES input coeff
REDEII
old value of REDEII
instant value of RED EII
RCF IND 1
RD IND 1
RF IND 1
Index of industrial production
RD index
RF index
initial output IND corrected
What's left 1
What's left 2
<consumption by individuals>
Total RES demand
RCF other sectors
net exports required
balance of payment
Balance of payments
credits to balance
debits to balance
invisible balance
fuel embodied energy balance

ECCO 1 loop



Industry Sector
in green, arrows related to service-corrected terms
Capital Stock
Thermal Energy
Primary Energy
Output
LESS Consumption
LESS Exports
LESS Investment in Other Sectors
oil demand IND
gas demand IND
coal demand IND
oil fraction TED IND
gas fraction TED IND
coal fraction TED IND
<Time>
Growth loop
RCF industry
TED IND before subs
Thermal energy demand coeff IND
energy efficiency coeff IND
CS IND ratio
investment in energy efficiency ratio IND
RCF energy conservation IND
CS energy conservation IND
LT energy conservation IND
RDC energy conservation IND
fraction of HP in DH
traditional DH efficiency
Augmentation in electricity use
HP performance coeff
electricity demand IND before subs
electricity demand IND after subs
electricity demand coefficient
EICTIND
FEREL
FEREL N
Primary energy demand IND corrected
RES industry
RES input coeff
<RDC Services>
<RES SER>
<PED SER>
Output SER
<thermal energy coeff SER 2>
<electricity coeff SER 2>
Output SER corrected
<CS Services>
<SER to IND coeff>
REDEII
old value of REDEII
instant value of REDEII
What's left 1
<consumption by individuals>
Total RES demand
RCF other sectors
net exports required
balance of payment
credits to balance
debits to balance
invisible balance
fuel embodied energy balance
Balance of payments

Results UK (1998)

Impossible to find a scenario which allows for transition to sustainable energy that allows continued growth in standard of living during the transition

Transition possible with flat standard of living during transition

Standard of living is not happiness/welfare

- bicycling across France can be more fun than flying!

Is this Economic Modelling?

- It models the physical aspect of the economy only (not the behavioural aspects)
- It explores what is physically possible
  - If it isn't physically possible, it isn't economically possible!
- Economists can then use economic (behavioural) models to explore trajectories within the envelope of physical possibility
  - Which economic policies will achieve the desired physical effects?

4See Models

- Stocks and Flows model of economy, focus on fixed capital
  - Embodiment of energy
  - Foundation of economic system
- Each sector both produces (flow out) and consumes (flow in)
- Demand-driven
- Uses input/output tables to determine how resources flow – best estimates of real flows

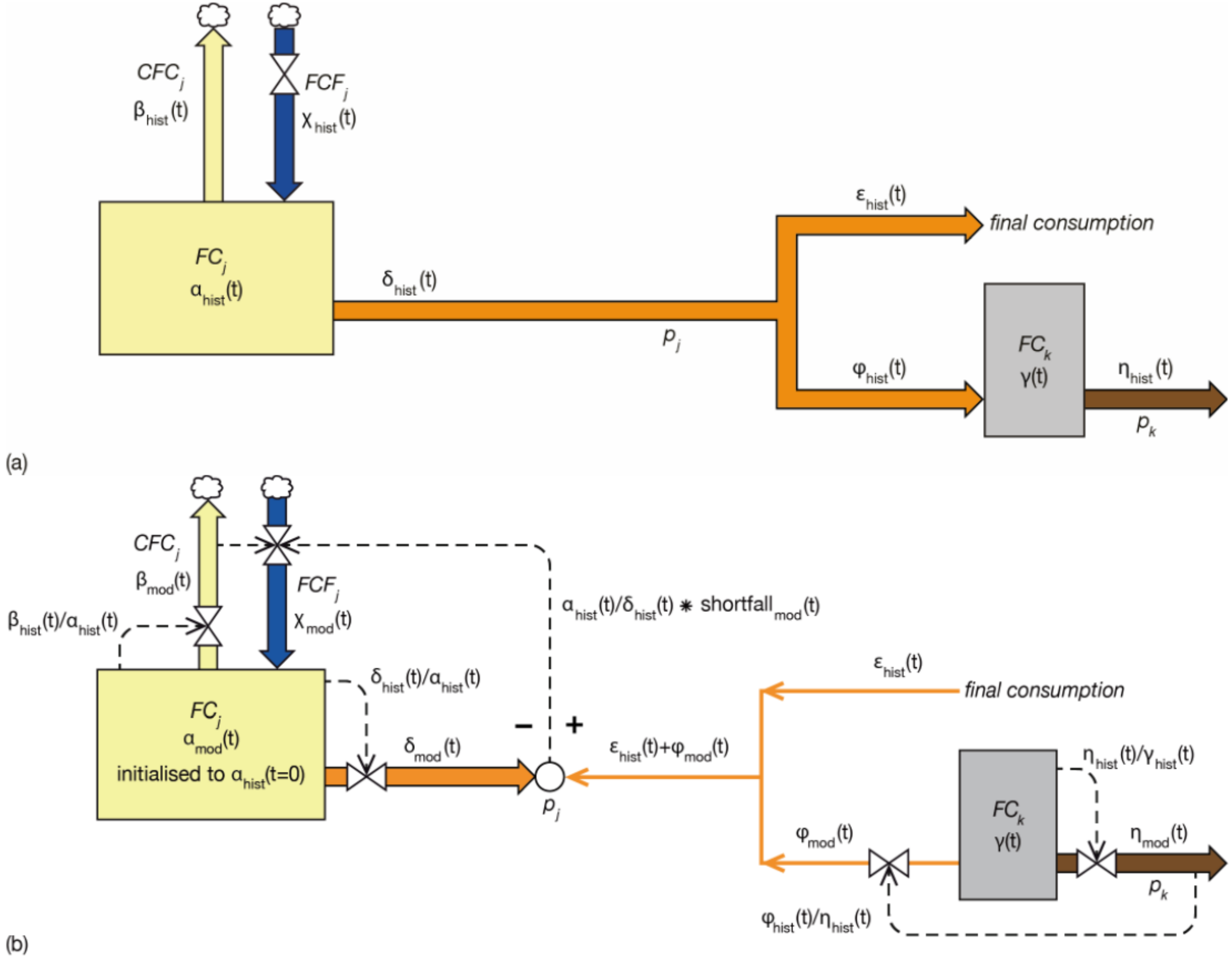


Fig. 2. Details of module-FC$_j$ for a type of infrastructure and its own distinct output p_j: (a) historical time-series data; (b) operationalised in the model with the circle marking the point where the model-generated supply needs to be reconciled with total demand.

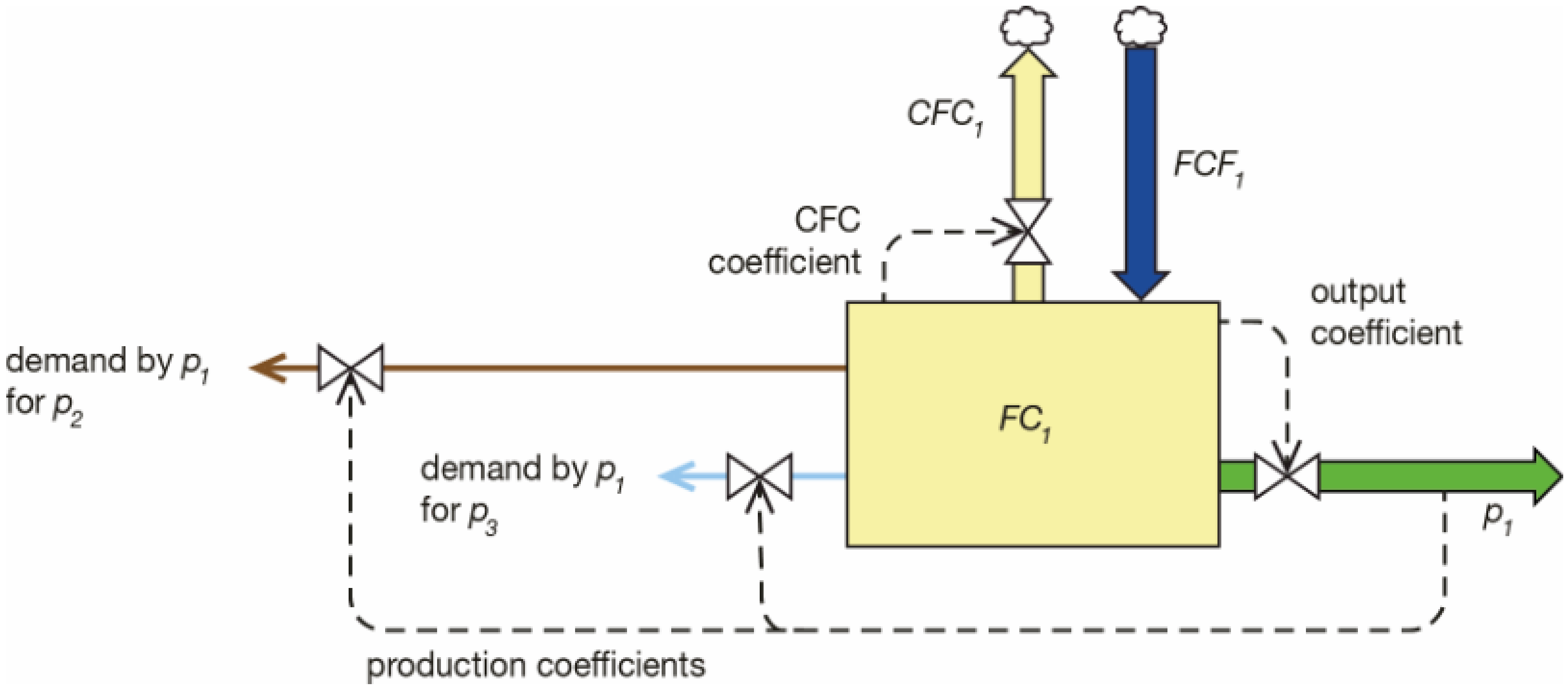


Fig. 3. Summary of the coefficients of CFC, output and production for infrastructure FC_1 and supply p_1.

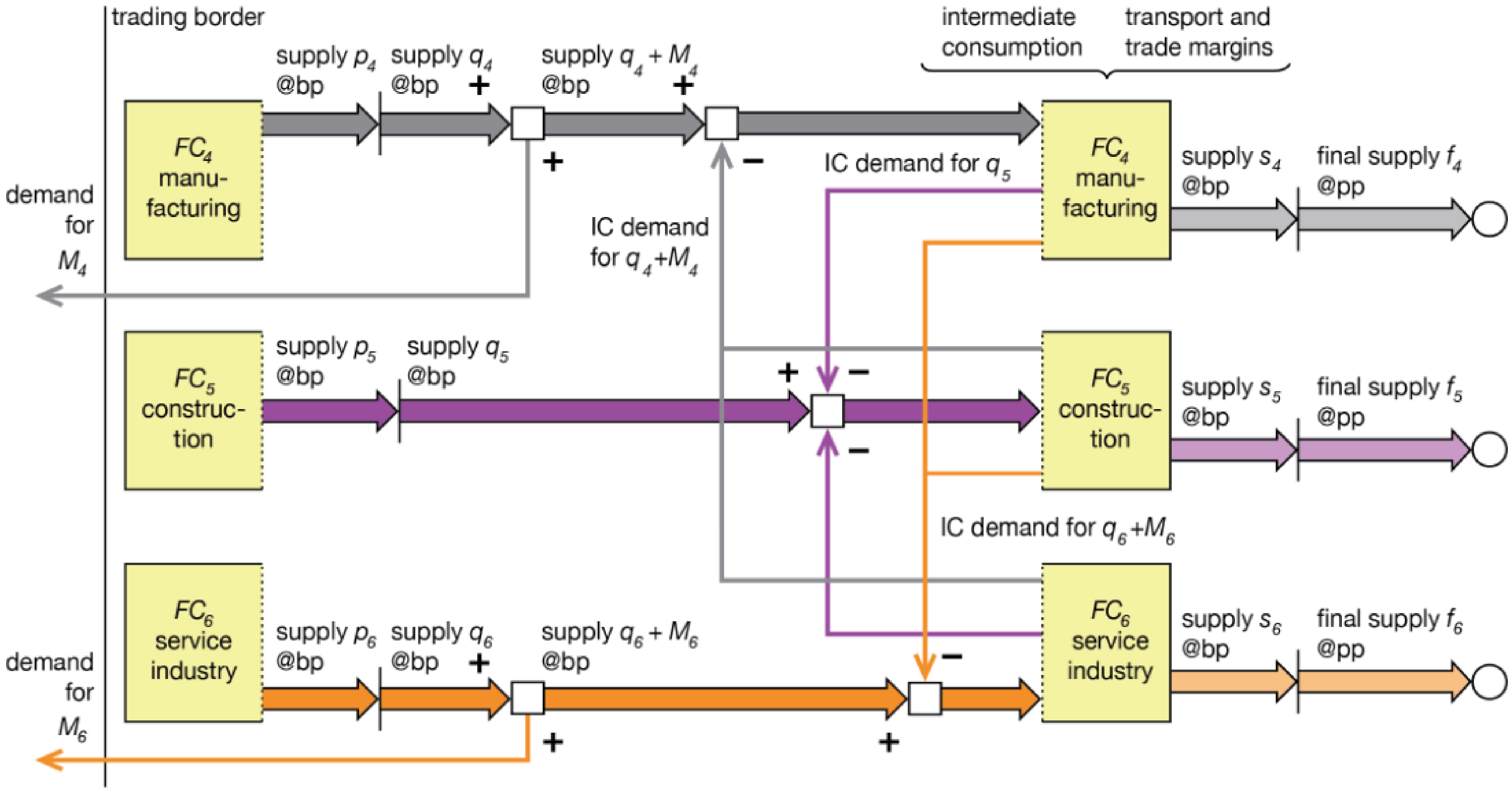
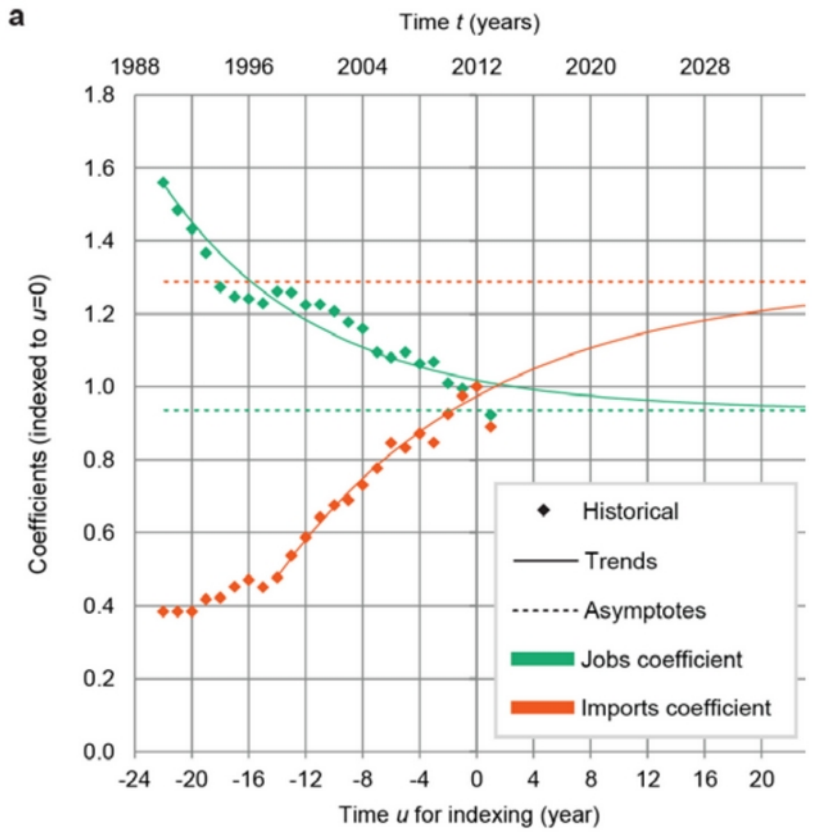


Fig. 4. Extension of the unique supply p= 4 to 6 from manufacturing, construction and service industry respectively (all at basic prices) following IC to produce evolved products, f = 4 to 6, at purchasers' prices up to the circle where each supply will be reconciled with its total demand. IC involving q of 1 to 3 is left off for clarity and because the size of their product volumes is small. (M: imports; @bp: economic volume at basic prices; IC: intermediate consumption; @pp: economic volume at purchasers' prices after addition of net taxation on products.) Supplies p, q, s and f are detailed in Appendix A.3.

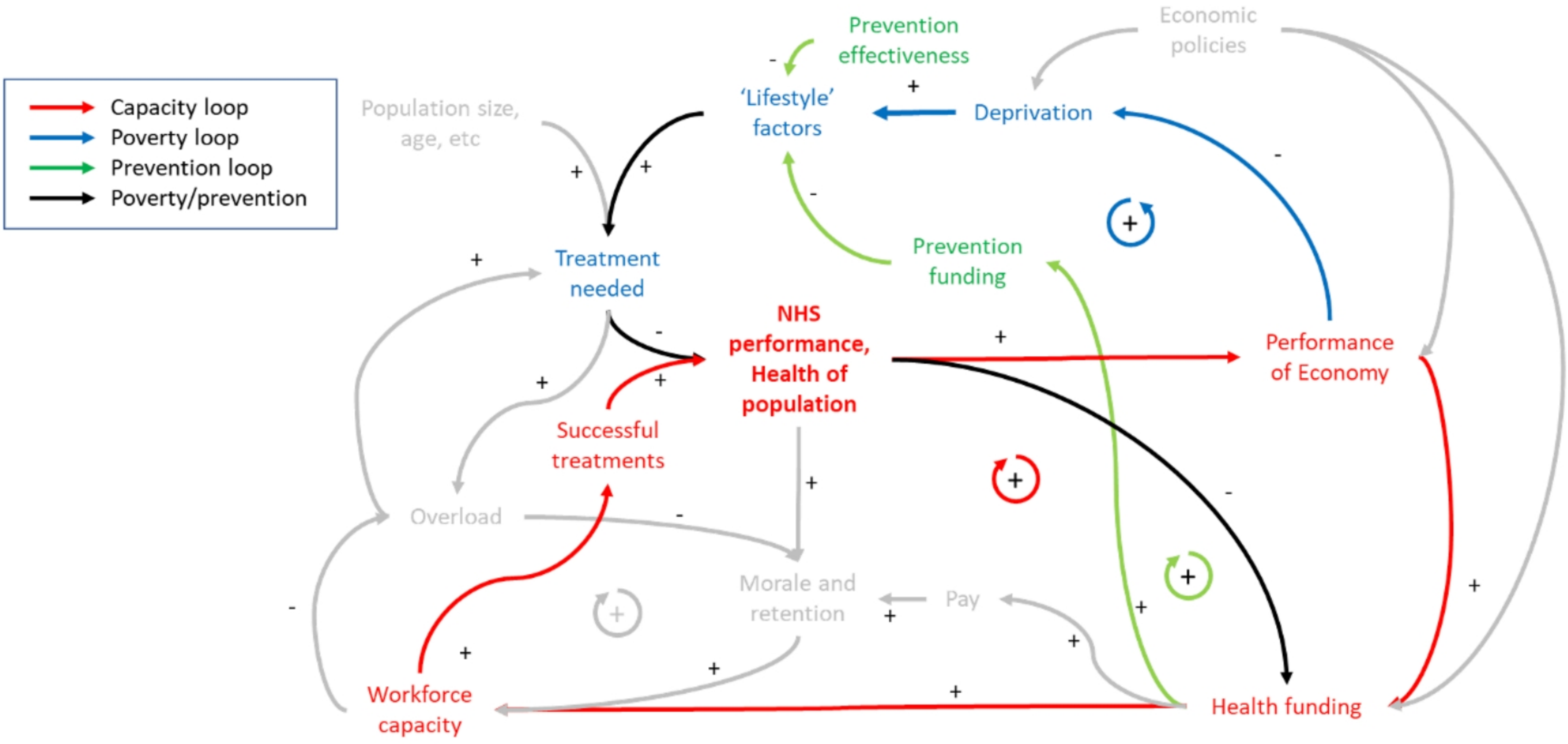


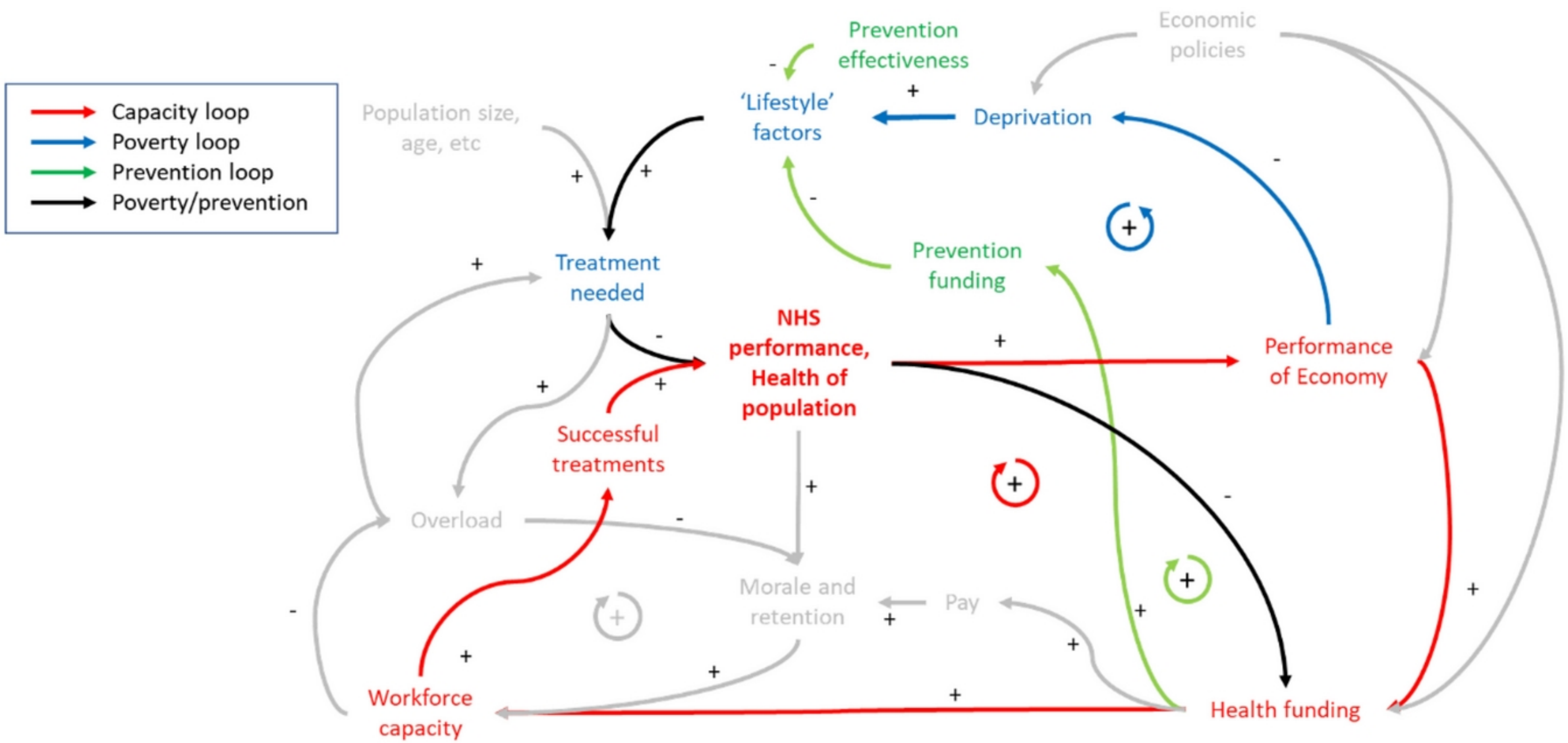
a
Time t (years)
1988
1996
2004
2012
2020
2028
Coefficients (indexed to u=0)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-24
-20
-16
-12
-8
-4
0
4
8
12
16
20
Time u for indexing (year)
Historical
Trends
Asymptotes
Jobs coefficient
Imports coefficient

Modelling the NHS/Economy

- Why? Campaigning organisations wanting to influence politicians, media and policymakers
- Scope – interactions between the NHS and the economy
  - Poorer health is a drag on the economy
  - Poverty is a strong factor in health outcomes
- Not peer-reviewed science! But in practical use
- System dynamics model

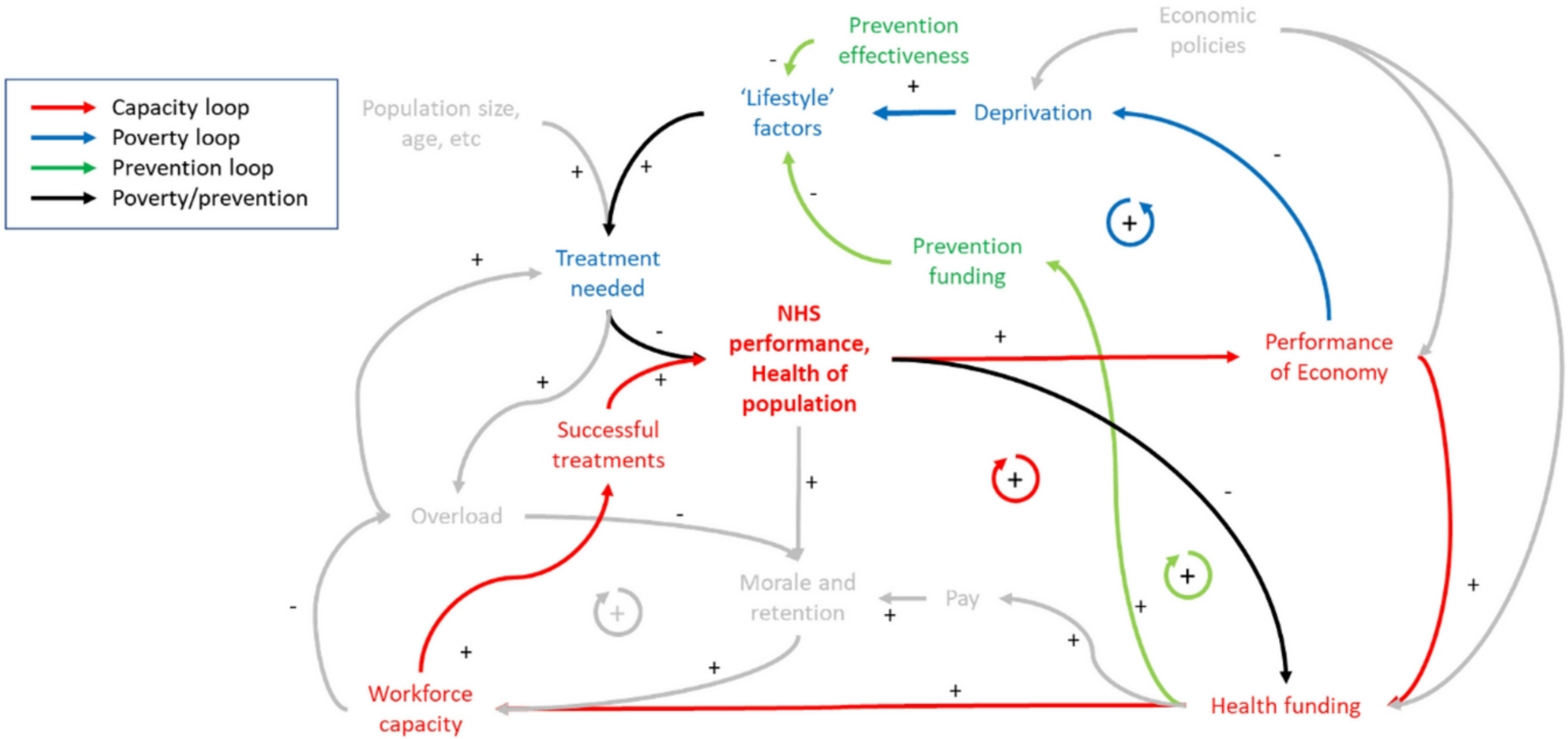
Figure 9: Interactions between Health and the Economy





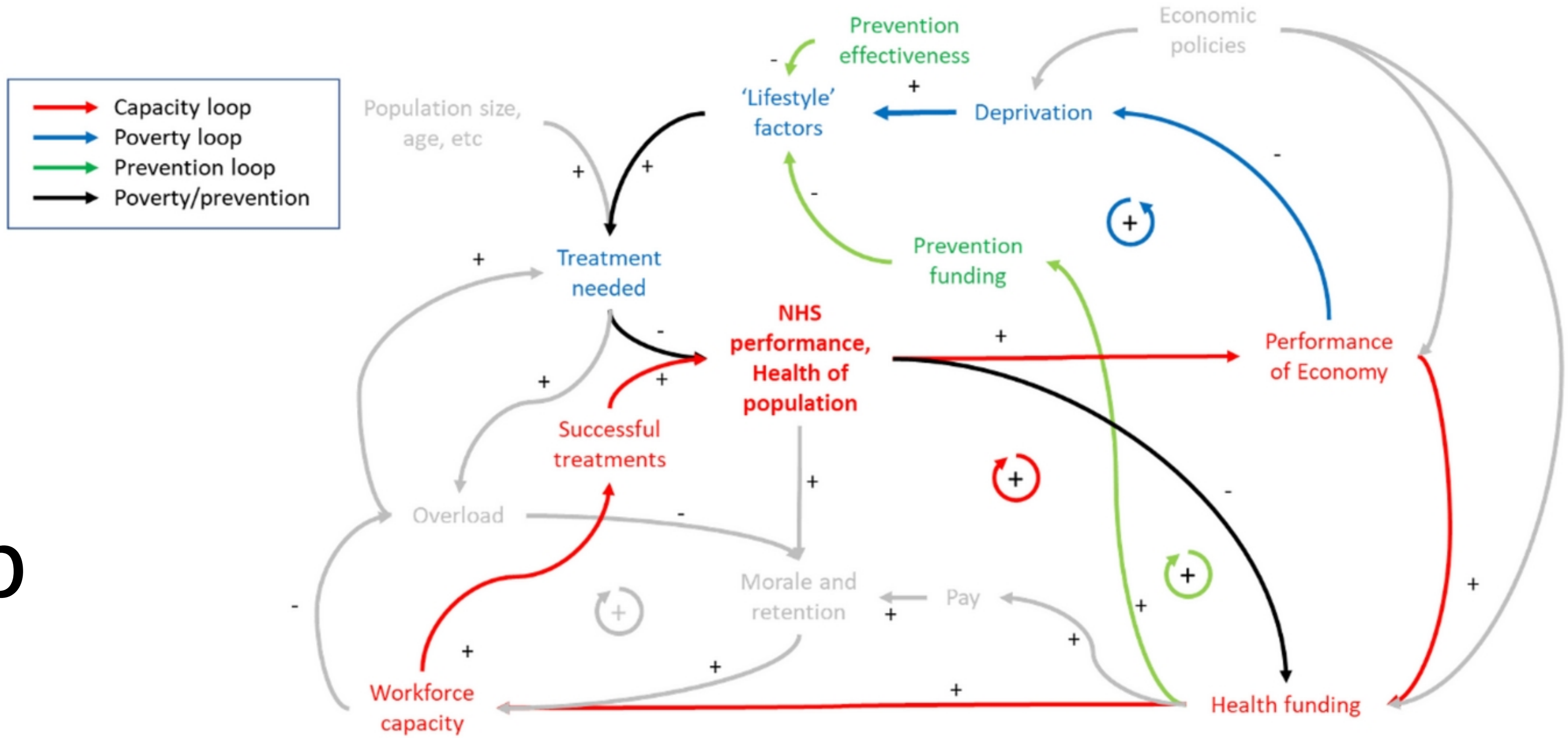
Capacity Loop

- Economic output enables economic decisions to fund;
- Funding drives capacity to treat;
- Capacity to treat (staff, hospital beds, etc) drives treatment provided;
- Treatment provided drives rates of recovery and hence number of healthy people – a huge number of working age adults are currently unable to work due to ill-health;
- Number of healthy people of working age drives economic output;



Poverty Loop

- Economic output enables economic decisions to address poverty;
- Poverty drives morbidity;
- Morbidity drives demand for treatment;
- Excess demand causes untreated illness;
- Untreated illness drives (negatively) number of healthy people;
- Reduced number of healthy people of working age decreases economic output;

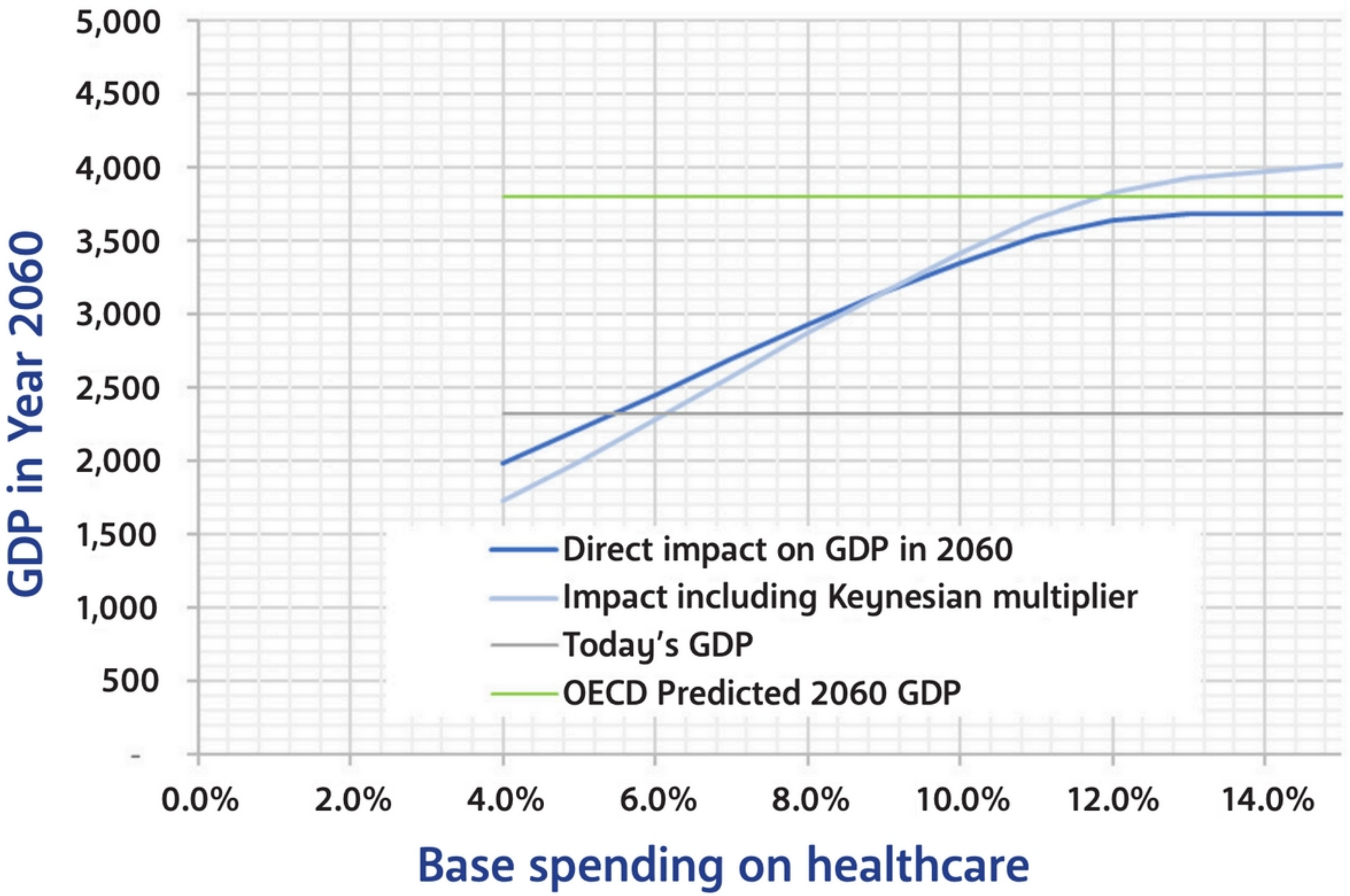


Prevention Loop

- o Spending on prevention reduces illness;
- o Reduced illness reduces need to treat;
- o Reduced need to treat reduces funding requirement for treatment capacity;
- o Reduced funding requirements make facilitates adequate spending.

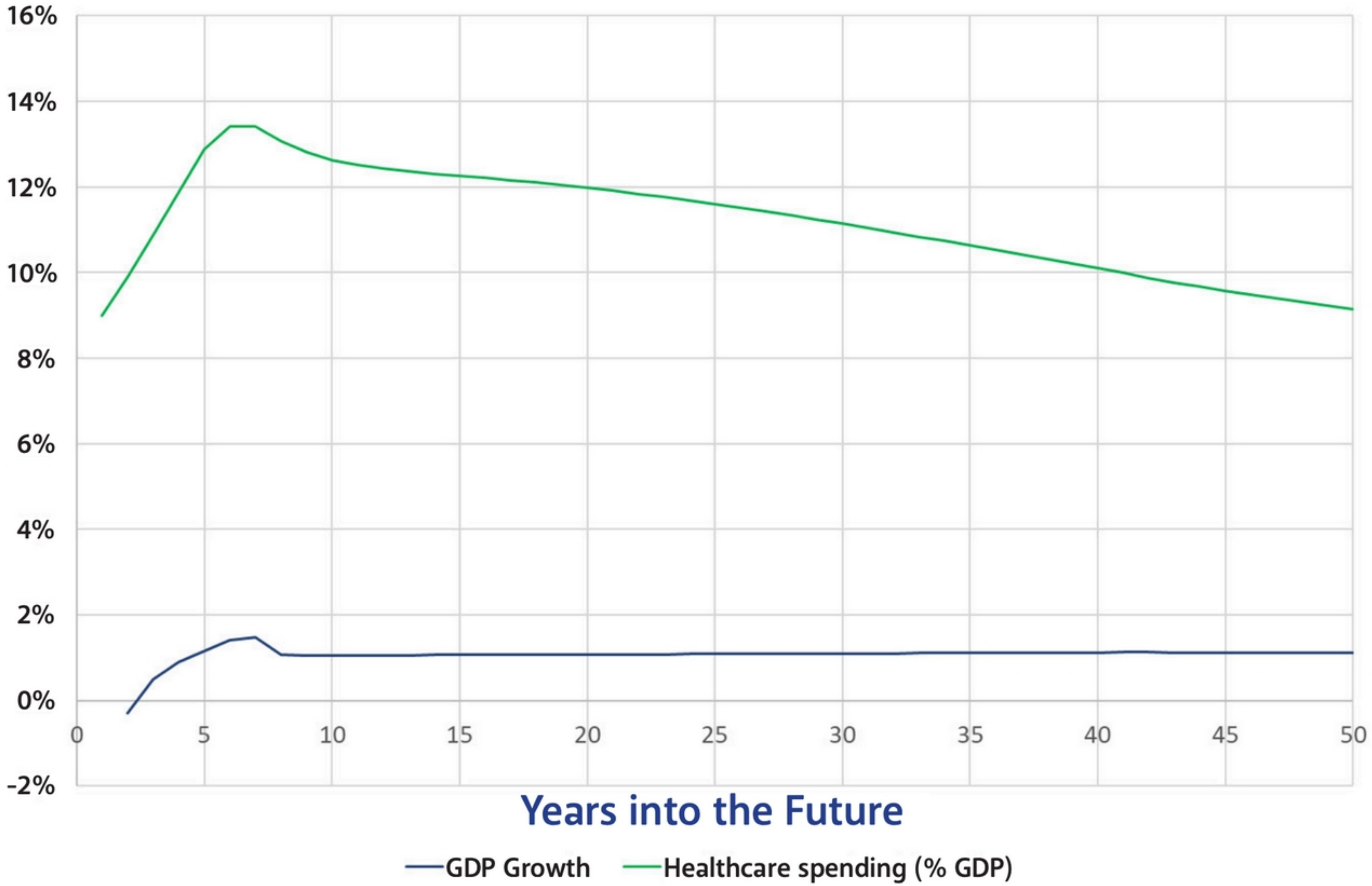
NHS-Economy Model Results I

Figure 10: Impact of different funding levels on long term GDP



NHS-Economy Model Results II

Figure 11: Long term sustainability of funding



Summary

- LIMNOSES social submodel in hybrid model
- ECCO/4See – energy-based modelling of the economy
- NHS / economy modeling for campaigning
- Next time: Guest lecture on communicating about models