

# Multi-level modeling of economic innovation dynamics and its implications for analyzing emission impacts

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*Presentation at the ECF-workshop „System dynamic models of coupled natural social systems“*

- I. Introduction
- II. Modeling innovation dynamics
- III. Linking innovation dynamics and growth
- IV. Driving forces and dynamics of environmental impacts
- V. Assessing political measures
- VI. Conclusions

# I. Introduction

- Subject matter

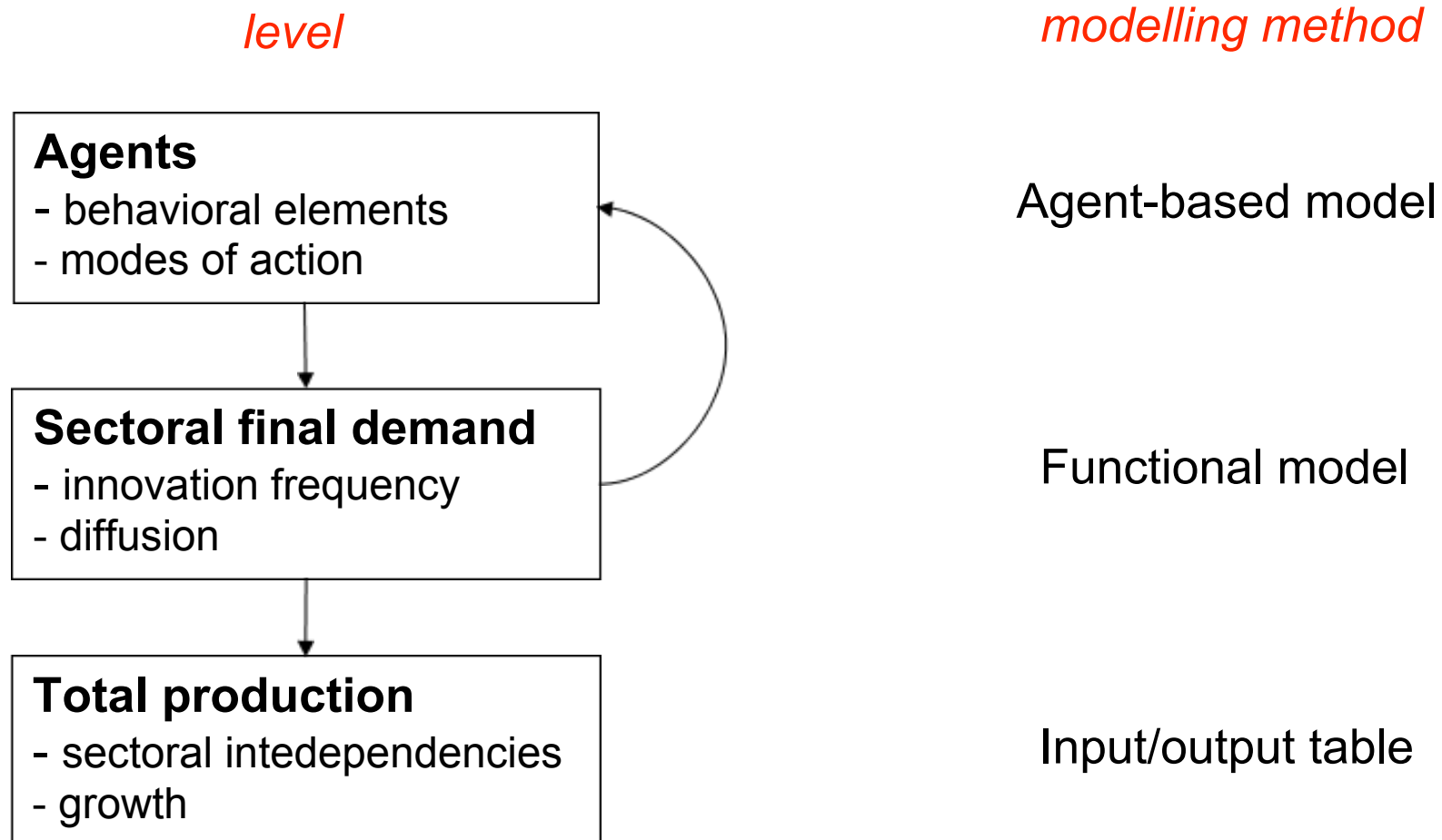
- Referring to growth (and stagnation) of economic aggregates as a background for ecological impacts
- Problem of endogenous explanation for growth dynamics
  - lack of microfoundation
  - non-linear interaction effects
- Identifying the driving forces: competition and innovation
  - microfoundation: behavioural trigger conditions for innovations
  - interactions: diffusion dynamics and sectoral interdependencies
- Relating ecological impact dynamics and innovation dynamics
- Constraints:
  - only supply side specified; simplified demand effects
  - only one exemplary emission

## ● Methodology

- Economy as a 'Complex Adaptive System' (CAS)
  - multi-scale property
  - emergent features
  - adaptation of agents
  
- Multi-scale property
  - economic aggregates (on the national level)
  - sectoral interdependencies
  - intrasectoral interaction
  
- Emergent features
  - diffusion of innovation
  - growth and the corresponding volume of emissions
  
- Adaptation of agents
  - no uniform optimization behavior: 'bounded rationality'
  - autonomy and heterogeneity
  - selecting different modes of interaction

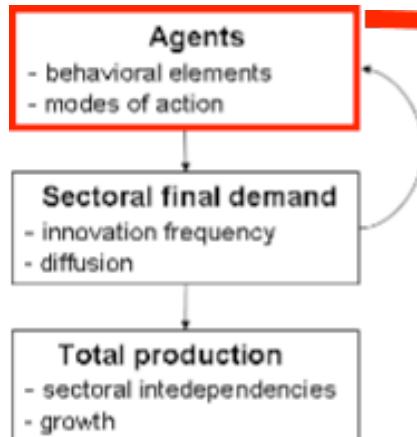
## II. Modelling innovation dynamics

- A multi-level approach is suggested
  - level 1: triggering conditions for innovation activities for autonomous agents
  - level 2: diffusion dynamics and market interaction in sectors
  - level 3: interdependencies between sectors and aggregation



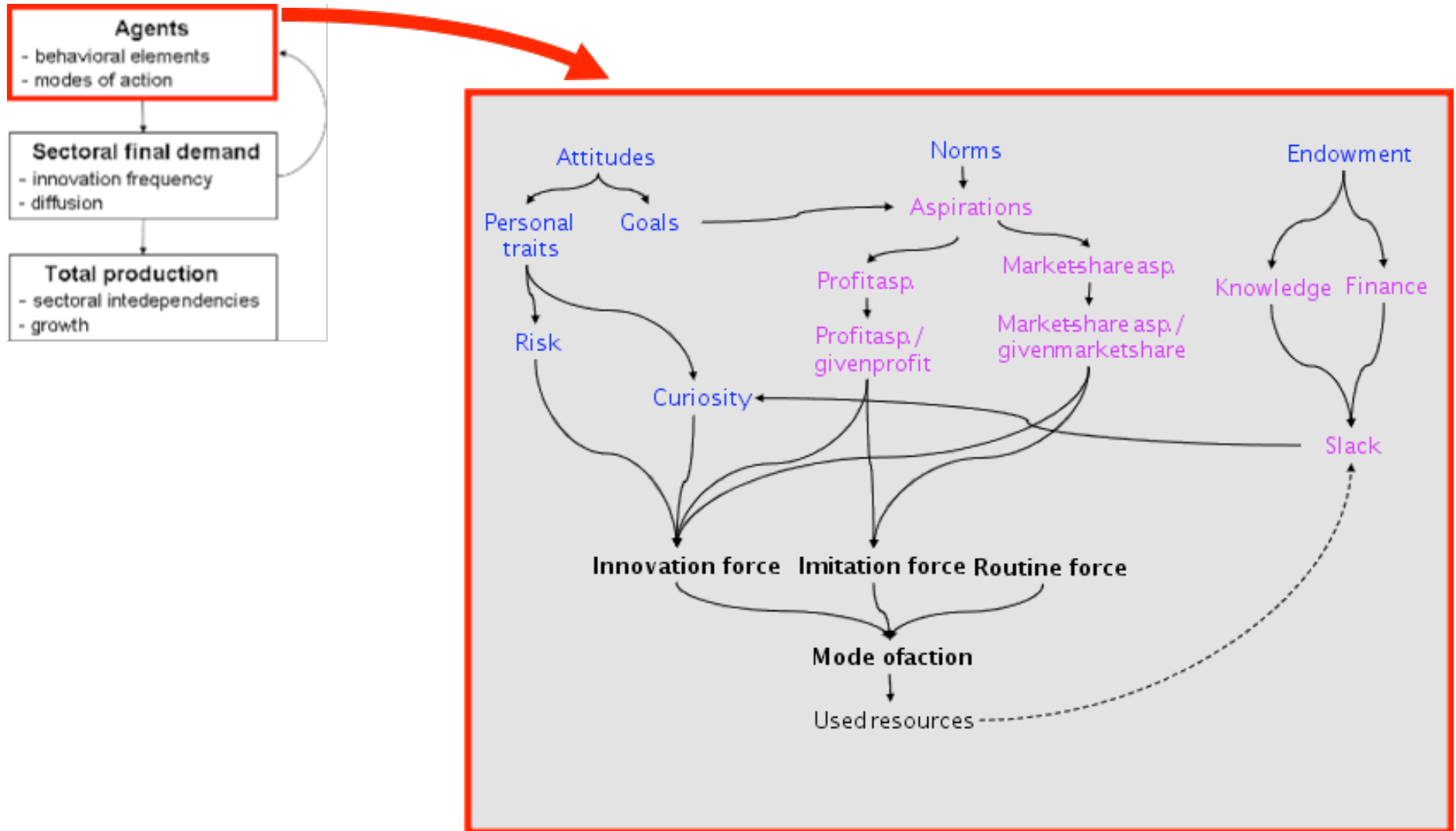
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# ● Level 1: Modelling the behavioural trigger conditions for novelty creating activities

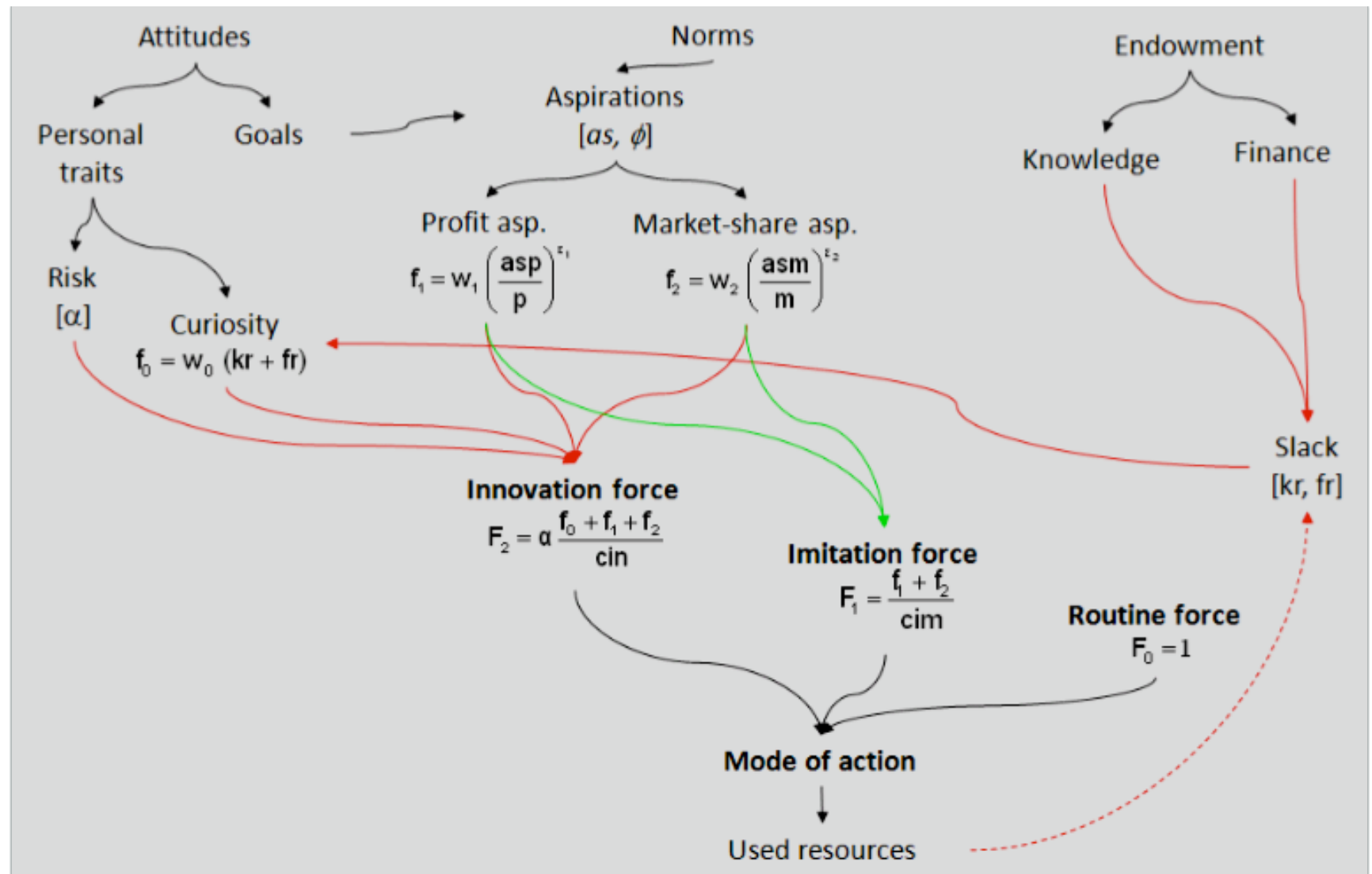


- Question to answer: Under what conditions and how do agents create novelties?
- Unsufficiency of functional and personal attempts to answer this question
- Need for behavioural foundation: role of attitudes, norms and endowment
- Ability to act is given in terms of different modes of action (routine, imitation and innovation)

- Level 1: Modelling the behavioural trigger conditions for novelty creating activities/cont.



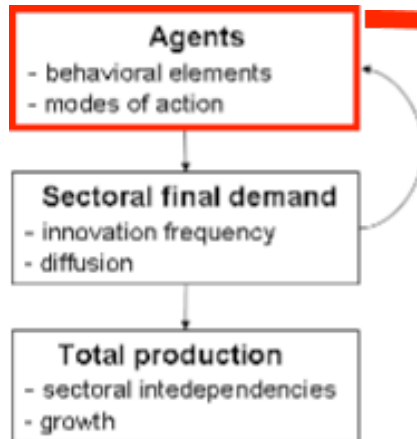
# Formal specification: behavioural dynamics





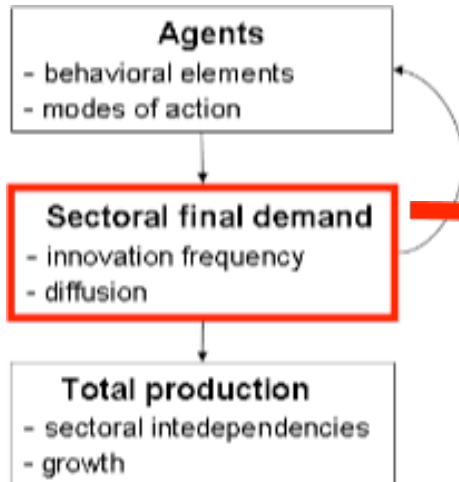
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- Level 1: Modelling the behavioural trigger conditions for novelty creating activities



- What happens if the innovation mode is selected?
  - \* individual innovation lottery
  - \* cooperative innovation lottery
- What happens if the imitation mode is selected?
  - \* limited observability of other agents
  - \* imitation lottery
- What happens if the routine mode is selected?
  - \* same procedure as before

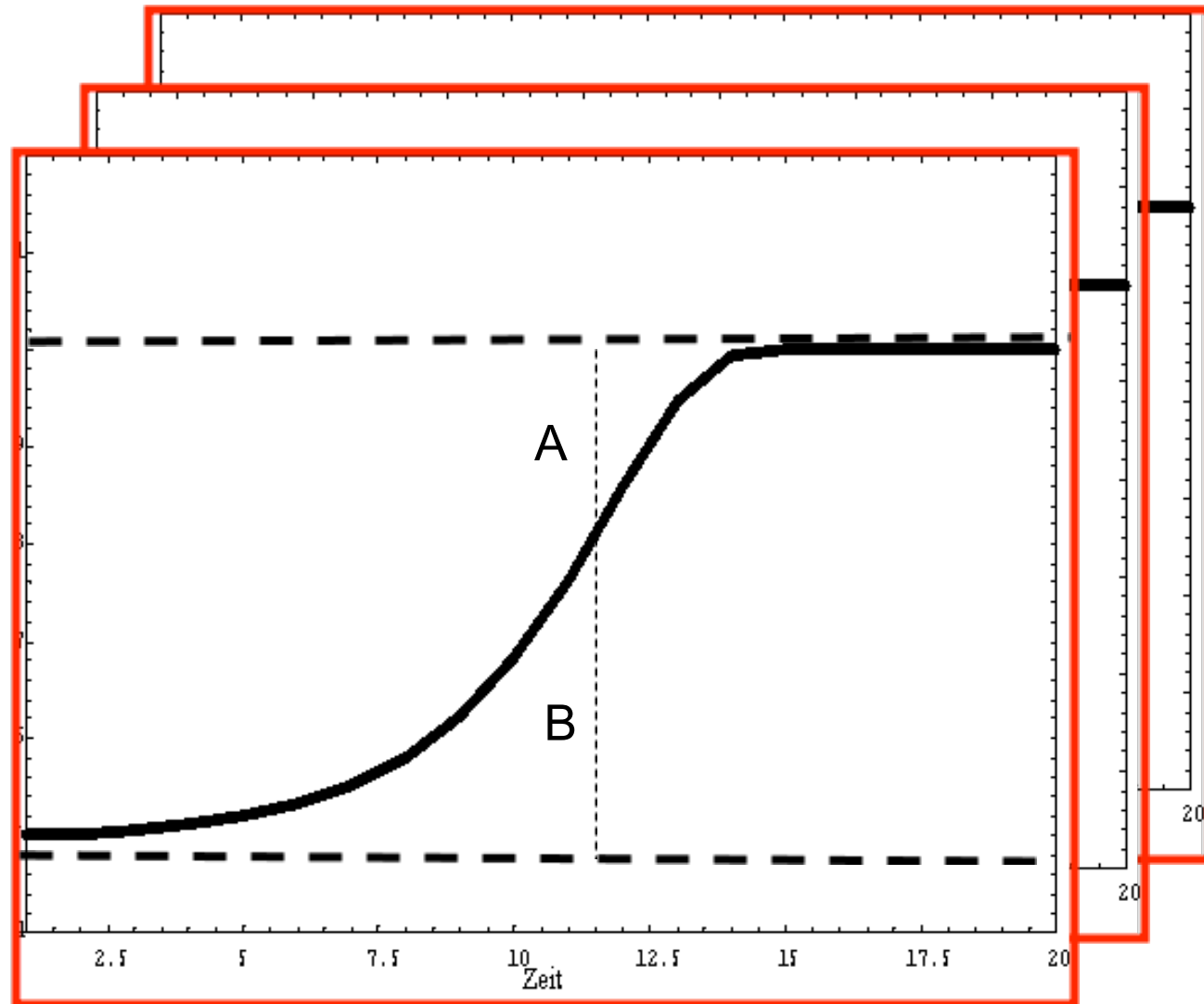
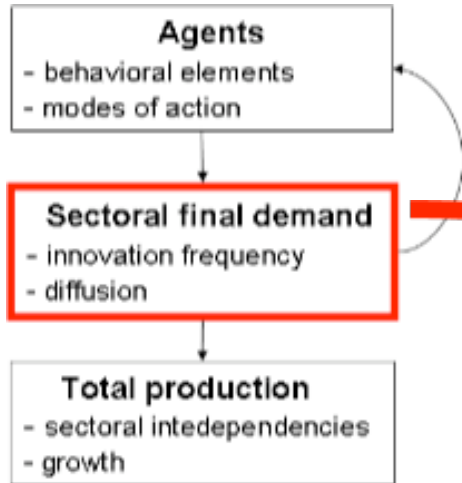
## ● Level 2: Modelling the sectoral diffusion dynamics



- Referring to stylized facts of diffusion analysis
- Assuming a ,critical mass‘
- Assuming a S-shaped diffusion of new products
- Variable speed of diffusion
- Depending on its frequency successful novelty creation has
  - (i) a growth effect for sectoral final demand
  - (ii) a growth effect for total production

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# ● Level 2: Modelling the sectoral diffusion dynamics /cont.



Logistic diffusion dynamics for product specific demand

- demand potential:  $y_{po}$
- critical mass  $y_{ts}$

$$y(t+1) = y(t) + v \frac{(y(t) - y_{ts})(y_{po} - y(t))}{y_{po} - y_{ts}}, \text{ if } y(t) \geq y_{ts}$$

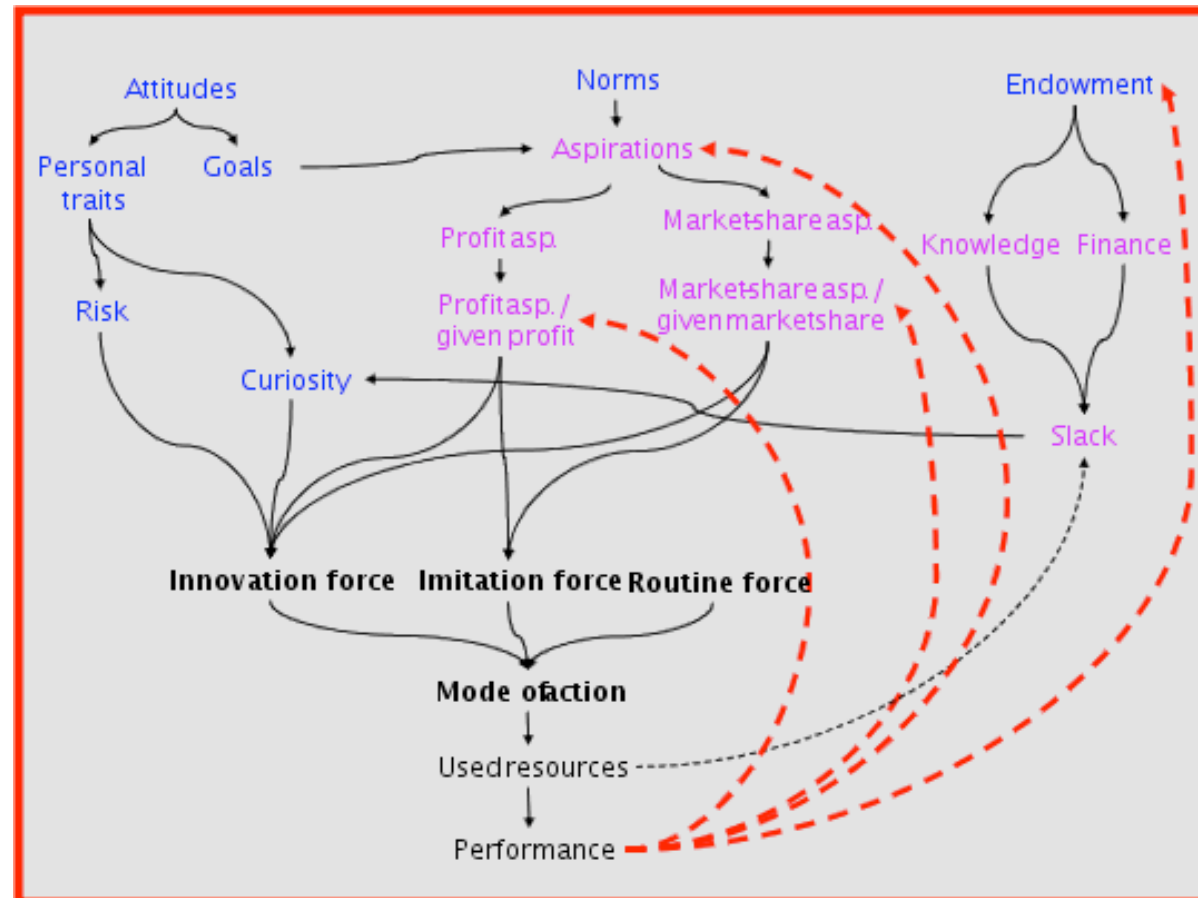
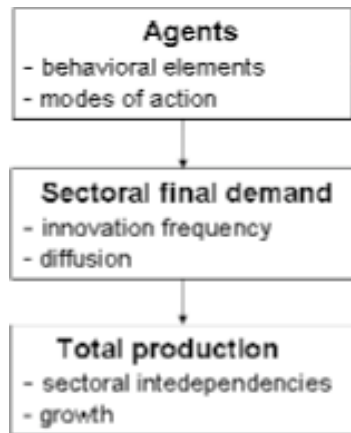
$$y(t+1) = y(t) + v \frac{y(t)(y(t) - y_{ts})}{y_{ts}}, \text{ if } y(t) < y_{ts}$$

Growth effect:  $w(t+1) = \sum_{k=1}^r (y_k(t+1) - y_k(t))$

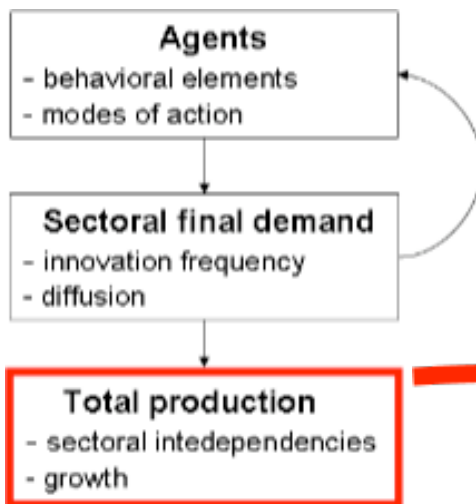
Substitution effect:  $0 \leq su \leq 1$

Growth rate for sectoral net production:  $\frac{Y(t+1) - Y(t)}{Y(t)} = \frac{(1 - su)w(t+1)}{Y(t)}$

- Feedbacks from the sectoral level (level 2) to the agent level (level 1)

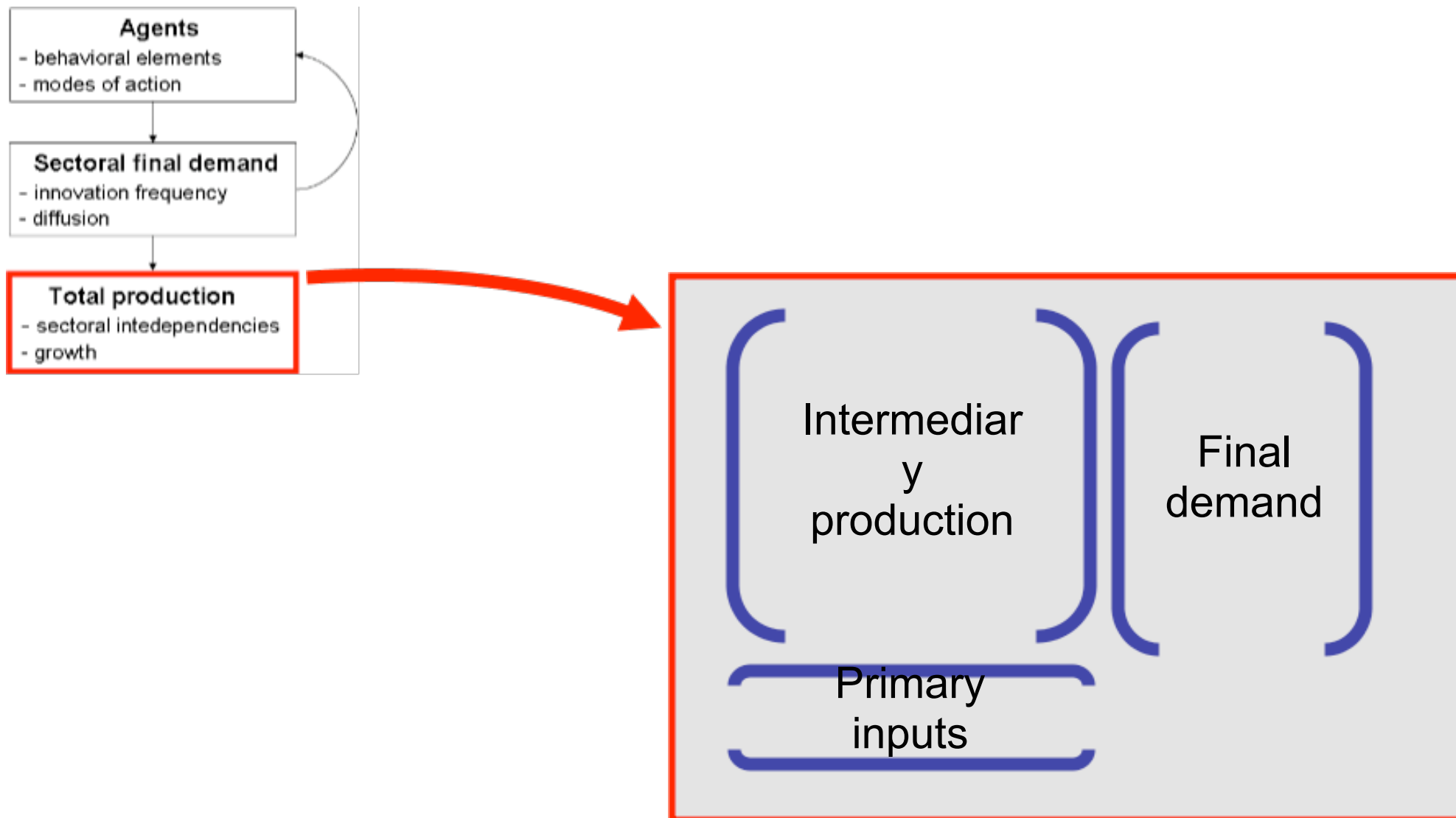


## ● Level 3: Modelling the intersectoral dynamics and gross production



- Using input/output tables (IOT) as an accounting scheme
  - (i) aggregation problem
  - (ii) static nature
- Mapping innovation into IOT
  - (i) Assuming fixed production coefficients
  - (ii) Sectoral final demand dynamics is the driver for the intersectoral dynamics

- Level 3: Modelling the intersectoral dynamics and gross production/cont.



## Formal specification: intersectoral dynamics

Vector of sectoral net production :  $\mathbf{Y}(\mathbf{t}) = \{Y_i(\mathbf{t})\}$

Matrix of 'technical' production coefficients:  $\mathbf{A}(\mathbf{t}) = \{a_{ij}(\mathbf{t})\}$

Vector of sectoral gross production:  $\mathbf{X}(\mathbf{t}) = (\mathbf{I} - \mathbf{A}(\mathbf{t})^{-1})\mathbf{Y}(\mathbf{t})$

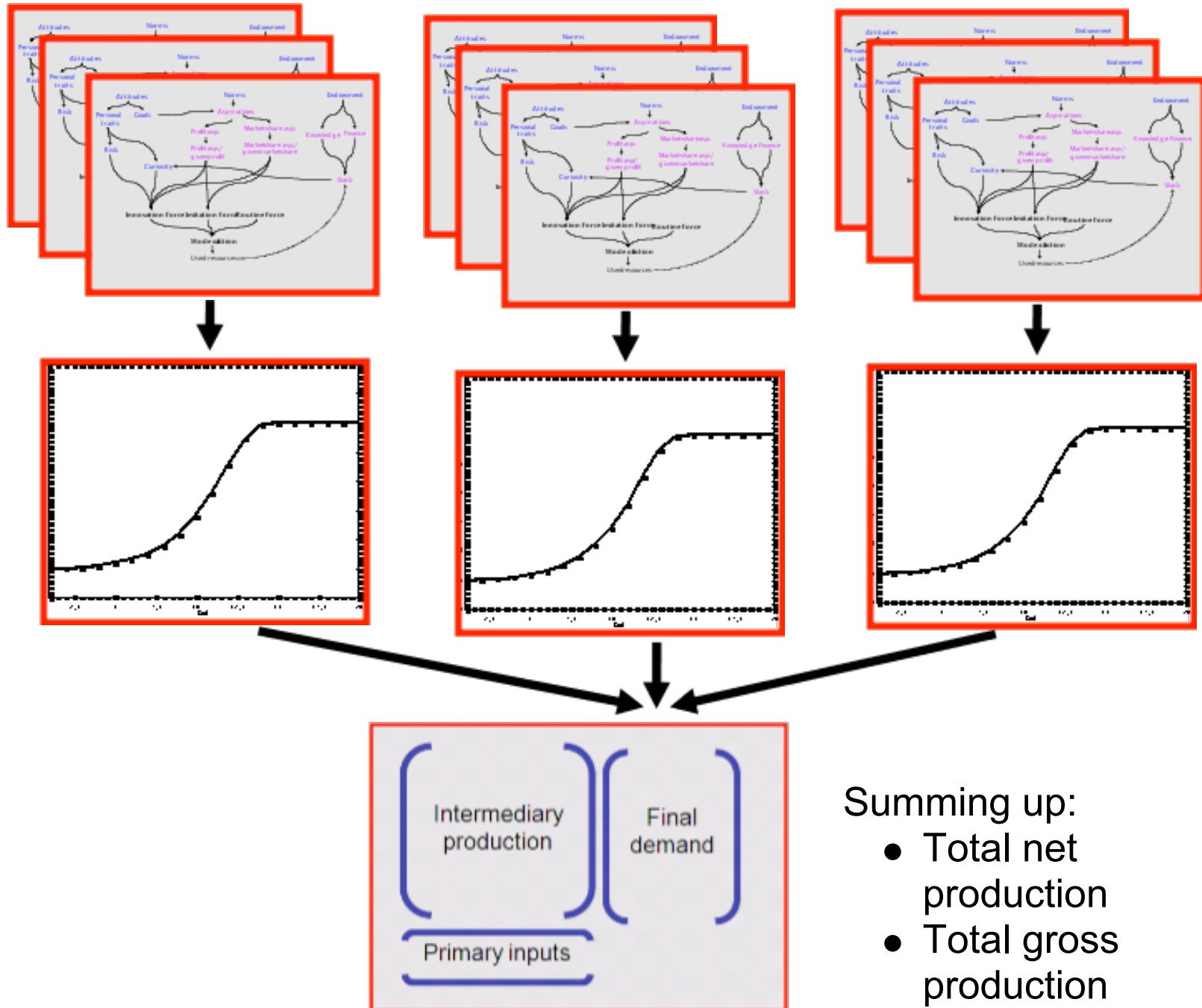
Aggregated net production:  $Y(\mathbf{t}) = \sum_{i=1}^n Y_i(\mathbf{t})$

Aggregated gross production:  $X(\mathbf{t}) = \sum_{i=1}^n X_i(\mathbf{t})$



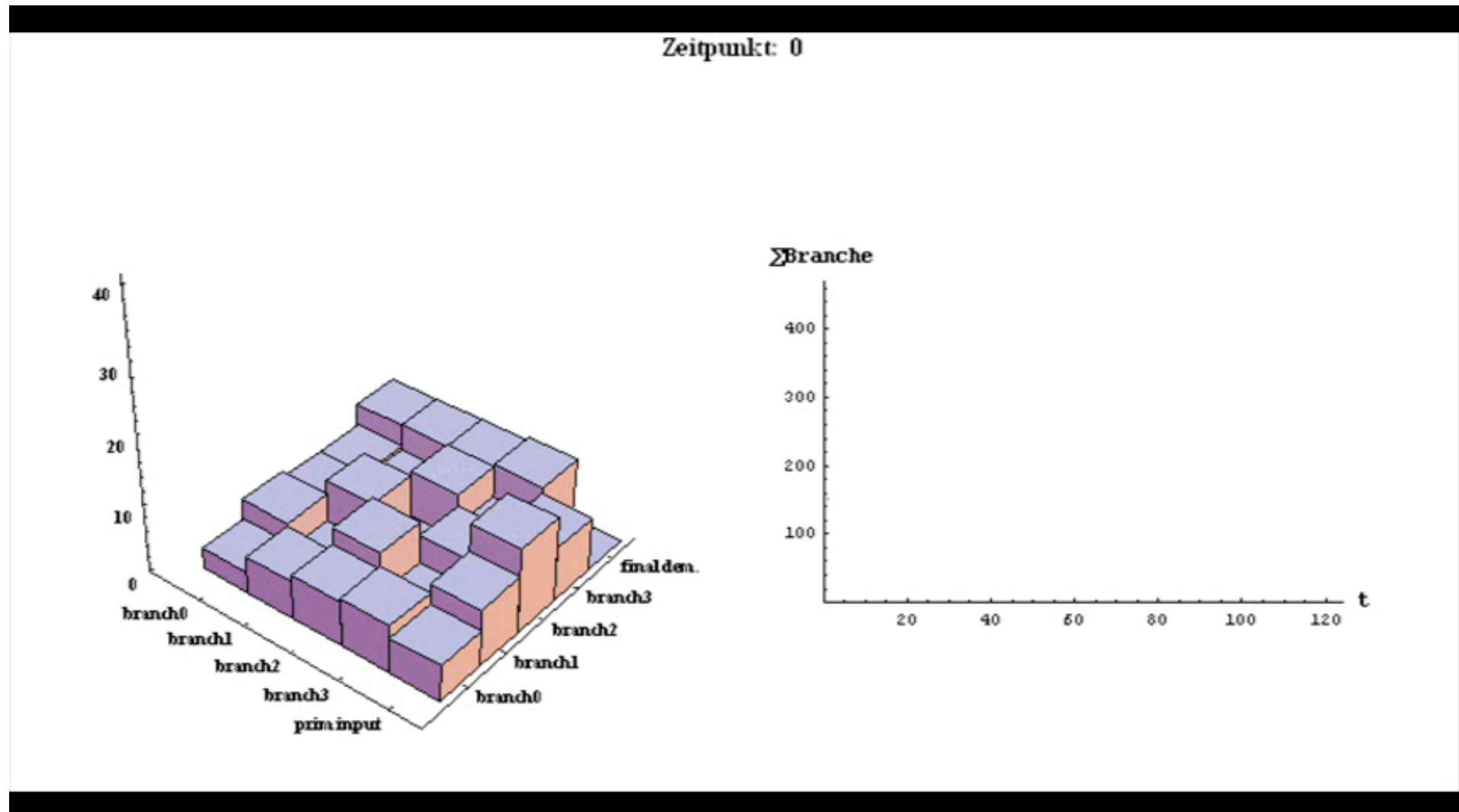
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# IV. Linking innovation dynamics and growth



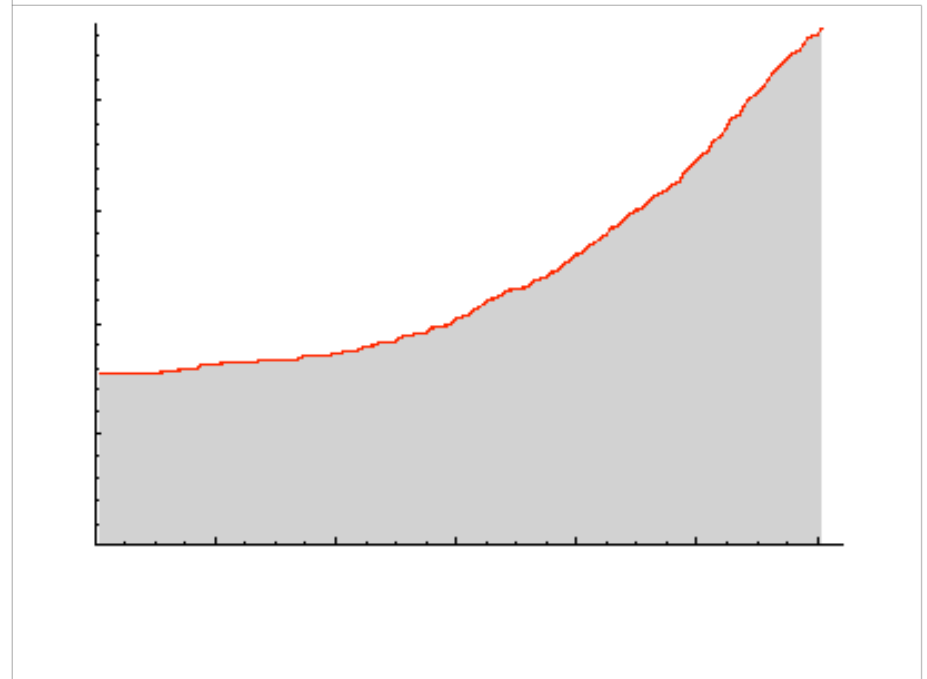
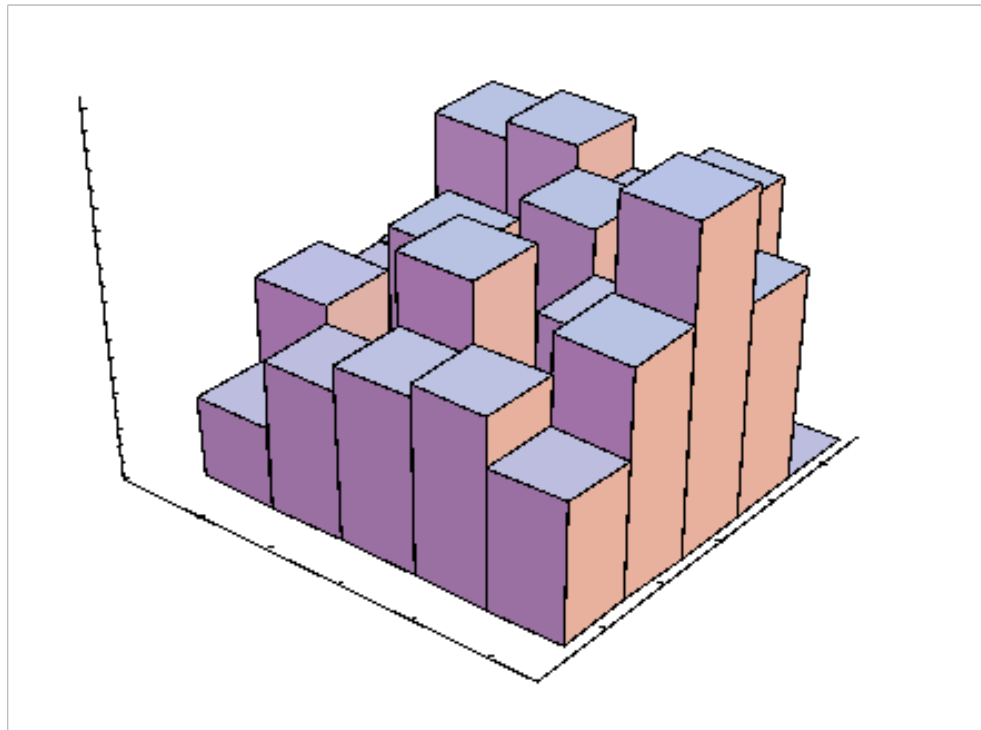
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- Macro level: intersectoral dynamics and total gross value production

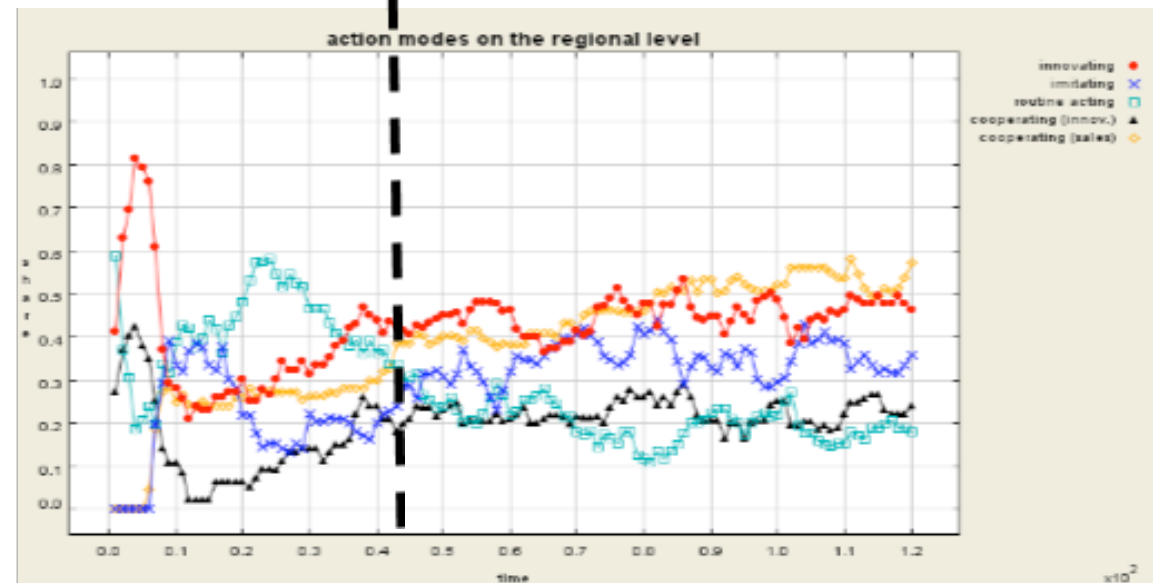
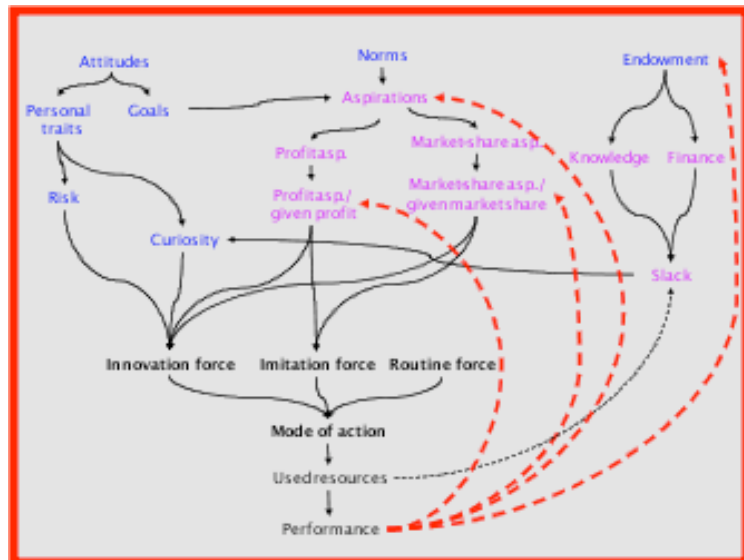
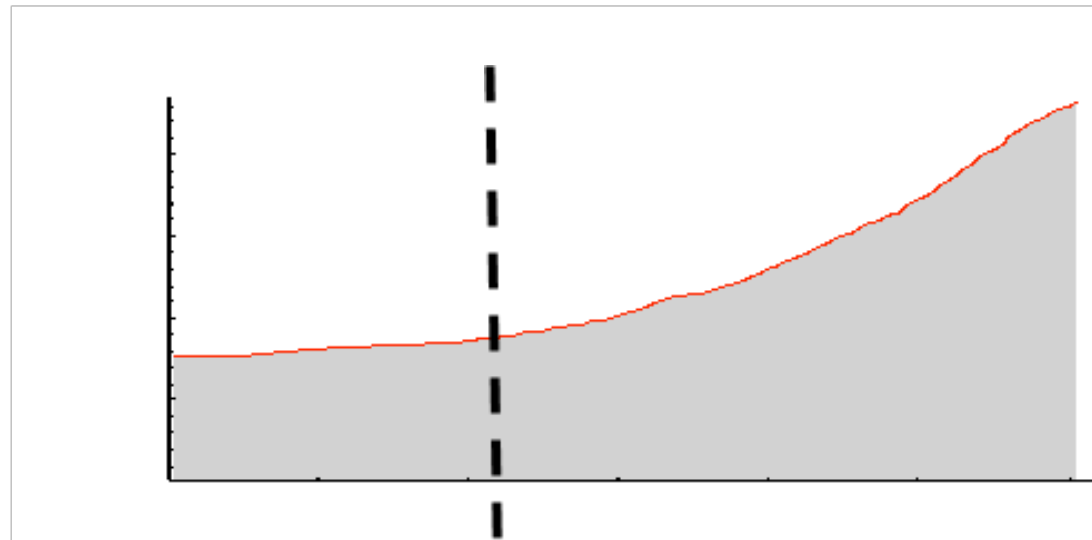


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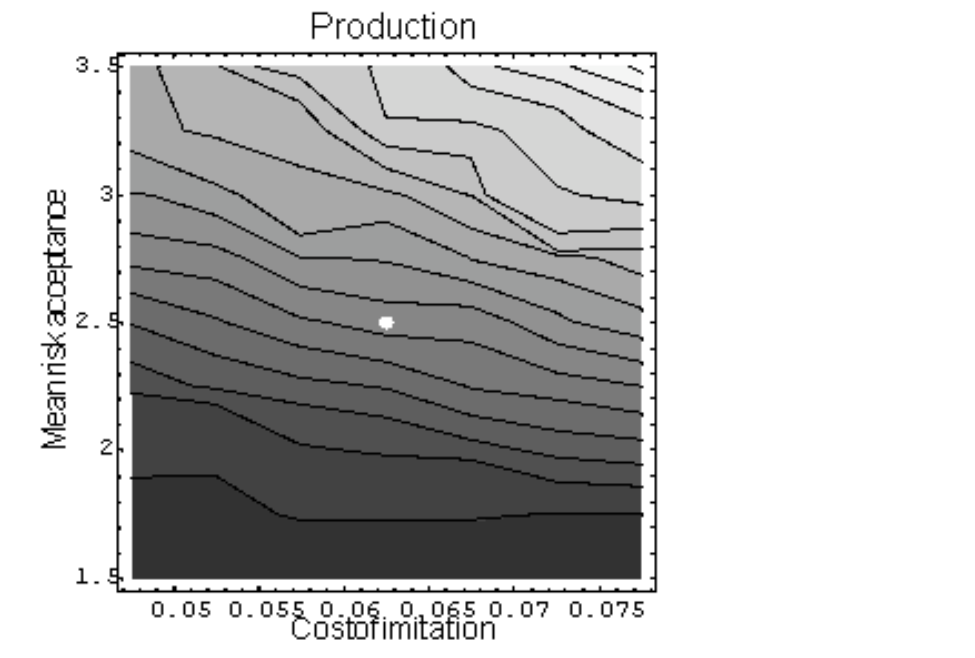
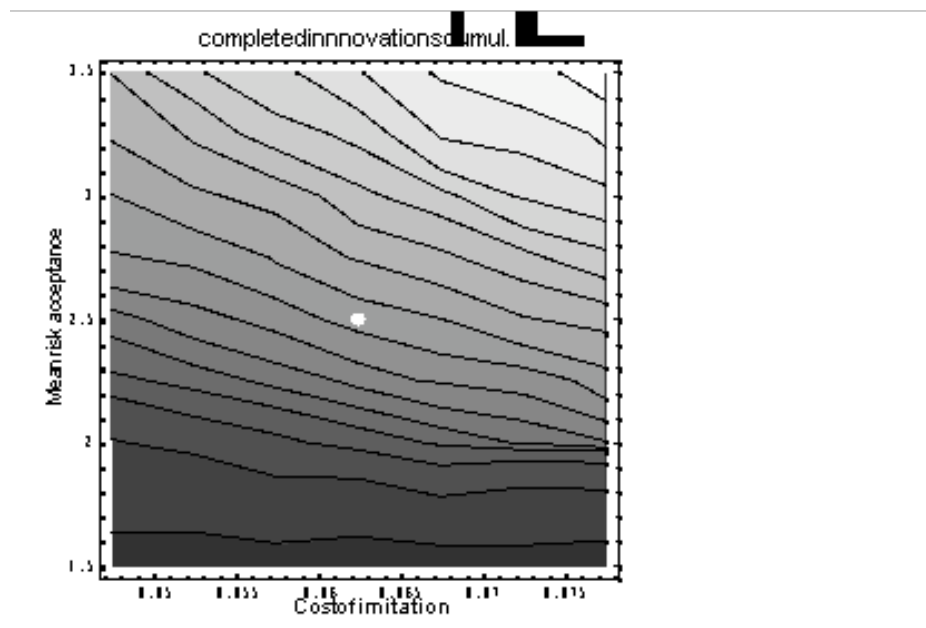
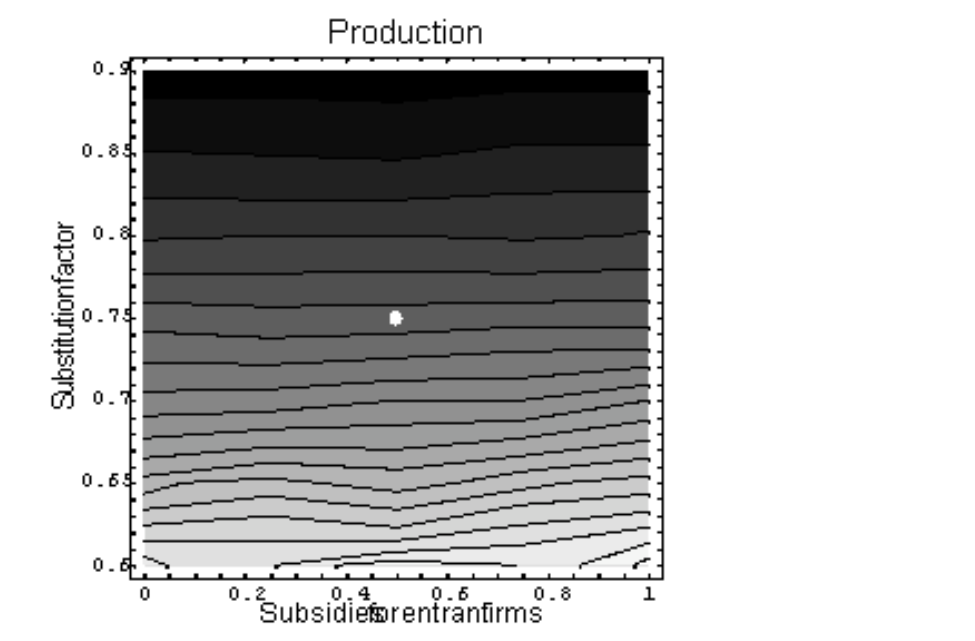
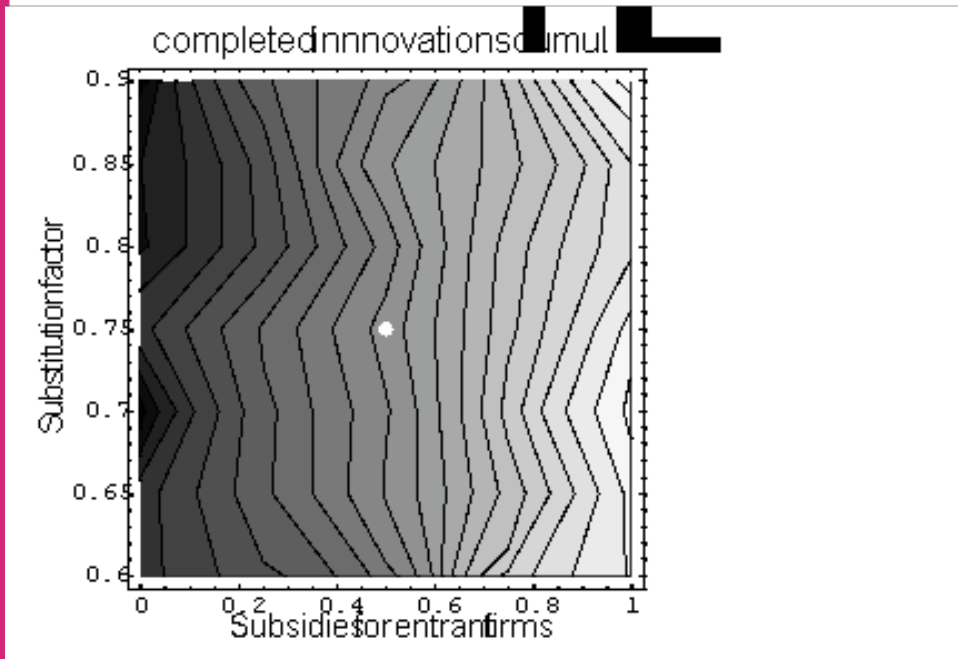
- Macro level: intersectoral dynamics and total gross value production



- Comparing macro-level and micro-level



- Sensitivity analysis as regards innovation and growth (gross production)



# V. Driving forces and dynamics of environmental impacts

## ● Assumptions

- only one exemplary type of emission (e.g. CO<sub>2</sub>)
- emissions related to the level of economic activity
- homogeneous sectors in terms of initial emissions

## ● Driving forces for emission dynamics

- frequency of innovation
- type of innovation as regards emission
- diffusion of innovation (critical mass, growth vs. substitution)
- intersectoral effects
- vintage structure of aggregates

## Formal specification of emission dynamics on the sectoral and national level

$$em_i(t) = \frac{em_i(t-1)Y_{i,old} + \sum_{j=1}^{P_i(t)} em_{i,j}(t)Y_{i,j}(t)}{Y_{i,total}}$$

$$em_{i,j}(t) = M em_{i,j}(t-1)$$

$$Em_i(t) = em_i(t) X_i(t)$$

$$Em(t) = \sum_i em_i(t) X_i(t)$$

- Simulating the dynamics of environmental impacts
- Classification of cases

Increasing emission ( $M > 1$ )/  
fast diffusion ( $v$  high)

Increasing emission ( $M > 1$ )/  
slow diffusion ( $v$  low)

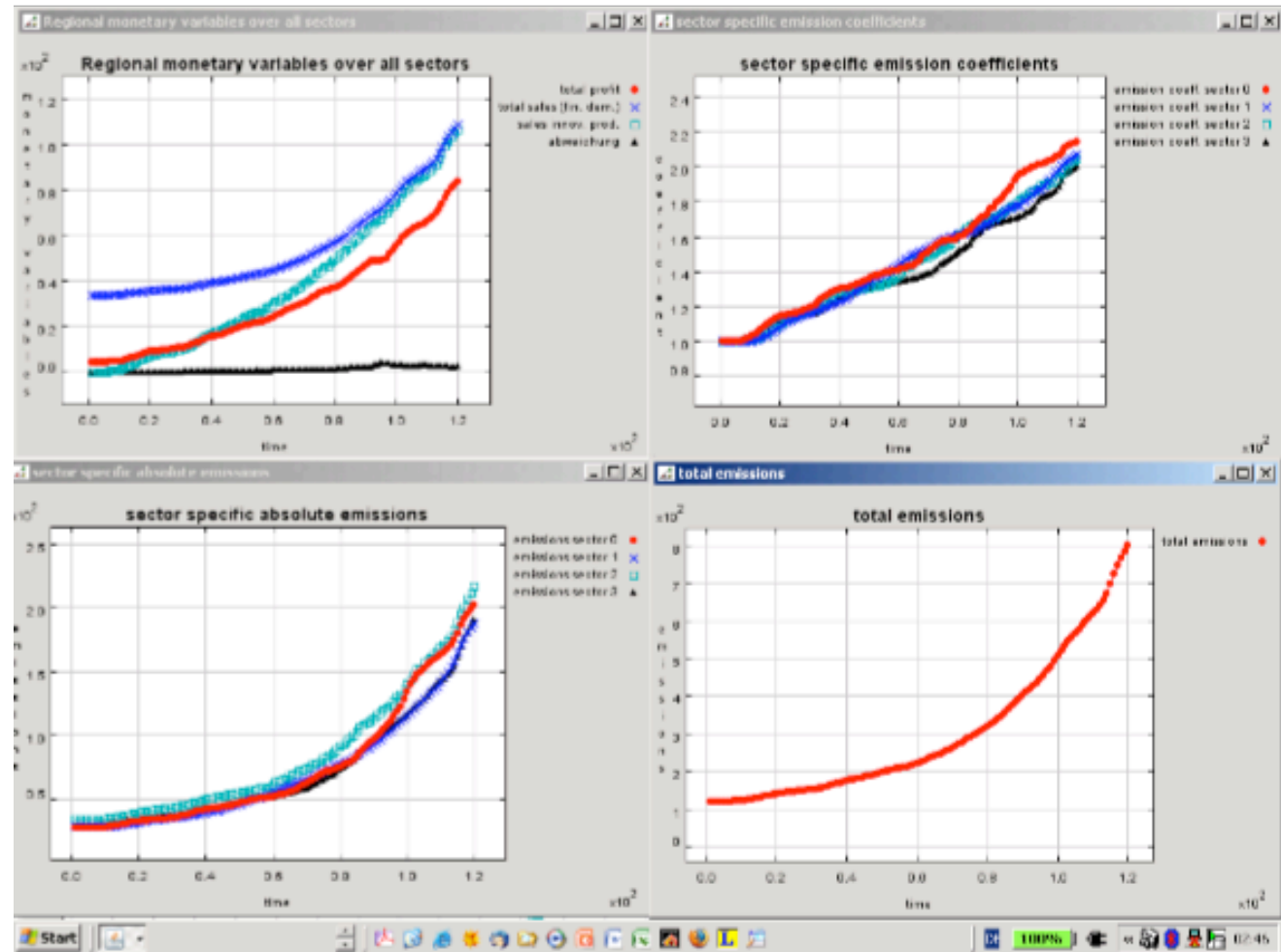
Decreasing emission ( $M < 1$ )/  
fast diffusion ( $v$  high)

Decreasing emission ( $M < 1$ )/  
slow diffusion ( $v$  low)

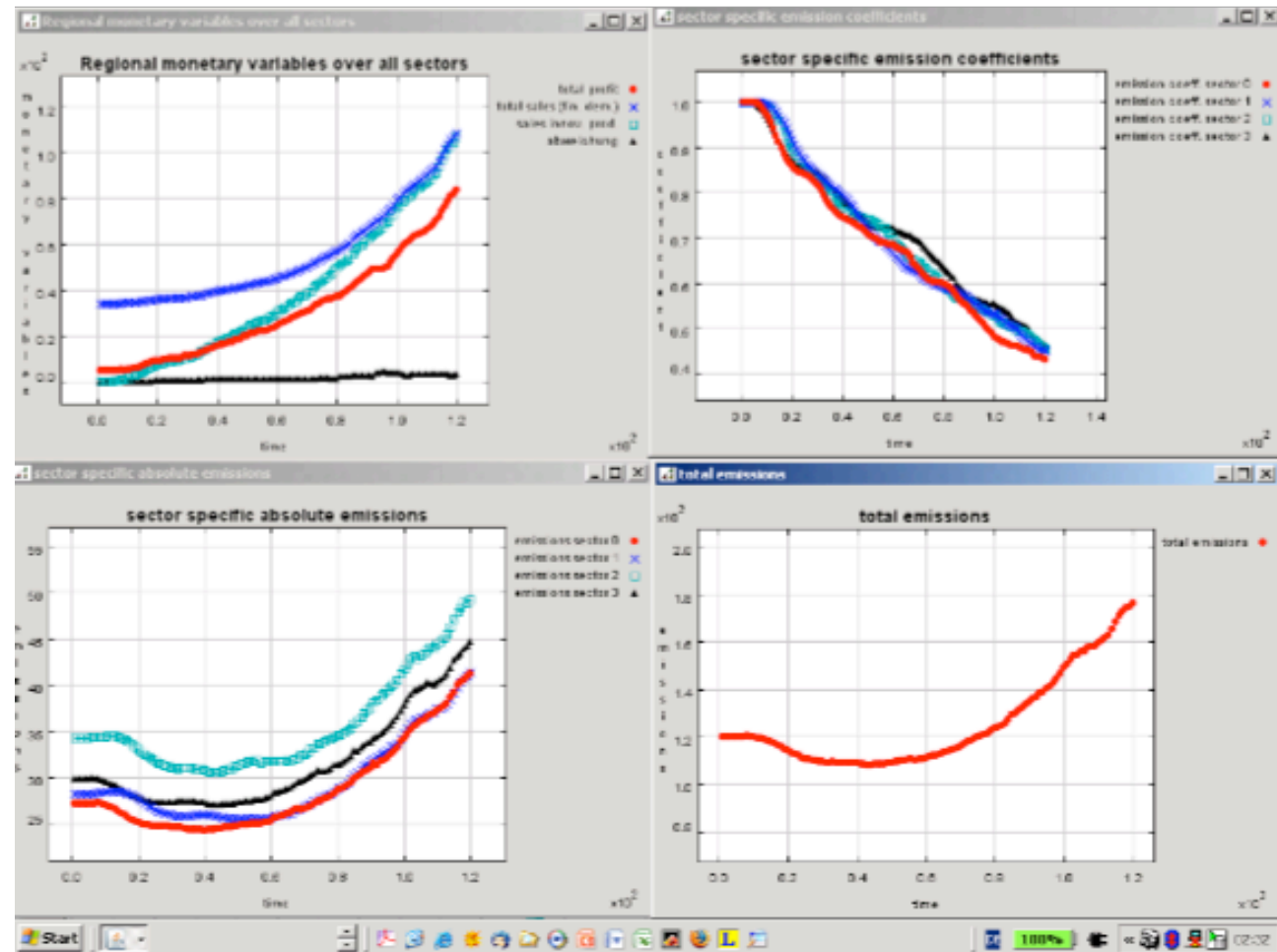


- Simulating the dynamics of environmental impacts/cont.

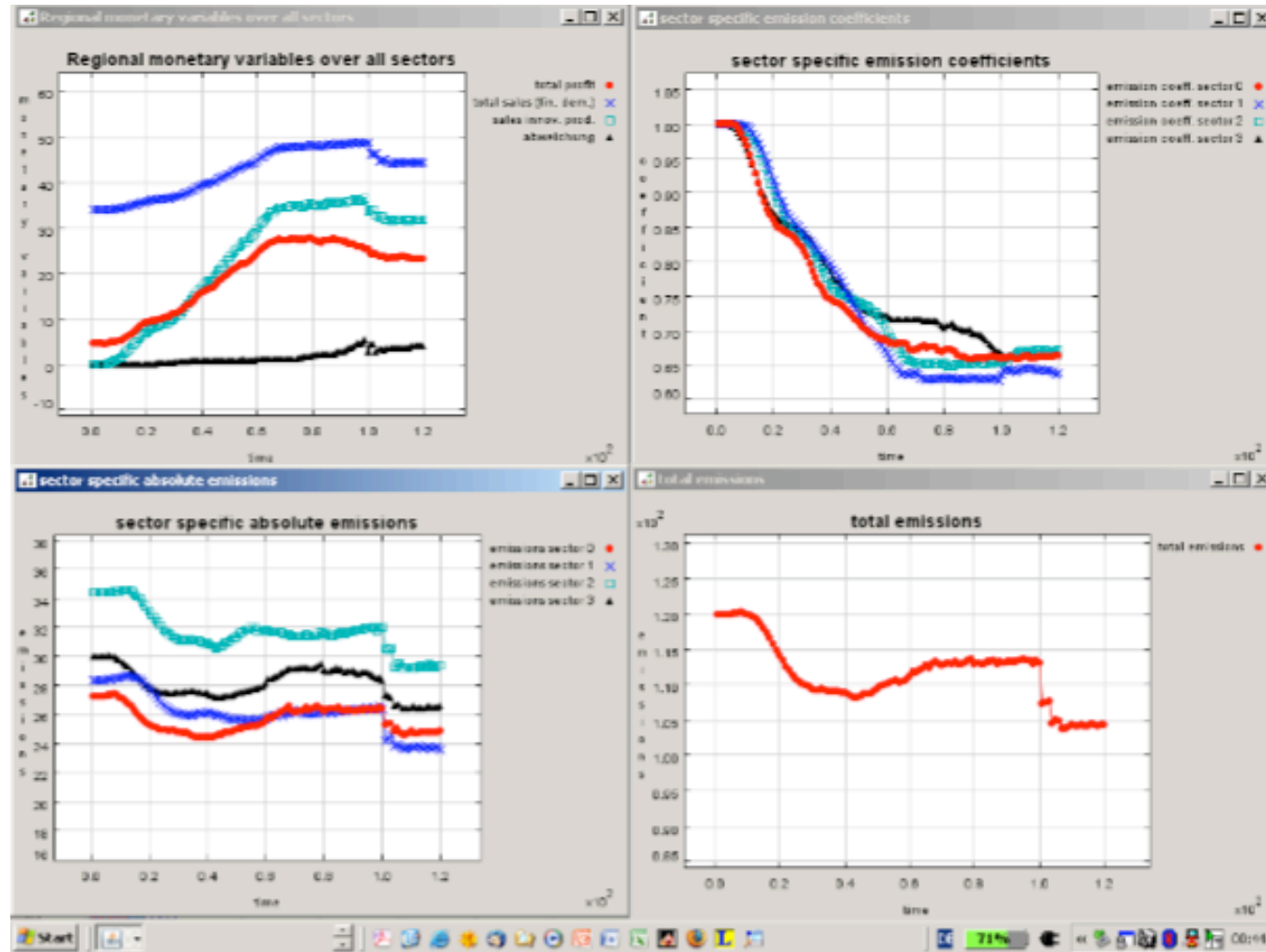
- case increasing emission/fast diffusion: specifying the worst case



- Simulating the dynamics of environmental impacts/cont.
  - case decreasing emission/fast diffusion: specifying the rebound effect



- Simulating the dynamics of environmental impacts/cont.
  - case decreasing emission/interrupted diffusion: specifying the crisis effect

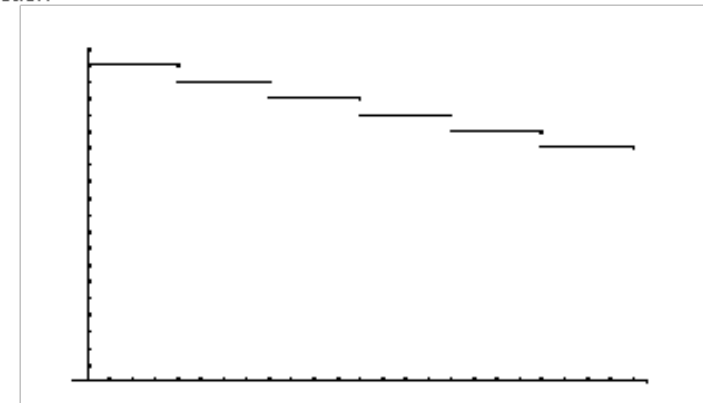


# VI. Assessing policy measures

- Core of market-induced innovation dynamics
  - self-organized nature
  - unpredictable outcome
  - „innovation trap“
- What are the policy options?
  - blocking the core?
  - fostering differentiation?
  - redirection?

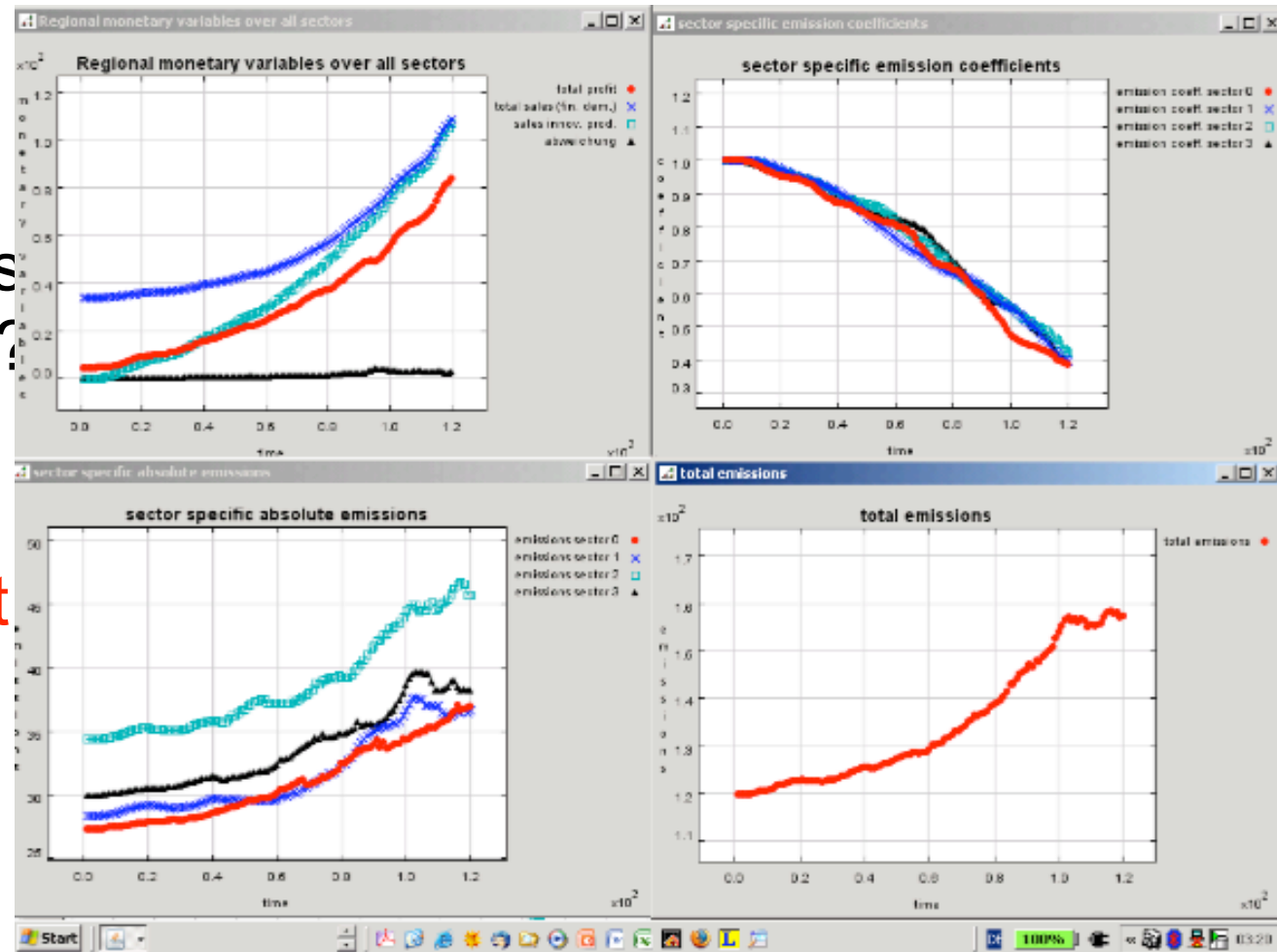
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Production



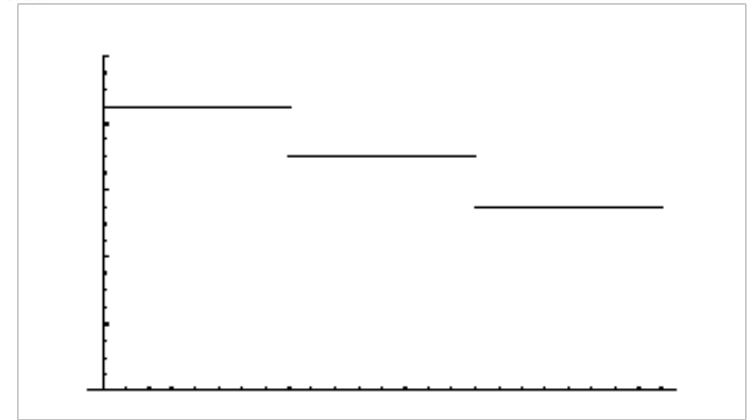
## ● Redirecting innovations

- which measures are appropriate?
- incremental dynamic short term abatement



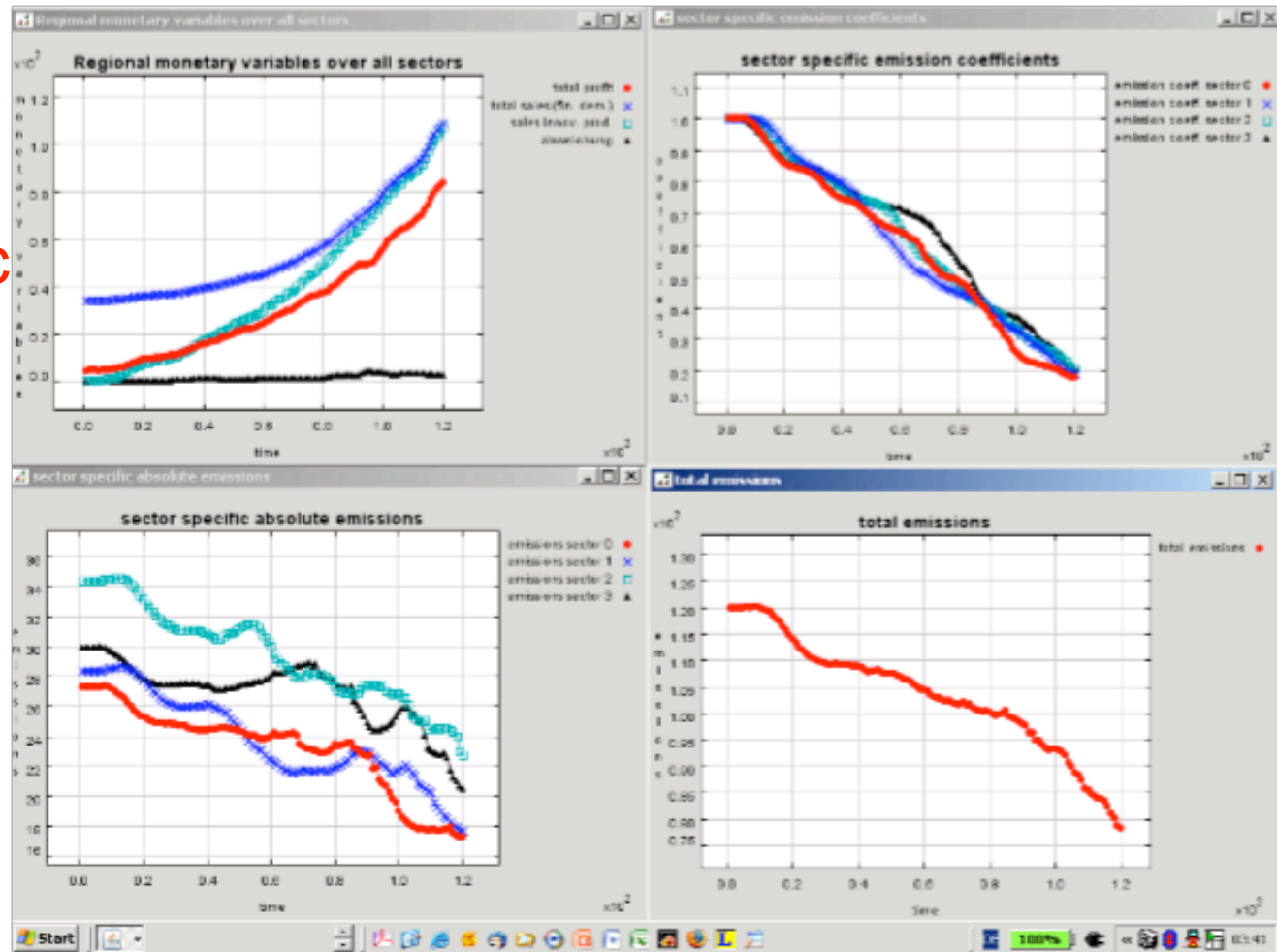
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interaction

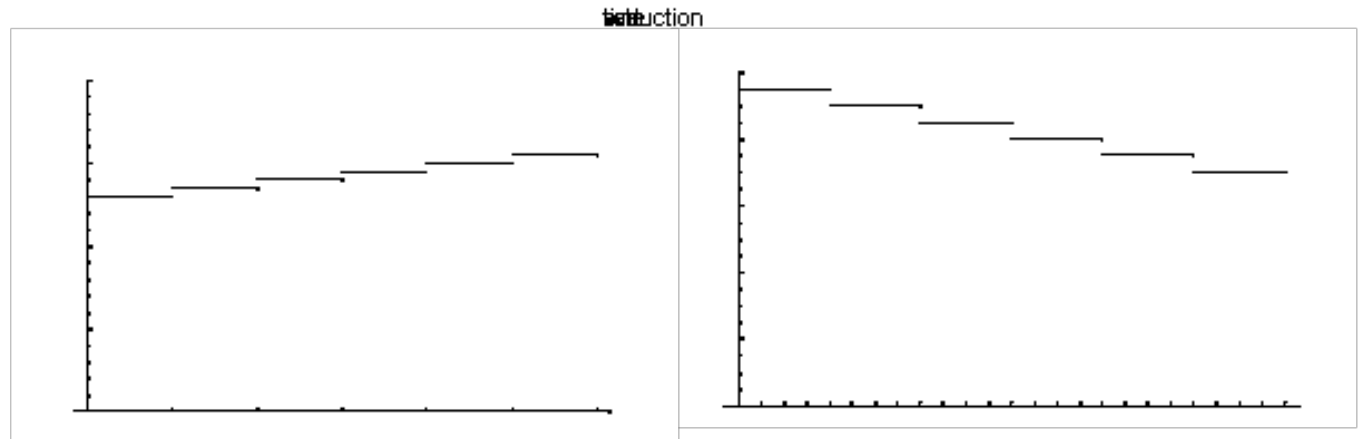


- Redirecting innovations

- radical dynamic long term abatement

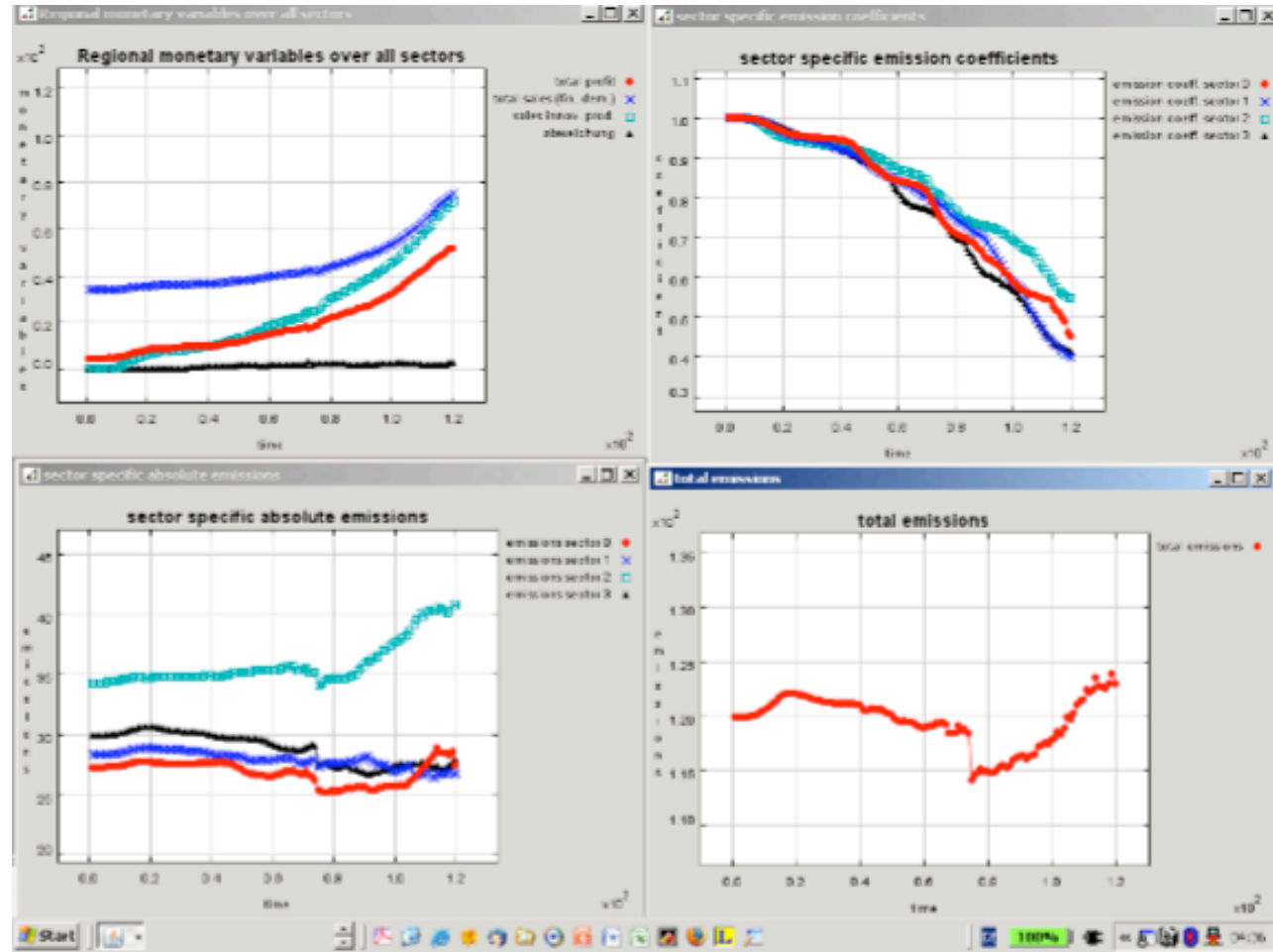


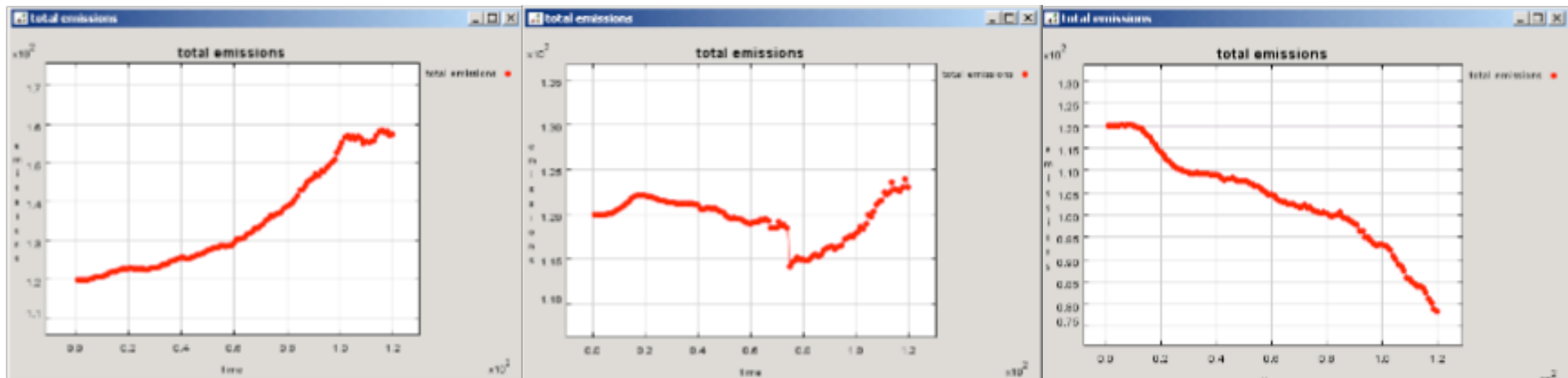
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- Redirecting innovations

- incremental dynamic short term abatement
- incremental increase of innovation costs

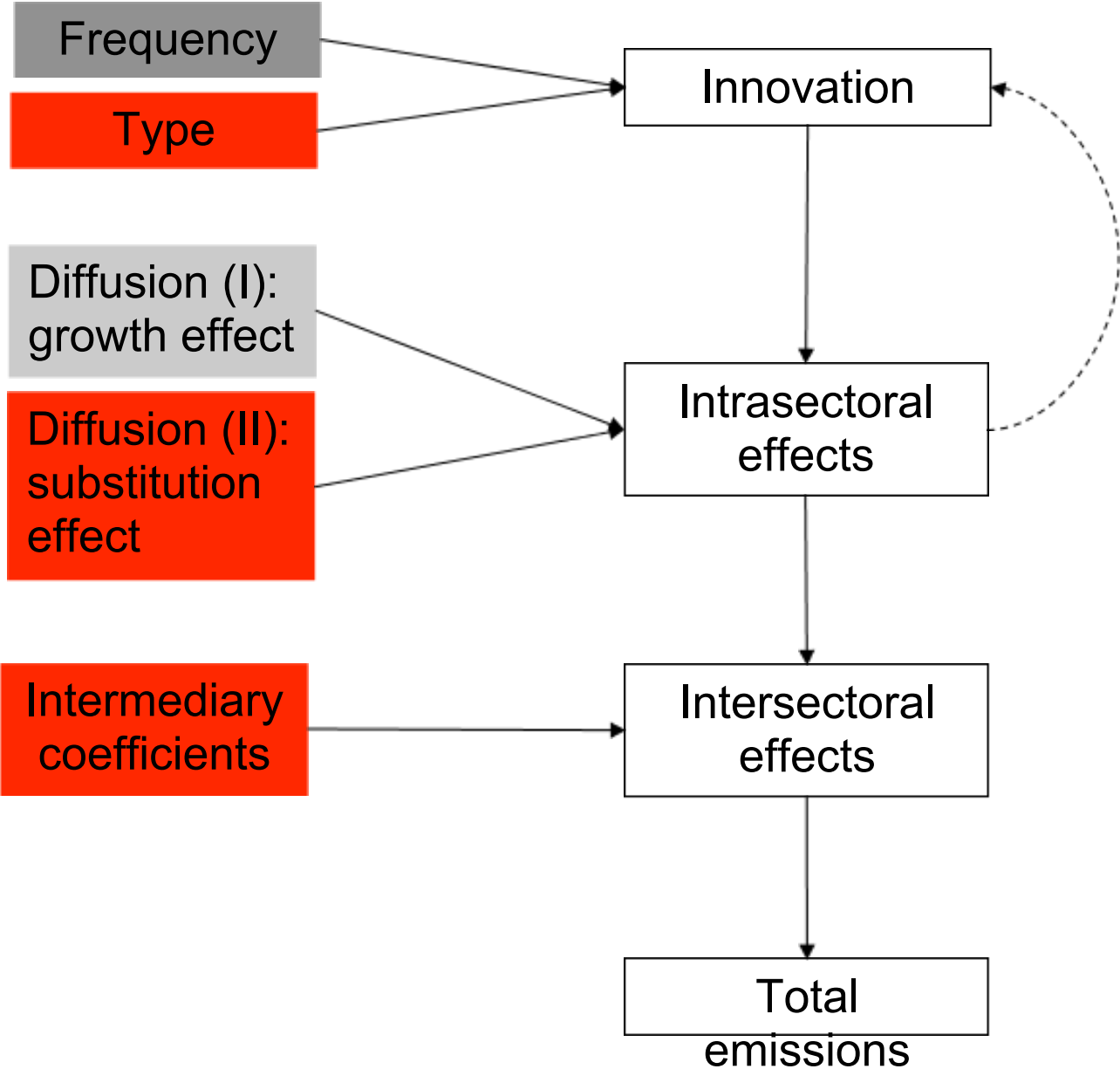




- Trade off for reaching emission targets
  - failure of incremental improvements
  - ambiguous results of increasing abatement costs
  - radical change of innovation dynamics possible?
  - need for accomplishment by changing life styles/use patterns



# VII. Conclusions



# VII. Conclusions

- Need for bringing more conceptual realism into economic models
  - bounded rational agents
  - endogenous explanation of innovation and diffusion
  - multi-level analysis: bottom up and top down
- Multi-agent models indicate that emission targets are not sufficient
  - necessity to take agents into account
  - as well as: the context they are operating in
  - the time structure of regulation
- There are different paths to fulfill (or to miss) a target
  - need for selecting a path
  - updating according to observable results required
- Problem of path dependency

Thank You for Your attention!

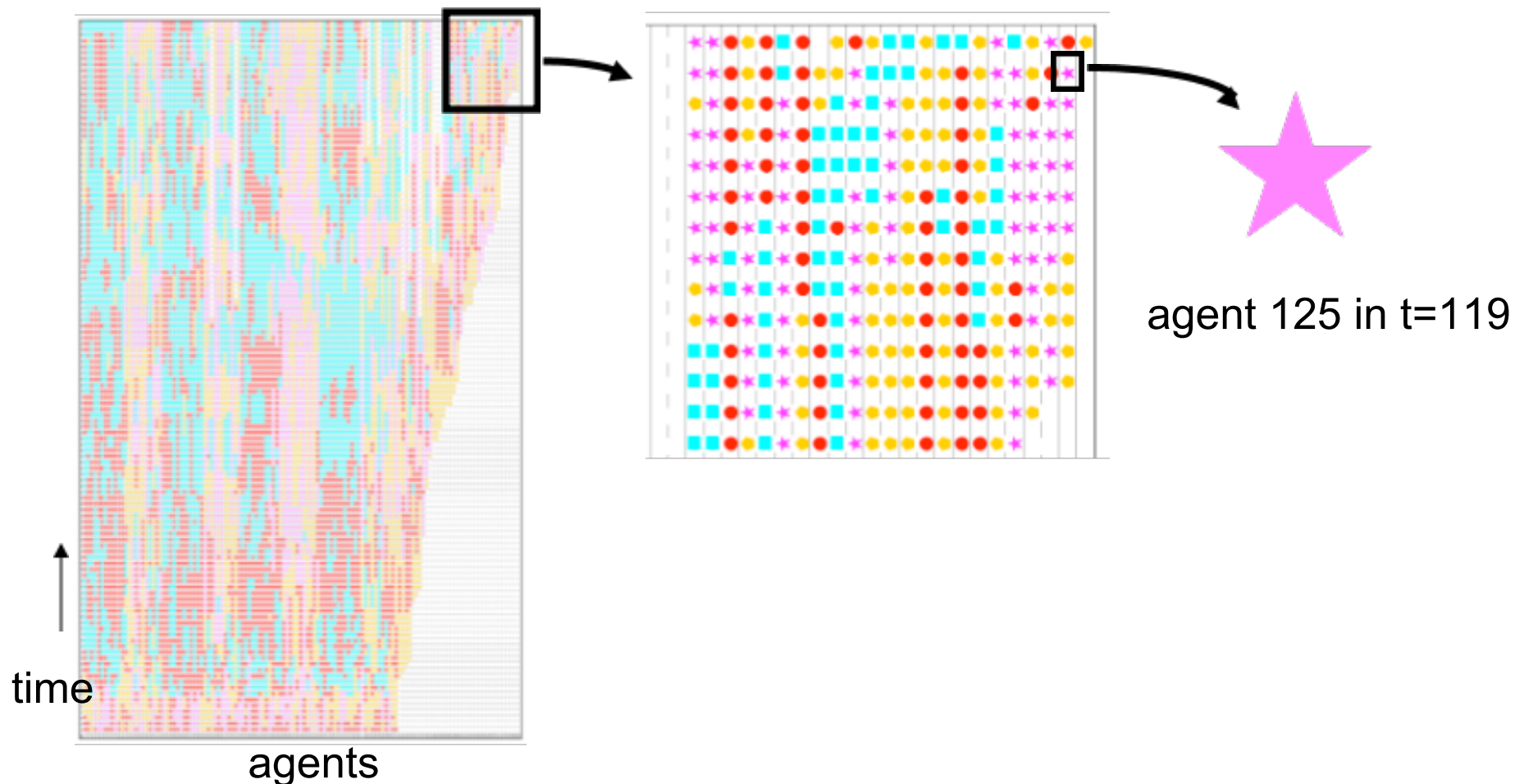
## More on agent-based economics:

<http://ivwl.uni-kassel.de/beckenbach/poabe.html>



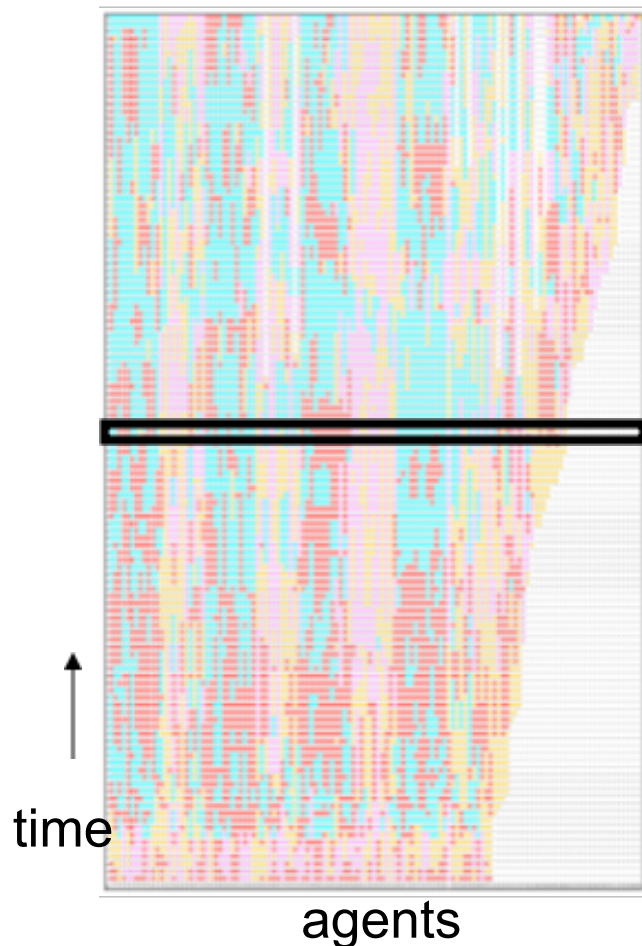
**[papers on agent-based economics](#)**

- New modelling perspectives: empirical agent-based dynamic modelling/cont.
  - What is it good for? (II): analysing states of agents over time



- New modelling perspectives: empirical agent-based dynamic modelling/cont.

- What is it good for? (III): analysing interaction of agents as a generating force for overall regional development



layers and networks in t=60

The screenshot shows the Eclipse IDE with the following components:

- Editor:** Displays the source code for `Modell.java`. The method `liesVerhaltParamFirmenAnzahl()` is highlighted. The code includes:
 

```

540 /**
541  * firmenanzahlen und verhaltensparameter einlesen
542  */
543 private void liesVerhaltParamFirmenAnzahl()
544 {
545     try
546     {
547         double tempNFirmenBr[] = new double[nBranchen];
548         Lesen.liesVektorKennwortKontro(verhaltPfad, "nFirmenBr");
549         for(int br=0; br<nBranchen; br++)
550             nFirmenBr[br] = (int) tempNFirmenBr[br];
551         Lesen.liesVektorKennwortKontro(verhaltPfad, "anteilFirmenTyp");
552         Lesen.liesVektorKennwortKontro(verhaltPfad, "koopNeigTyp");
553         Lesen.liesVektorKennwortKontro(verhaltPfad, "optimismusTyp");
554         Lesen.liesVektorKennwortKontro(verhaltPfad, "risikoNeigTyp");
555         Lesen.liesVektorKennwortKontro(verhaltPfad, "forschNeigTyp");
556         Lesen.liesVektorKennwortKontro(verhaltPfad, "neuHandlKoeff");
557         Lesen.liesVektorKennwortKontro(verhaltPfad, "neuHandlKoeff");
558         Lesen.liesVektorKennwortKontro(verhaltPfad, "neuHandlKoeff");
559         Lesen.liesVektorKennwortKontro(verhaltPfad, "neuHandlKoeff");
560         Lesen.liesVektorKennwortKontro(verhaltPfad, "absorpKap");
561     }
562     catch(IOException e)
563     {
564         System.out.println("Eingabedatei "+verhaltPfad+" existiert nicht");
565         e.printStackTrace();
566         for(int br=0; br<nBranchen; br++)
567             nFirmenBr[br] = -24;
568         for(int ty=0; ty<nTypen; ty++)
569         {
570             anteilFirmenTyp[ty] = 1./nTypen;
571             koopNeigTyp[ty] = 1;
572             optimismusTyp[ty] = 0.;

```
- Outline:** Shows the project structure with the following methods:
  - setup()
  - buildModel()
  - erzeugHistogramme()
  - liesVerhaltParamFirmenAnzahl() (highlighted)
  - liesWettbewerbParam()
  - liesIOTInt()
  - berechProduktWertInt()
  - prüfFlauschPrimärInput()
  - berechProduktKoeffLeontiefInverse()
  - liesEmissKoeff()
  - liesAndFakEmissKoeffNeu()
  - erzeugFirmen()
  - erzeugGrapherHM()
  - new Sequence() {...} (multiple instances)
- Project Explorer:** Shows a project named `RIS10.Emiss` with subfolders `uebung_1`, `uebung_2`, `uebung_3`, and `uebung_p32`.
- Status Bar:** Shows the current file path: `src.risModell.Modell.liesVerhaltParamFirmenAnzahl(): void - RIS10.Emiss`.