CT561: Systems Modelling and Simulation

Week 5:
Causal Links and Feedback

https://github.com/JimDuggan/CT561

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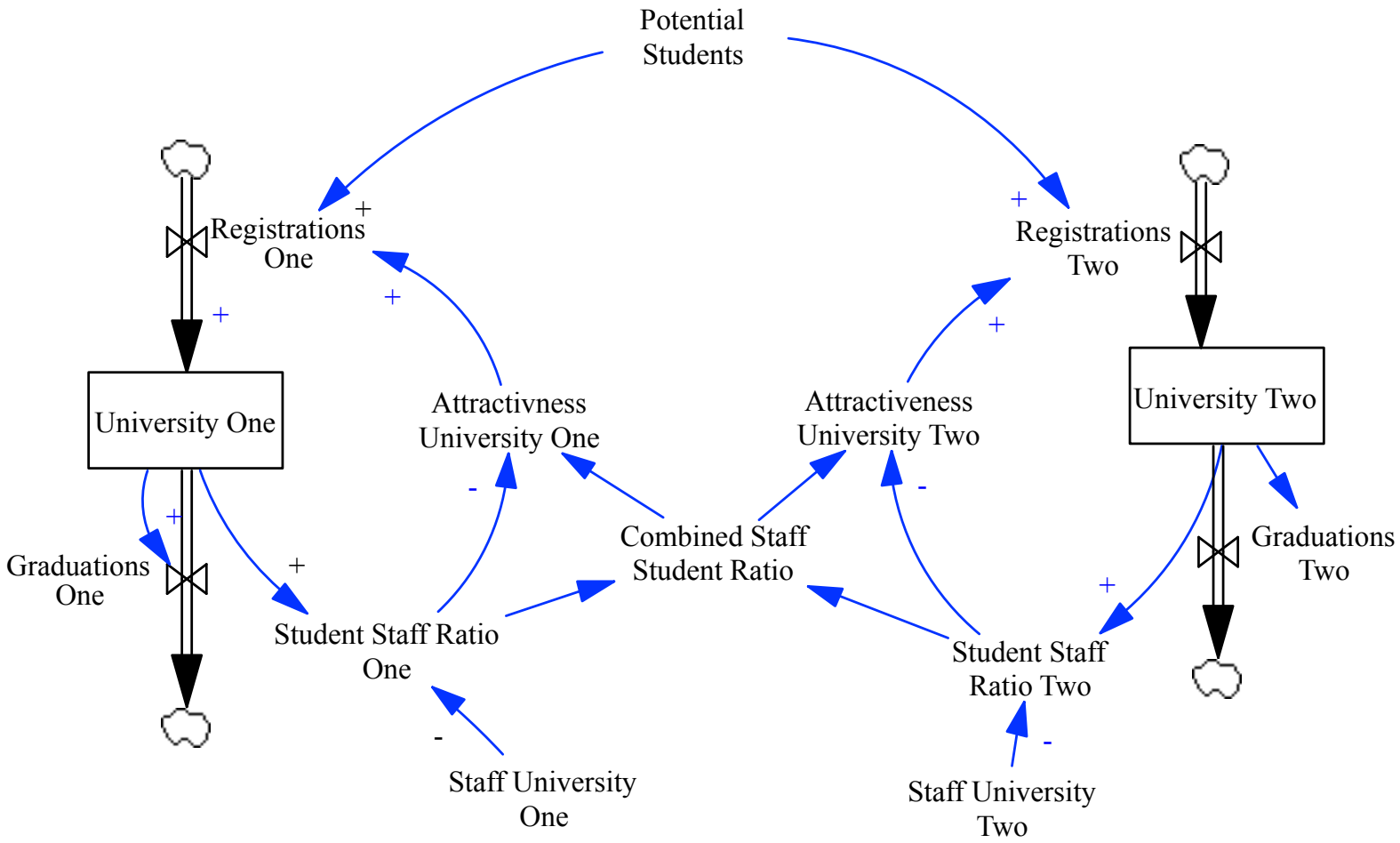
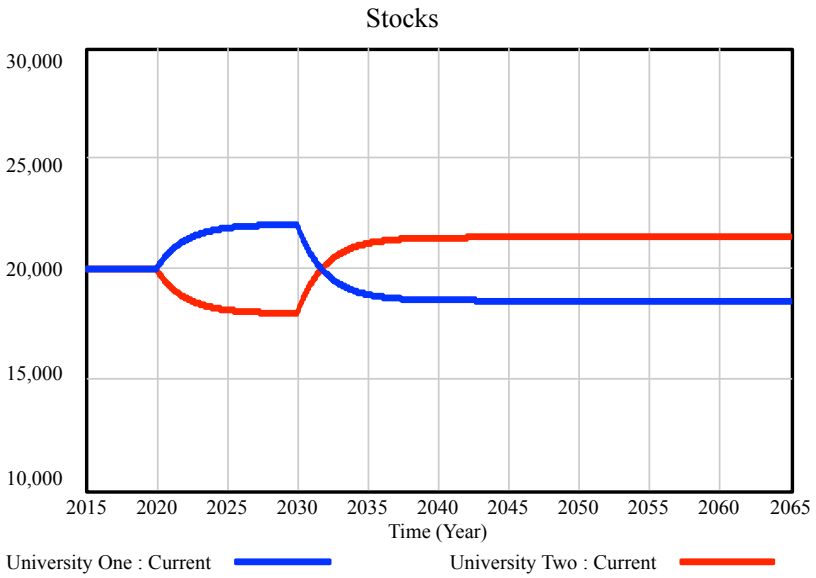
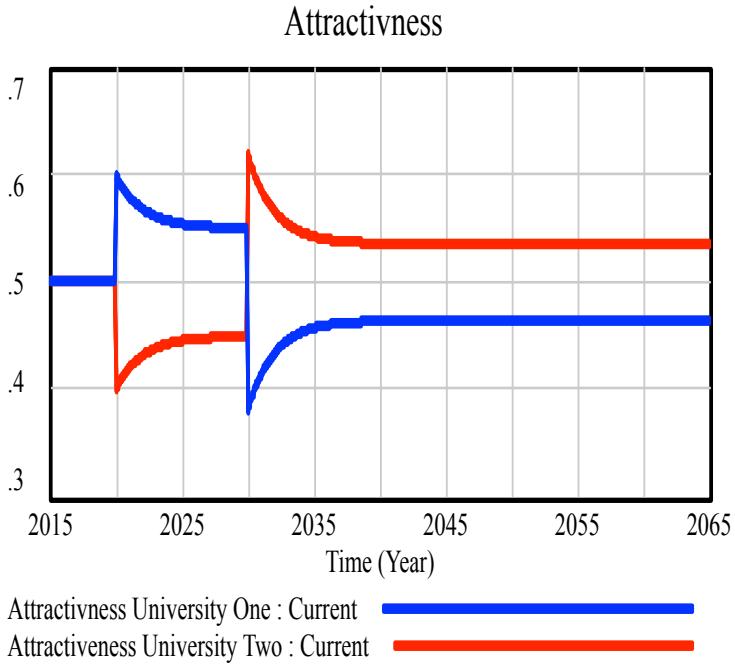
University Competition Model



Simulation Output:
Impact of changing resources



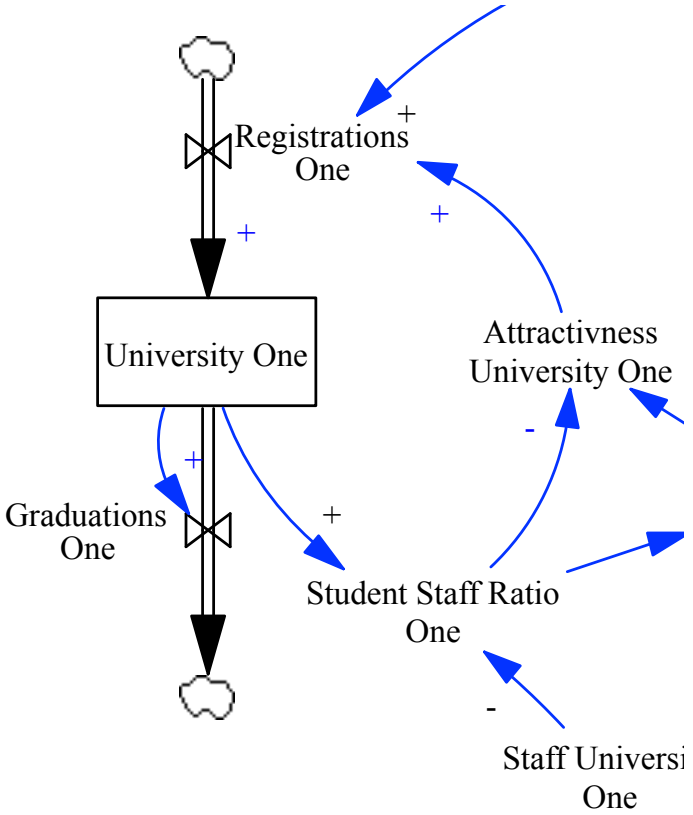


Staff University One = 2000+step(1000,2020)

Staff University Two = 2000+step(2000,2030)

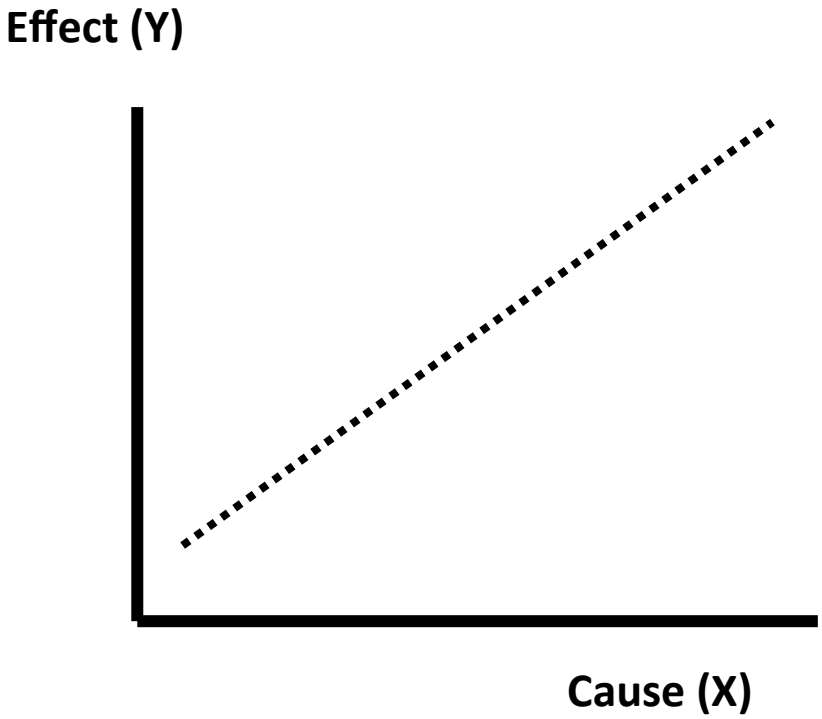
Further Model Analysis

- Cause an effect between variables
  - Link Polarity
- Sets of variable that form a loop
  - Feedback loop
- Insights from feedback loops
  - Positive feedback
  - Negative feedback



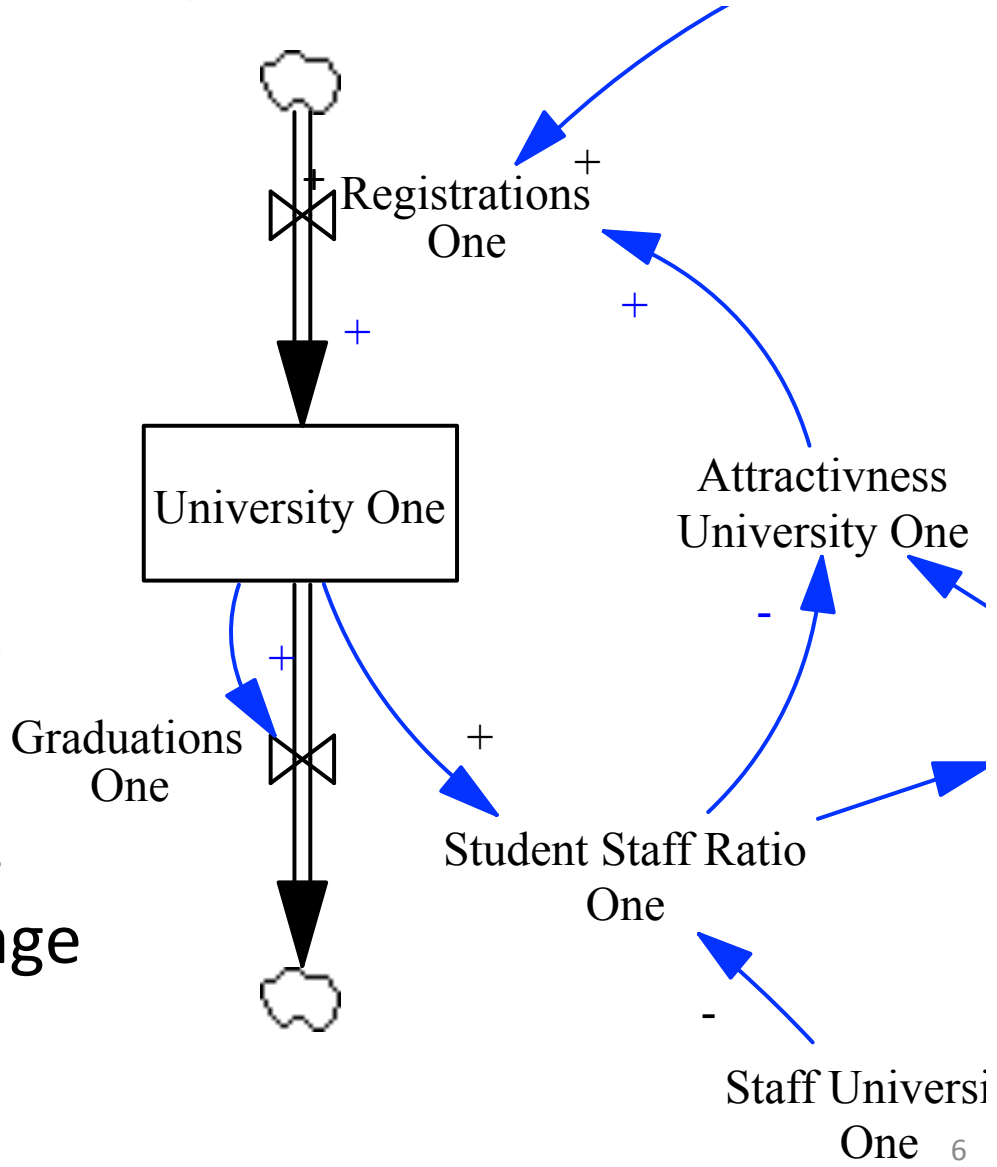
Link polarity – Positive Link

- A positive link means that if the cause **increases**, the effect **increases** *above what it otherwise would have been,* and if the cause **decreases**, the effect **decreases** below what it would otherwise have been.



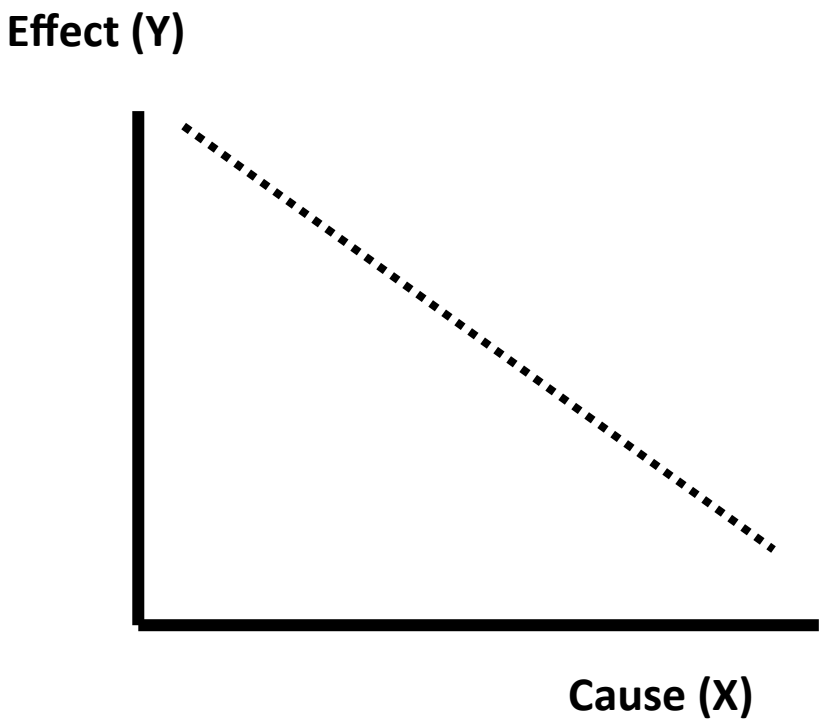
A positive link…

- As **Attractiveness of University One** increases…
- So to does **Registrations One**
- *The variables move in the same direction*
- The shape/function is not needed at this stage of analysis



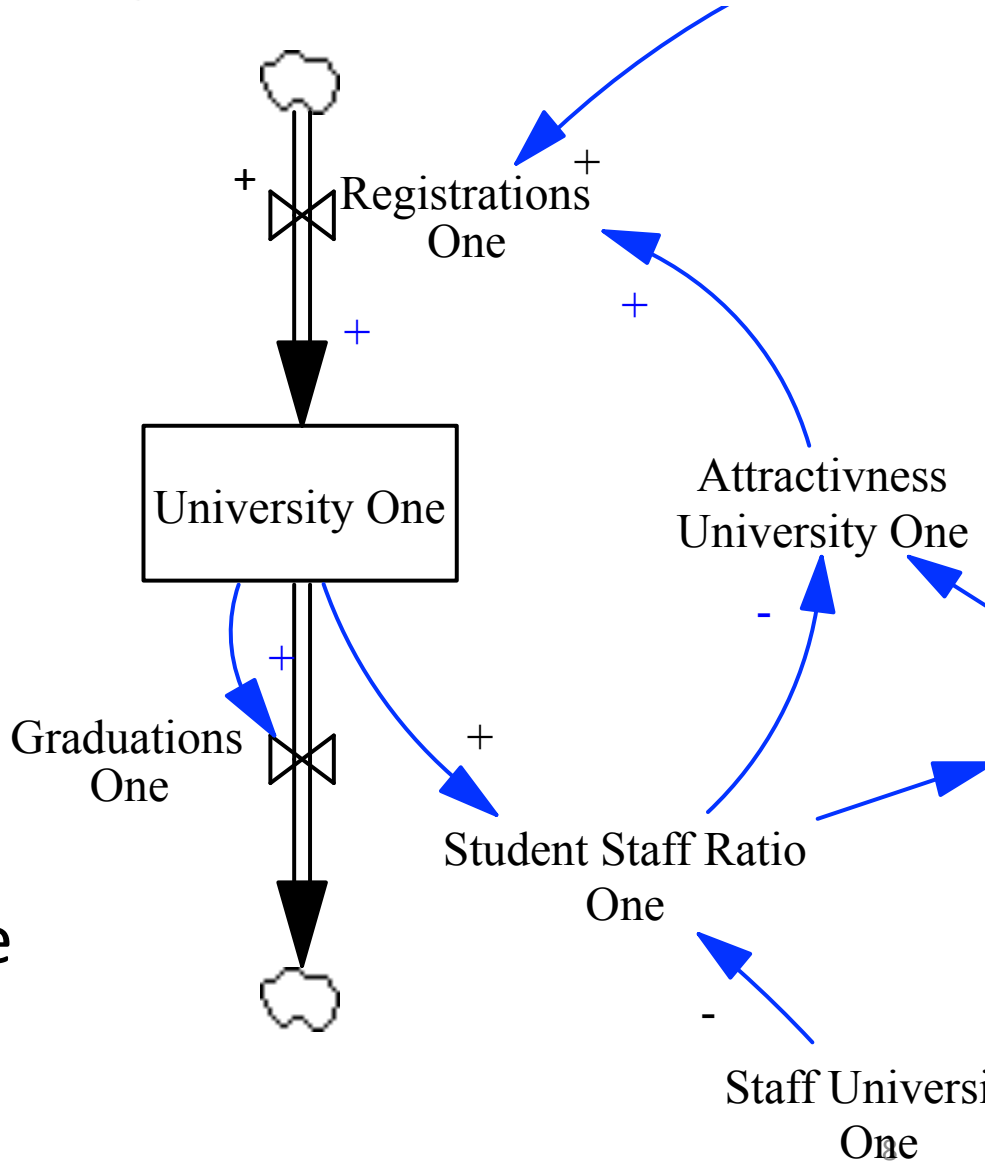
Link polarity – Negative Link

- A negative link means that if the cause **increases**, the effect **decreases** *below what it would otherwise have been*, and if the cause **decreases**, the effect **increases** *above what it might otherwise have been*.



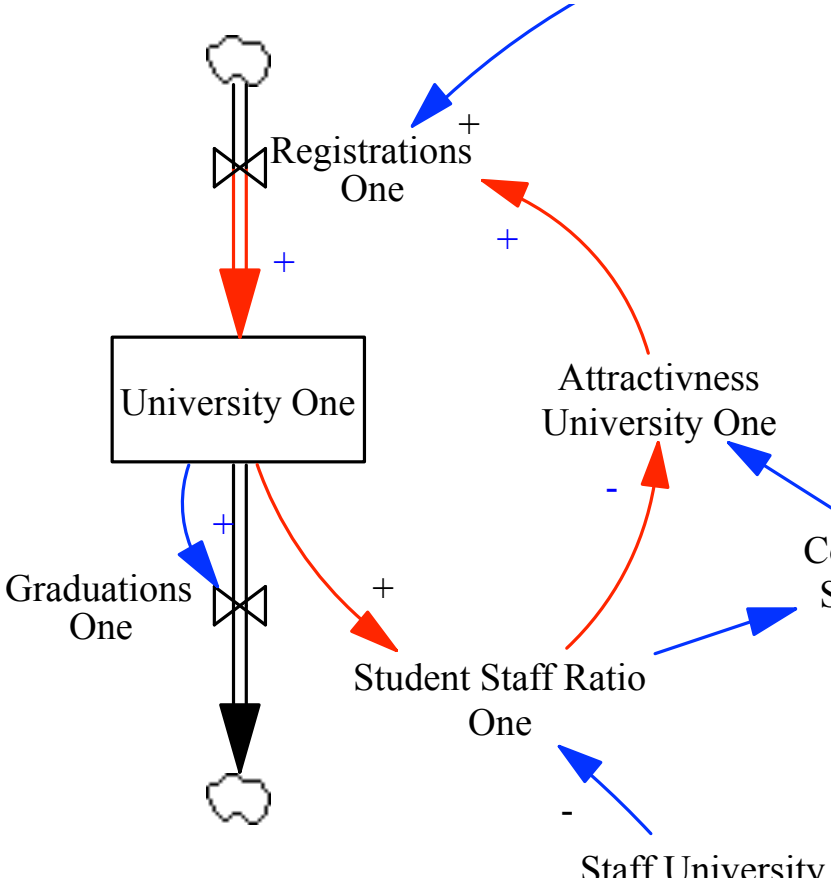
A negative link…

- As **Student Staff Ratio One** increases…
- **Attractiveness University One** decreases.
- *The variables move in the opposite direction*
- The shape/function is not needed at this stage of analysis



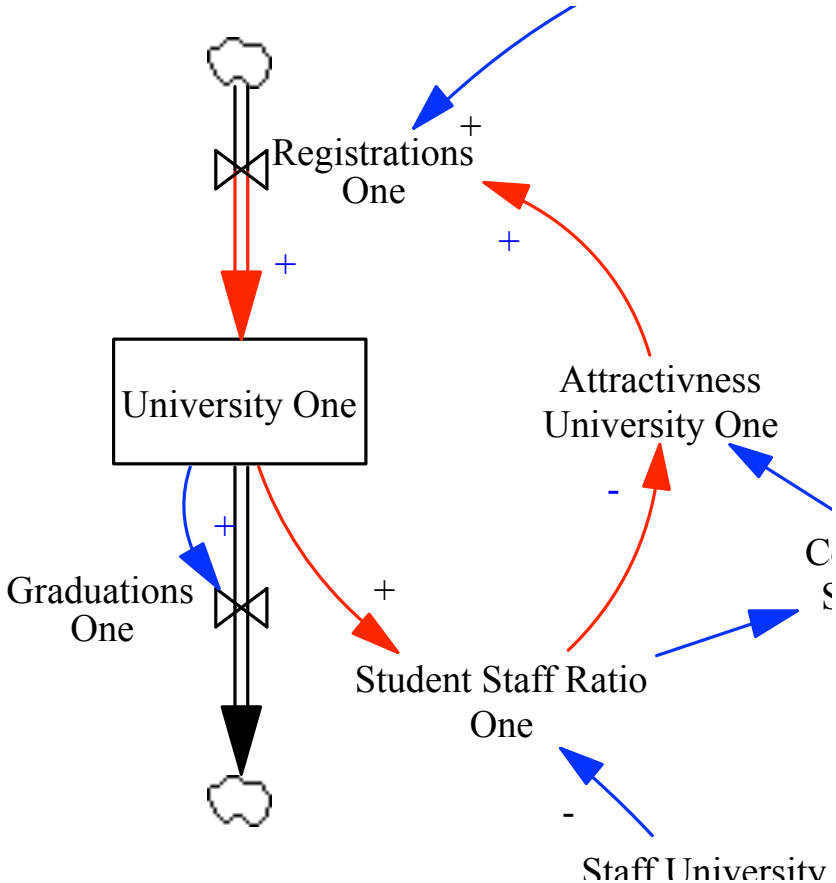
What if the links form a loop?

"A feedback loop is a **closed chain of causal connections** from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow to change the stock."



Determining Loop Polarity (1)

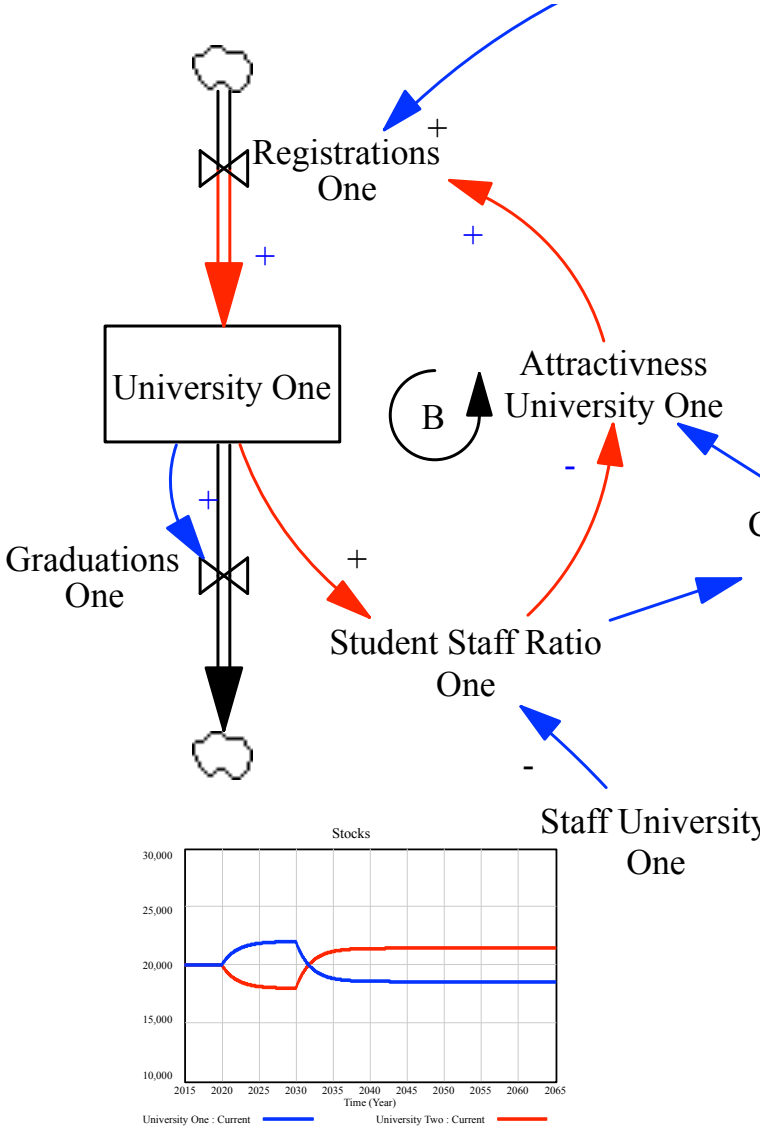
Cause	Dir	Effect	Dir
Registrations One	↑	University One	↑
University One	↑	Staff Student Ratio	↑
Staff Student Ratio	↑	Attractiveness University One	↓
Attractiveness University One	↓	Registrations One	↓



Determining Loop Polarity (1)

Cause	Dir	Effect	Dir
Registrations One	⇧	University One	⇧
University One	⇧	Staff Student Ratio	⇧
Staff Student Ratio	⇧	Attractiveness University One	⇩
Attractiveness University One	⇩	Registrations One	⇩

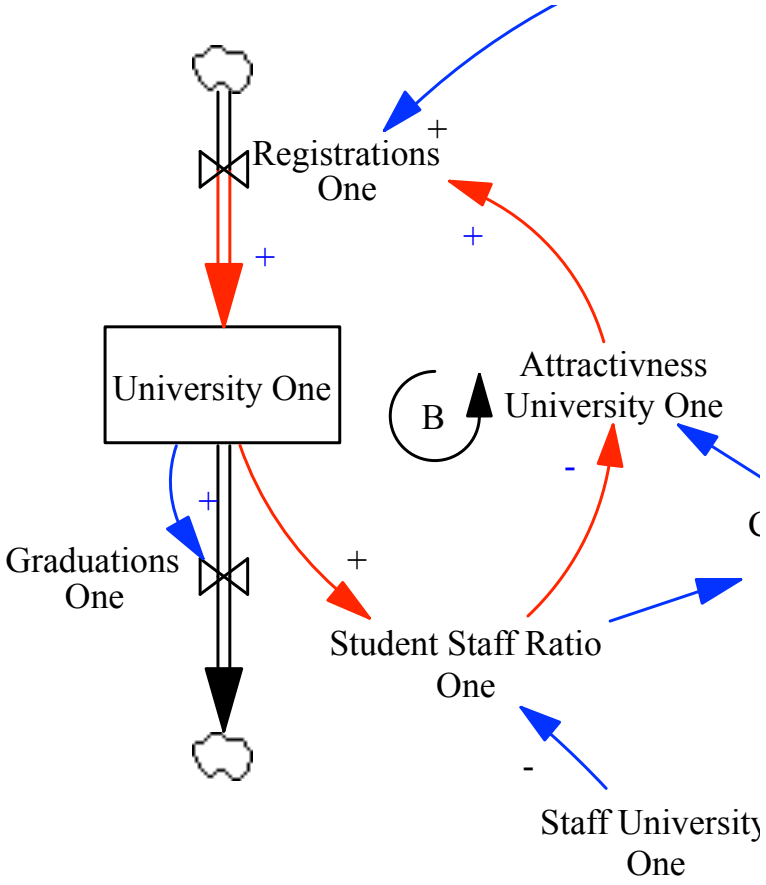
"A balancing feedback loop opposes whatever direction of change is imposed on the system." Meadows (2008)



Balancing Loop

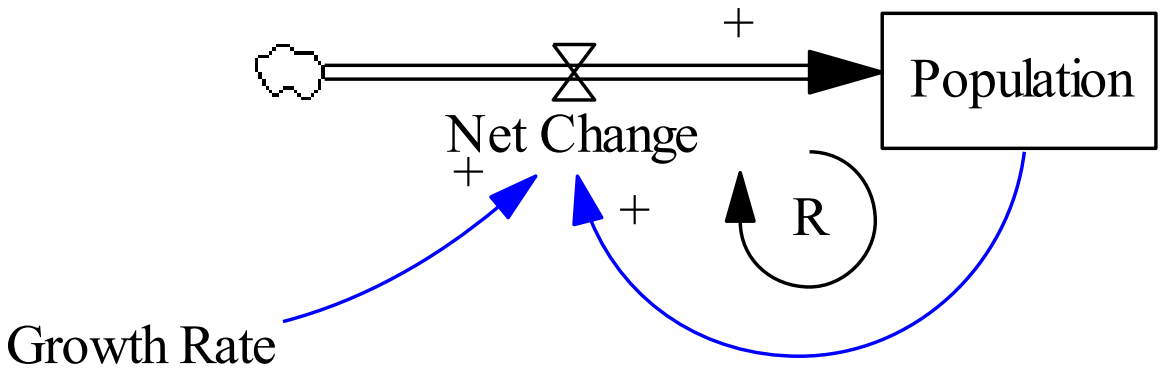
Balancing feedback loops are **equilibrating** or **goal-seeking** structures in systems and are both

- sources of **stability** and
- sources of **resistance to change**.



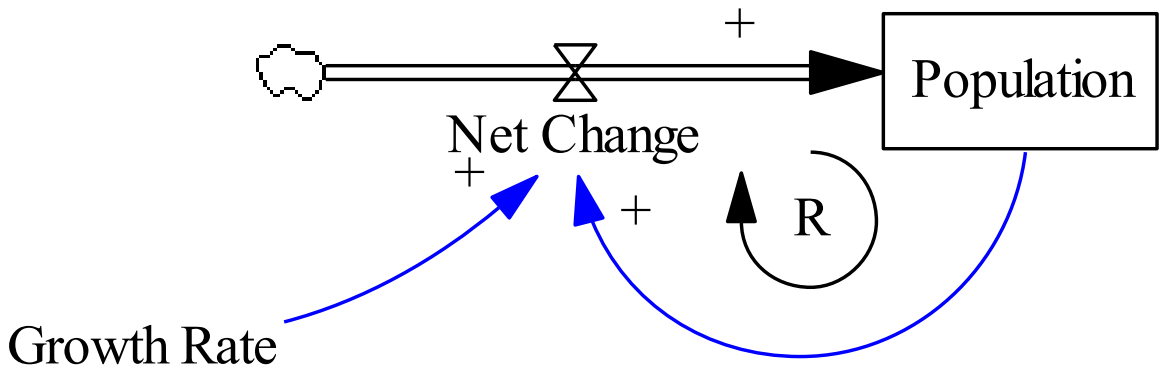
Determining Loop Polarity (2)

Cause	Dir	Effect	Dir
Population	⇧	Net Change	⇧
Net Change	⇧	Population	⇧



Determining Loop Polarity (2)

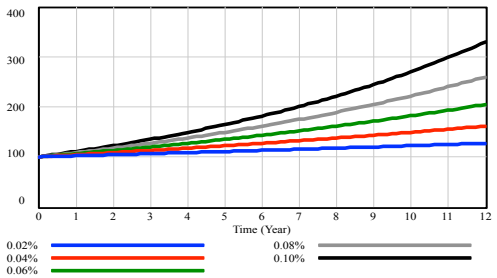
Cause	Dir	Effect	Dir
Population	⇧	Net Change	⇧
Net Change	⇧	Population	⇧

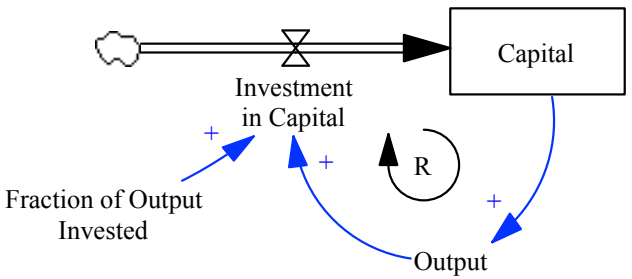


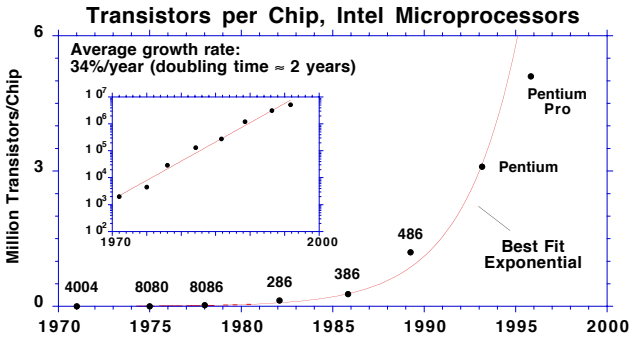
"The second kind of feedback loop is amplifying, reinforcing, self-multiplying, snowballing—a vicious or virtuous circle that can cause healthy growth or runaway destruction." Meadows (2008)

Reinforcing Loops

- **"Reinforcing feedback loops are self-enhancing, leading to exponential growth or to runaway collapses over time.**
- They are found whenever a stock has the capacity to reinforce or reproduce itself."







Positive Feedback (Sterman 2000)

Bill Gates quotes…

- "The biggest advantage we have is that good developers like to work with good developers." [Success to the successful].
- "The growth [Windows NT] continues to amaze us and it's a positive feedback loop. As we got more applications, NT Servers get more popular. As it's gotten more popular, we've got more applications." [Complementary goods Effects]

Calculating Polarity?

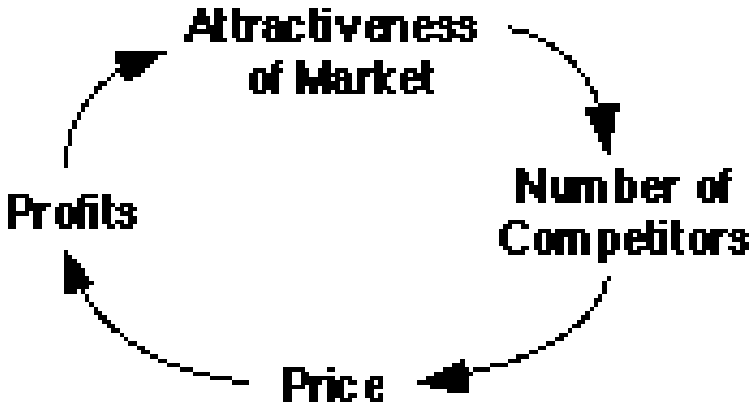
The Fast Way

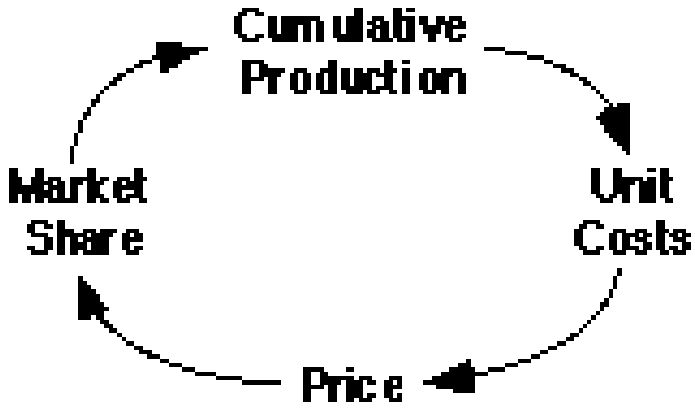
- Count the number of negative links in the loop
- If this number is even (including zero)
  - Positive Feedback
- If this number is odd
  - Negative Feedback

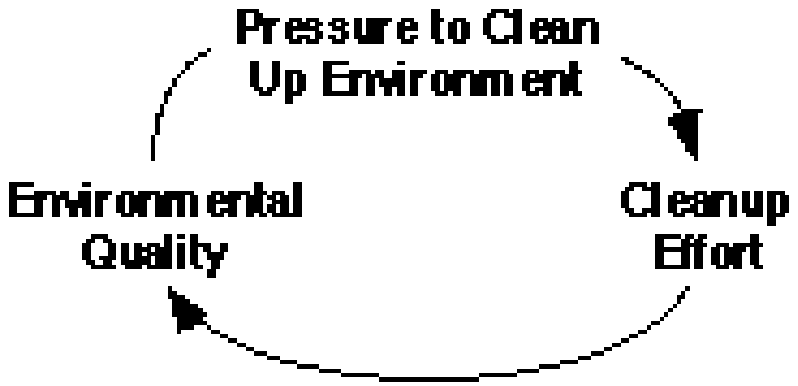
The Right Way

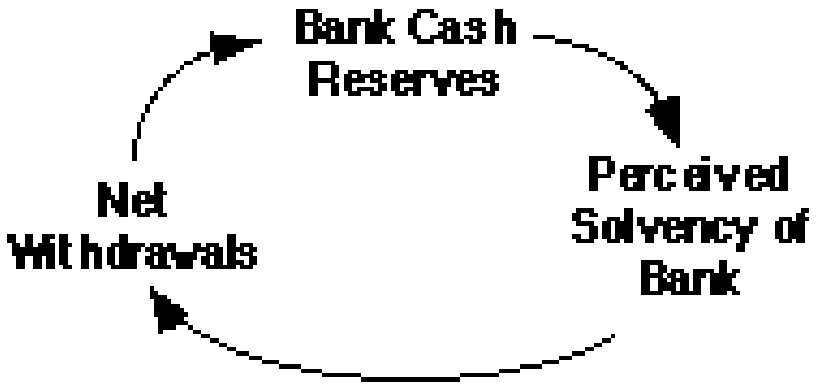
- Trace the effect of a small change in one of the variables as it propagates around the loop
- If the loop reinforces the original change, it's a positive loop
- If it opposes the original change, it's a negative loop

Challenge 5.1:
Calculate Link and Loop Polarity







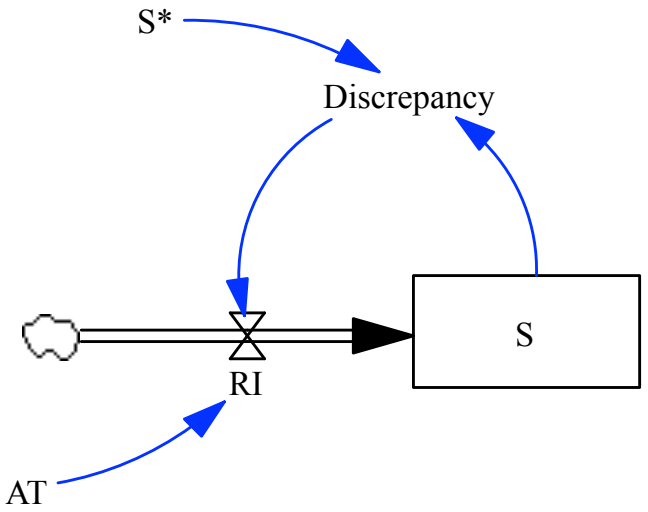


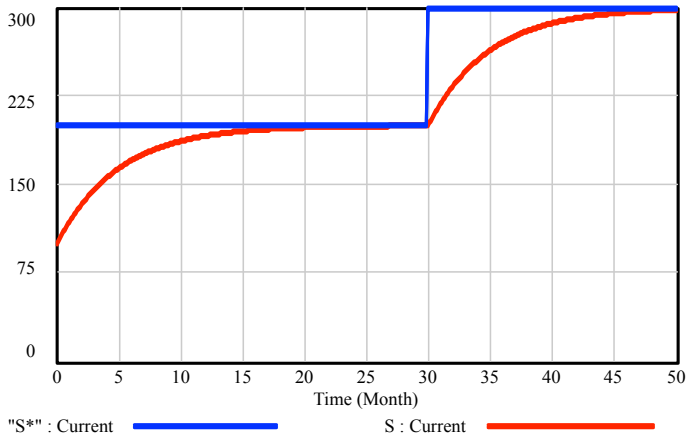
Adjustment to a Goal (Sterman 2000)

- Managers often seek to adjust the state of the system until it equals a goal or a desired state
- The simplest form is:

  RI = Discrepancy/AT

  = (S^*-S)/AT
- Where:
  - Discrepancy is the gap between the desired state S^* and the actual state S.
  - AT is the average time required to close the gap.





Challenge 5.2

- Modify the original model so that staff are now stocks
- These stocks are controlled using a goal adjustment process
- The goal is a staff student ratio of 10
- From that, the desired staff can be calculated
- Identify any new feedback loops
- Run the model so that potential students ramp up by 7500 a year from 2020.
- Set one University's adjustment time to 1, the others to Infinity.
- What results might you expect?