Greenhouse technology evolution

Advanced ABM

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01-02-2013

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Adapted version of process of making an Agent-based model

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  - Explanation agents (greenhouse owners)
- Software implementation
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- Model experimentation
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  - Experiment B - Diversification VS Specialisation
- Conclusions and recommendations

System analysis

What is the problem context?

System analysis

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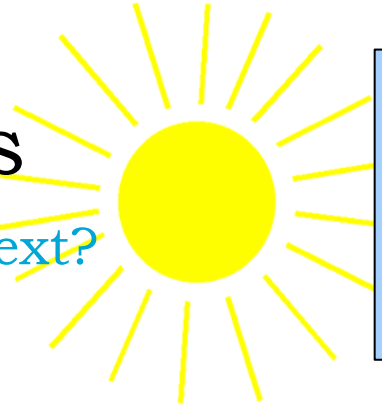

External climate:
Temperature: 18 °C
CO2: 400 ppm
Humidity: 74%
Light intensity: 1000 lux

Ideal climate:
Temperature: 24 °C
CO2: 1200 ppm
Humidity: 87%
Light intensity: 1700 lux

Technology A

Technology B

Technology C

Technology D

System analysis

What is the problem?

- What is that we do know:
  - Technologies not only influence primary function
  - Performance is emergent property of interaction between technologies
  - Technology developers mainly focus on primary function
- What it is that we want to know:
  - What will be the effect on the overall performance of the greenhouse sector, when technology developers also take the secondary functions into account while improving technologies?
- **Hypothesis:**
  - Overall performance of the greenhouse sector will increase

Conceptualisation

Explanation environment (technology markets)

- Properties
  - Four technology markets (A, B, C, D)
  - Five products per market
- Example of a product array
  - Product: {A; B; C; D; Emission; Cost price; Lifetime}
- Technology category A
  - Product A1: {0.60; 0.04; -0.02; 0; 500; 1900; 5}
  - Product A2: {0.55; 0.02; -0.01; 0; 300; 2000; 5}
  - Product A3: {0.48; 0.04; -0.04; 0; 450; 1800; 5}
  - Product A4: {0.64; 0.08; -0.03; 0; 700; 1700; 5}
  - Product A5: {0.72; 0.06; -0.02; 0; 250; 1200; 5}

Conceptualisation

Explanation environment (technology markets)

- Every tick, one of the markets will:
  1. Select a product
     1. **Highest main function**
     2. **From best performing greenhouse**
  2. Create three copies and improve them
  3. Select one of the created copies
     1. **Highest main function**
     2. **Highest sum of all functions**
  4. Replace the 'old' product with the improved version

- Three 'styles' to go through the steps above
  1. Protected development **1.1** - 2 - **3.1** - 4
  2. Limited cooperation **1.1** - 2 - **3.2** - 4
  3. Open source cooperation **1.2** - 2 - **3.2** - 4

Conceptualisation

Explanation environment (technology markets)

- Important design choice considering improvement of technologies: **ImproveSameTechCounter**

- Example for Protected development
  - Technology Market A
    - Product A1: {0.60; 0.04; -0.02; 0; 500; 1900; 5}
    - Product A2: {0.55; 0.02; -0.01; 0; 300; 2000; 5}
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    - Product A4: {0.64; 0.08; -0.03; 0; 700; 1700; 5}
    - **Product A5: {0.81; 0.07; -0.09; 0; 250; 2100; 5}**

Conceptualisation

Explanation agents (greenhouse owners)

- Properties
  - Crop type (flowers or veggies)
  - Four different products (one of A, B, C and D)
  - Library with opinions of each product
- Actions
  - Calculate production
  - Revise opinions [actual production/ potential yield]
  - Share opinions
  - Buy technologies

Conceptualisation

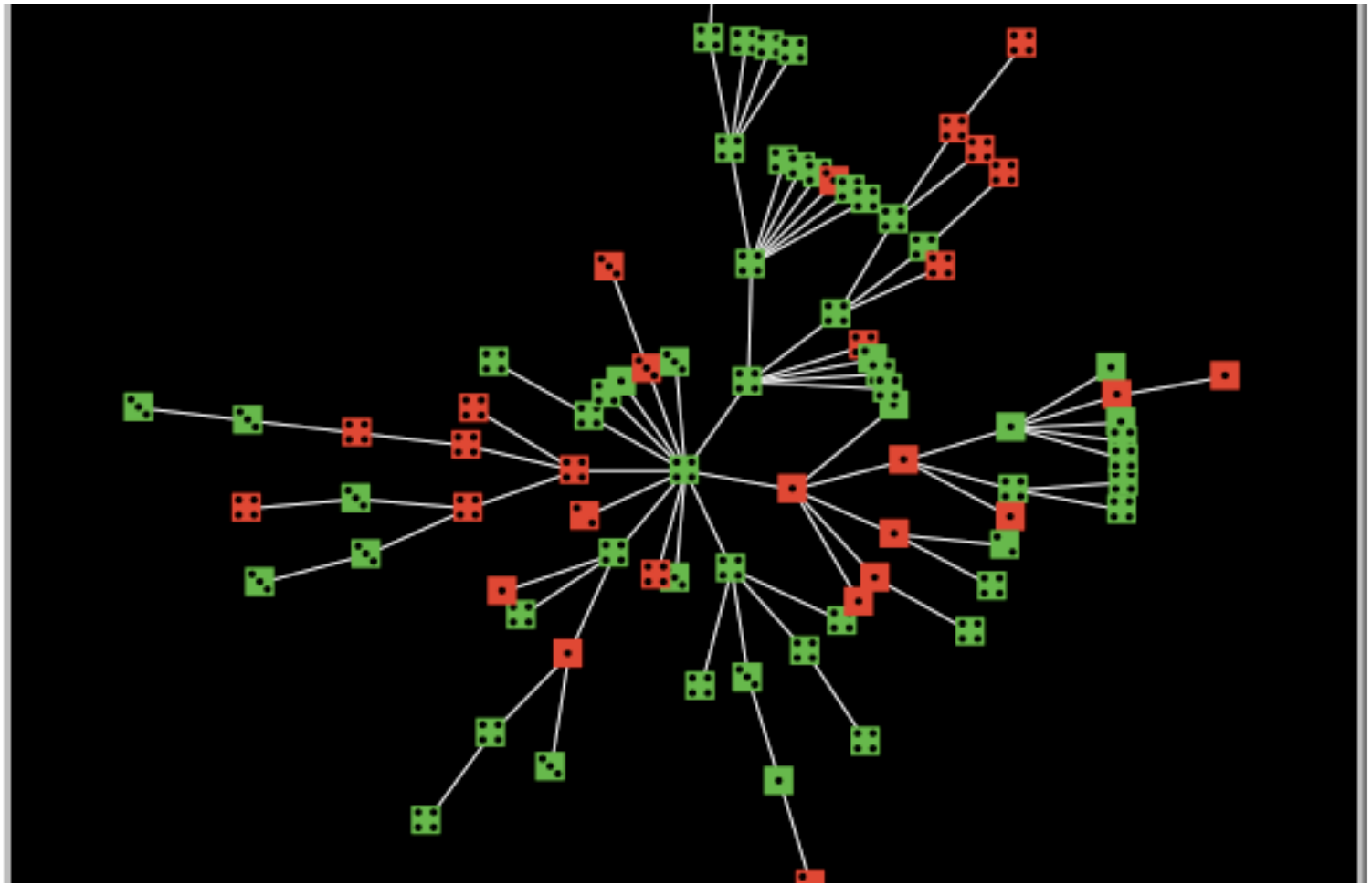
Explanation agents (greenhouse owners)

- Important design choice considering Share opinions: **StubbornnessFactor (adaption rate)**

- Example
  - Variables
    - Opinion Neighbour 0 TechA_1 = A
    - Opinion Neighbour 1 TechA_1 = B
    - StubbornnessFactor = X
  - Share information
    - Opinion Neighbour 0 becomes = (A + X * B) / (1+X)
    - Opinion Neighbour 1 becomes = (B + X * A) / (1+X)

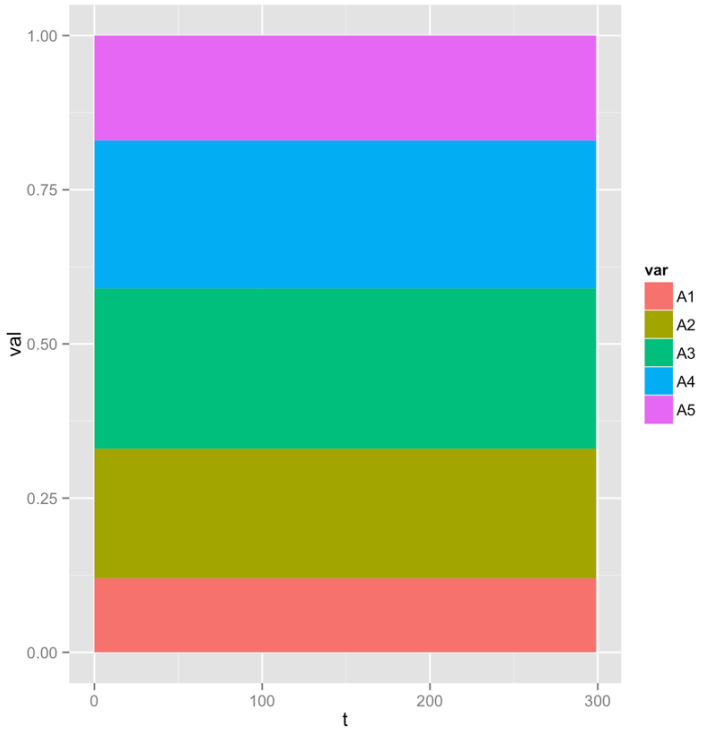
Software implementation

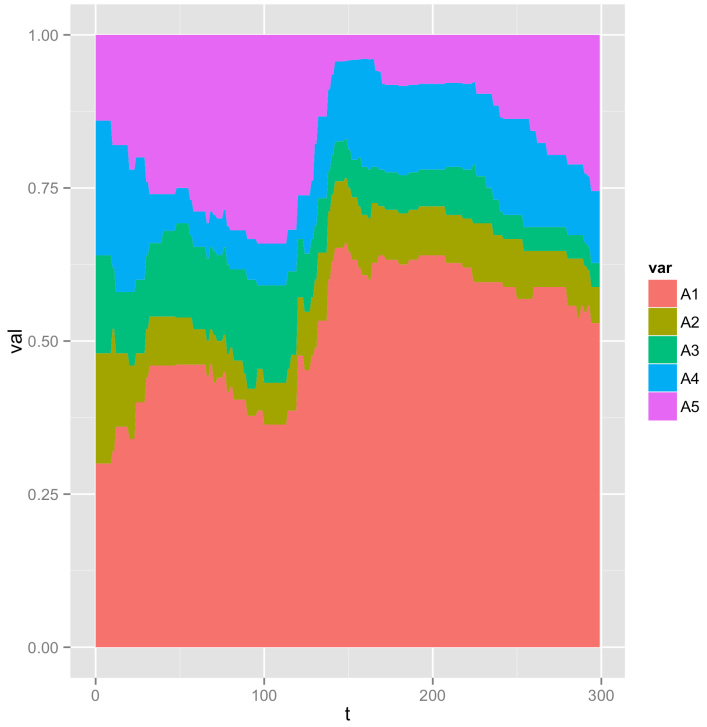
Multi-agent verification 1 → neighbours with same product



Software implementation

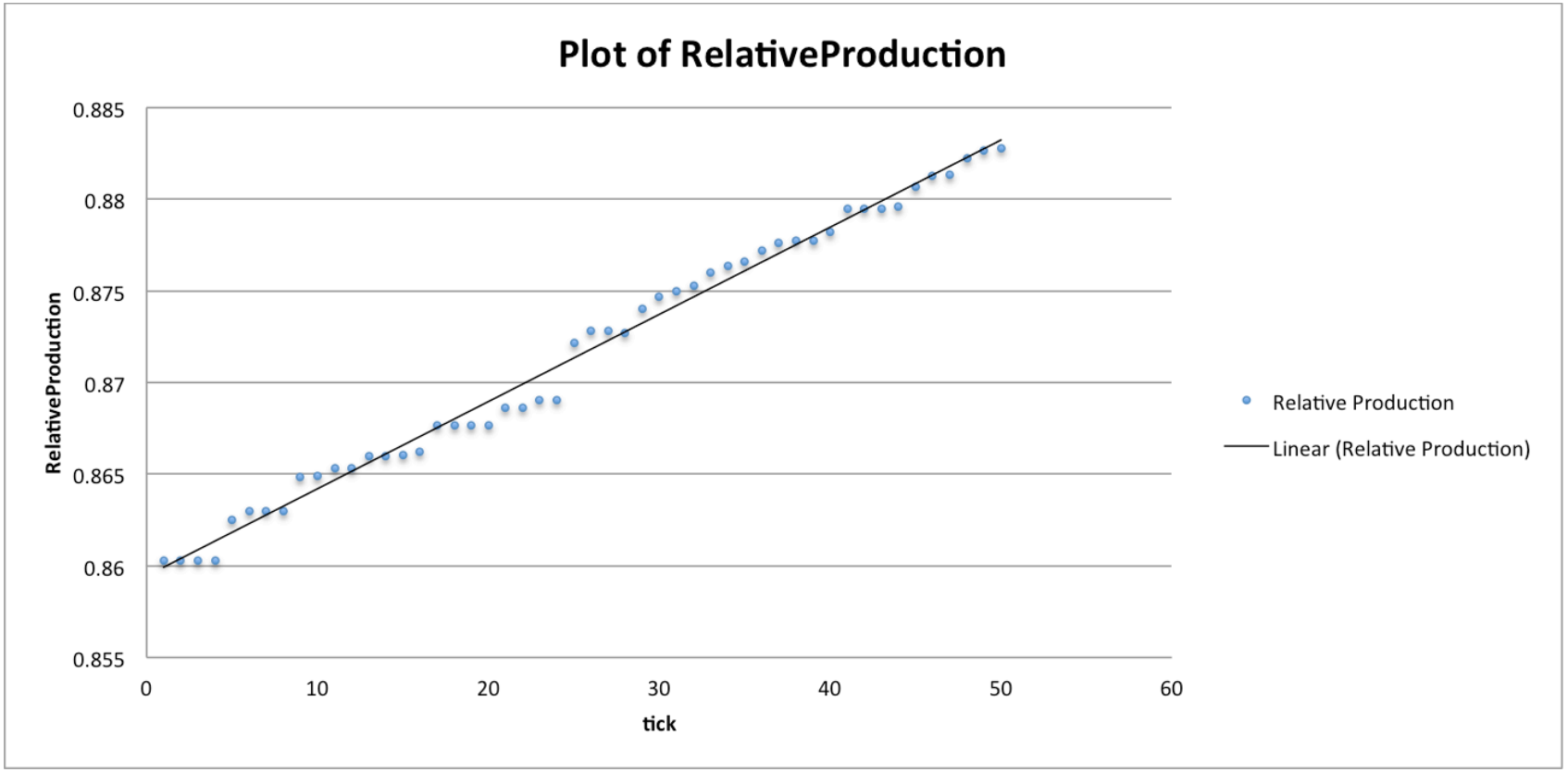
Minimal model interaction verification → Technology diffusion





Software implementation

Multi-agent verification 2 → increasing average production



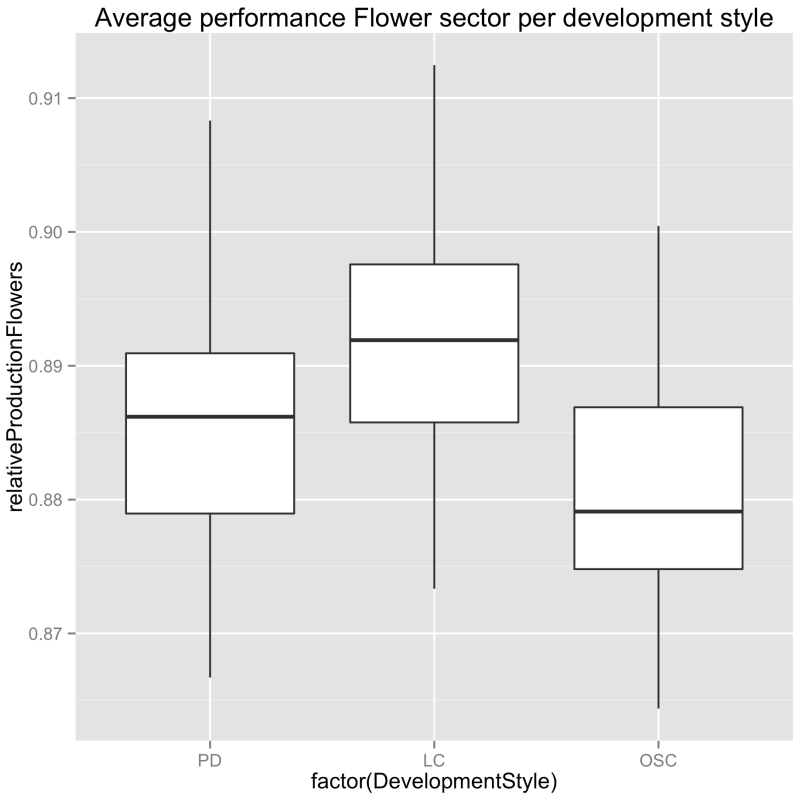
Model experimentation

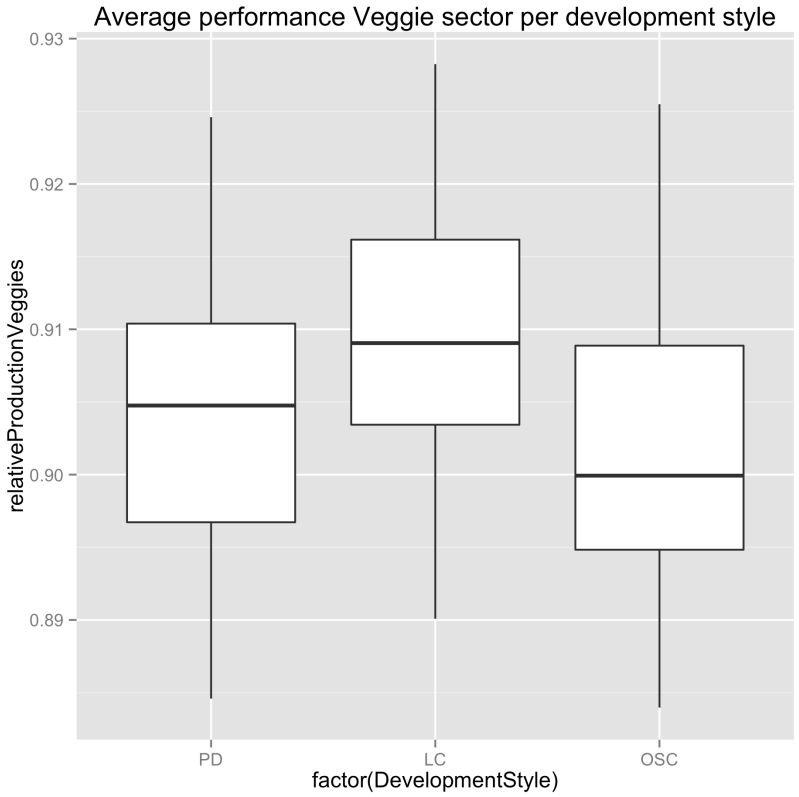
Experiment A – Answer on central question

- Which development style will lead to the highest overall performance of the greenhouse sector?
- Approach: Exploratory Modelling Analysis
- Key uncertain parameters:
  - Stubbornness factor, Improvement influence ranges, Fuel price
- Number of scenario's per development style: 144
- Output: average relative production for both flowers and veggies

Model experimentation

Experiment A – Answer on central question





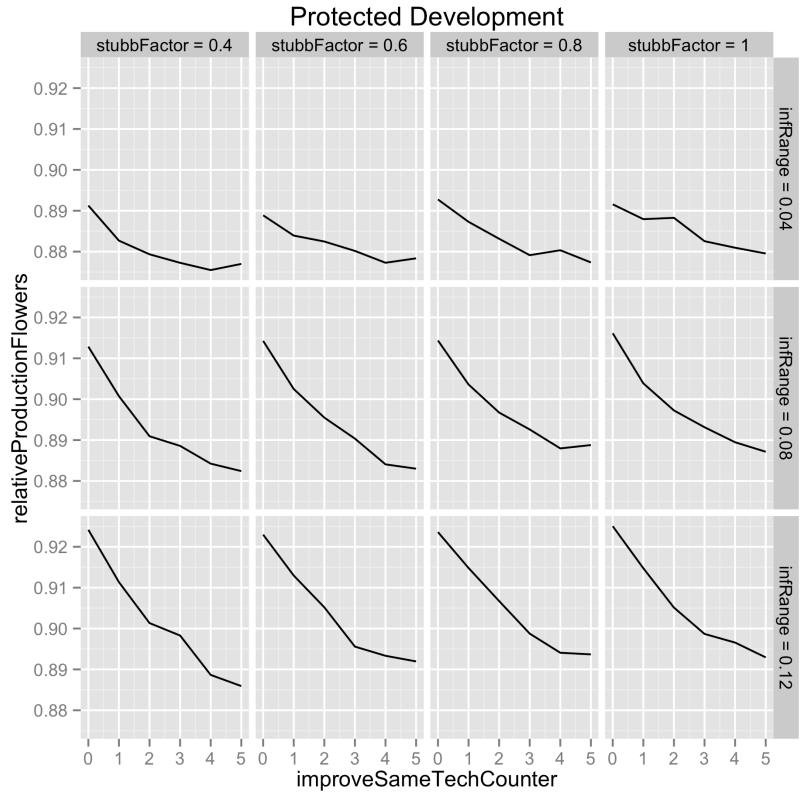
Model experimentation

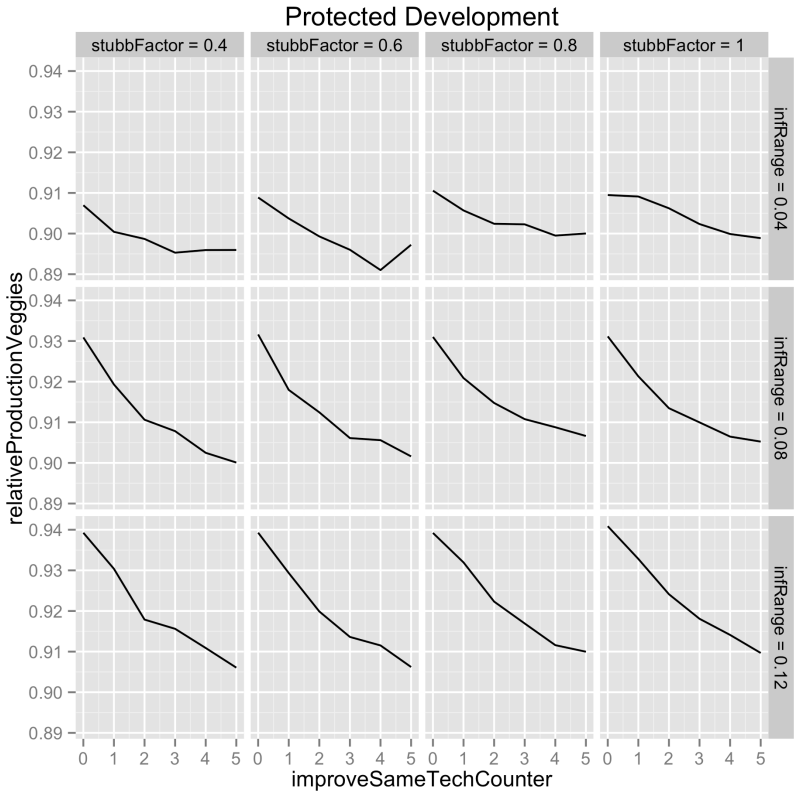
Experiment B – Diversification VS Specialisation

- Is it better for technology developers to focus on improving one product or to focus on improving all their products?
- Key uncertain parameters:
  - Stubbornness factor, Main improvement range
- Number of scenario's per development style: 72
- Output: average relative production for both flowers and veggies

Model experimentation

Experiment B – Diversification VS Specialisation





Conclusions & recommendations

- Experiment A
  - While improving technologies, paying attention on secondary functions matter!
  - Technologies developers should take those influences into account
- Experiment B
  - Specialisation will lead to a higher overall performance of the greenhouse sector
  - Technology developers should pay attention to all their products instead of just one

Questions

Appendix

Sum of the parts != whole

	External climate	Climate tomatoes	
Temperature	18	26	
Humidity	0,74	0,75	
Light intensity	1000	1400	
CO2	400	1500	
Potential yield		500	
	Package 1	Package 2	
Temperature	0,930	0,900	
Humidity	0,730	0,400	
Light intensity	0,900	0,860	
CO2	0,100	0,500	
Total	2,660	2,660	
Average influence	0,822	0,889	
Actual yield	411	444	

Appendix

Formula to calculate production

$$Actual\ production = Potential\ yield * Average \sum 1 - \frac{(Zex - Zideal)}{Zideal} - Zinfl * (\frac{(Zex - Zideal)}{Zideal})$$