

# CT561: Systems Modelling & Simulation

## Lecture 3: Exploring Feedback

Dr. Jim Duggan,  
School of Engineering & Informatics  
National University of Ireland Galway.

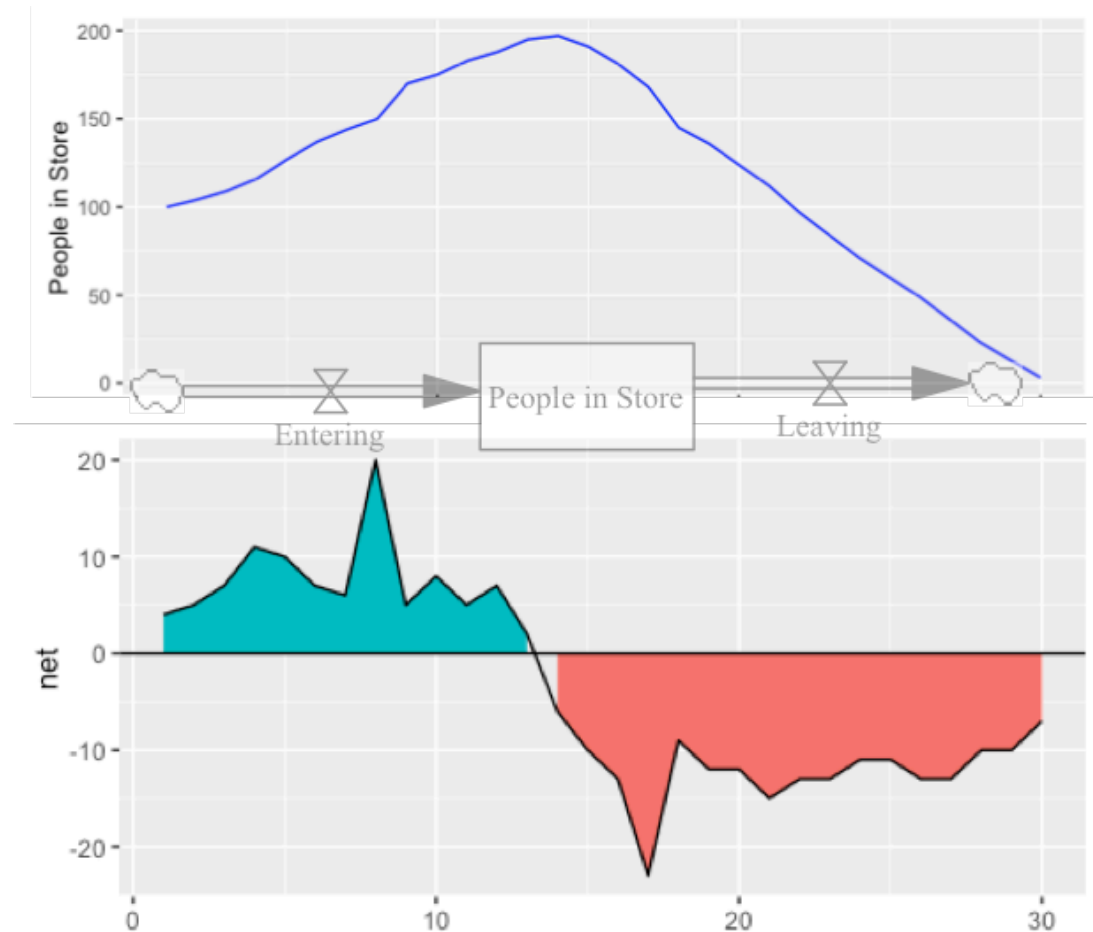
<https://github.com/JimDuggan/SDMR>

[https://twitter.com/\\_jimduggan](https://twitter.com/_jimduggan)



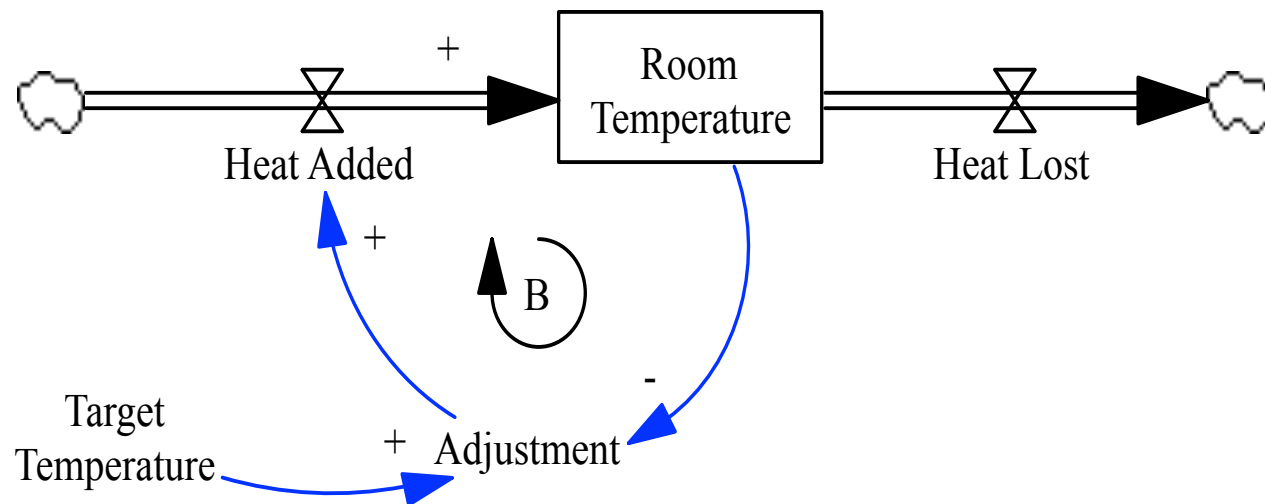
# Summary to date...

- Stocks:
  - Accumulations
- Flows:
  - Change the stocks
- Equations
  - Integrals for stocks
  - Flows (to date)
    - Constant
    - Time based
    - Fractional increase/decrease



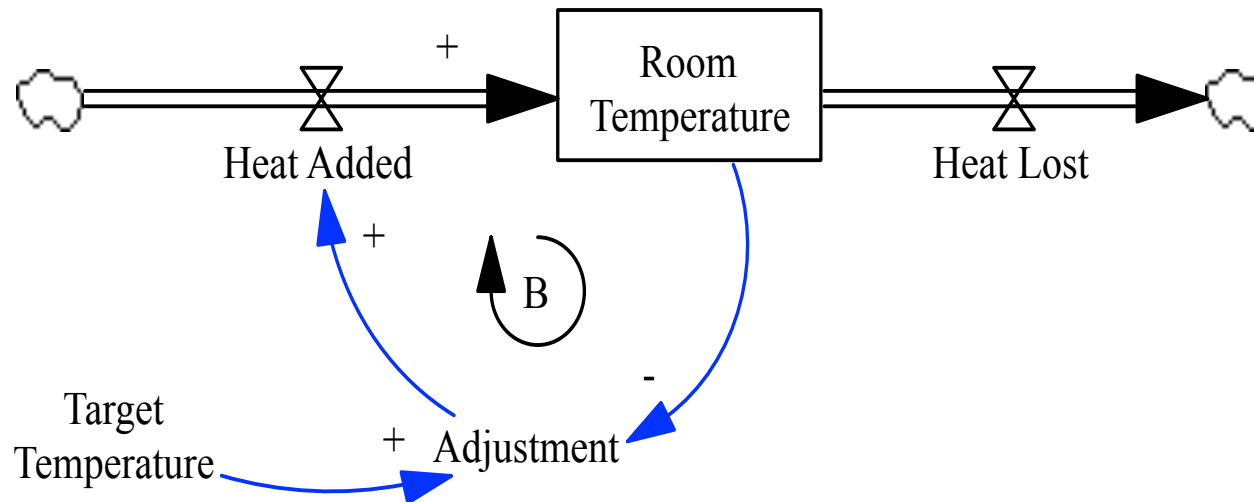
# Feedback

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.



# *A goal seeking system...*

The level of a stock (heat in the room) determines the amount of heat added (the flow) which in turn changes the heat in the room (the stock).



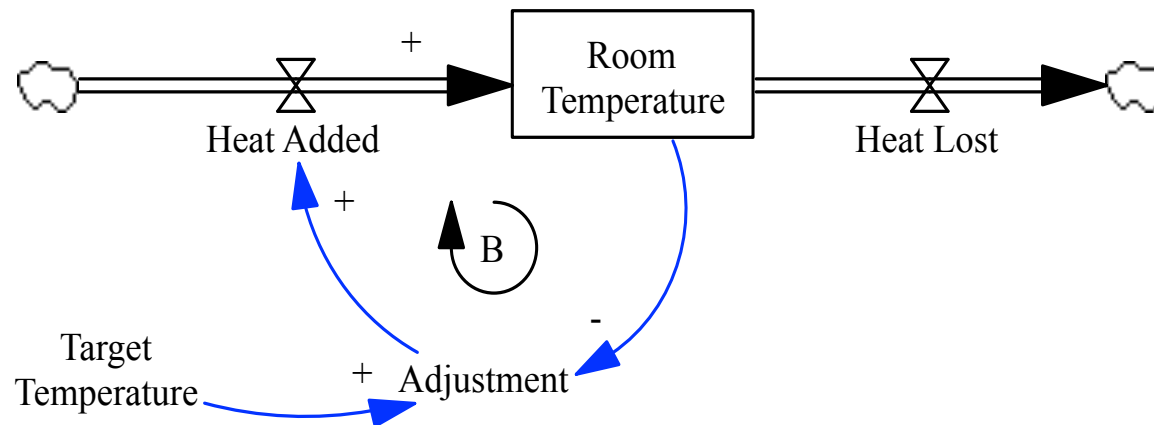
# Challenge 3.1

Create a one-stock feedback model for Inventory in a warehouse.



# Loop Polarity

*The loop is broken down into a set of the causal links, and the impact of a change in one variable is traced through the causal chain, and back to the original variable.*



<b>Room Temperature</b>	↓	Adjustment	↑
Adjustment	↑	Heat Added	↑
Heat Added	↑	<b>Room Temperature</b>	↑

# 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

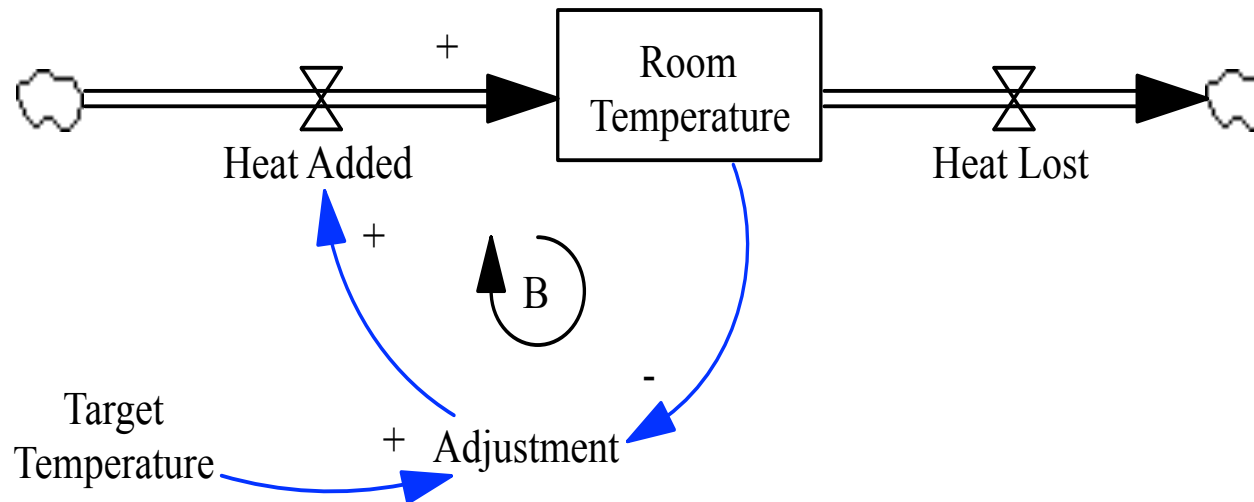
- Trace the effect of a small change in one of the variables as it propagates around the loop
- If the loop reinforces the original change, it's a positive loop
- If it opposes the original change, it's a negative loop



# Balancing Loop

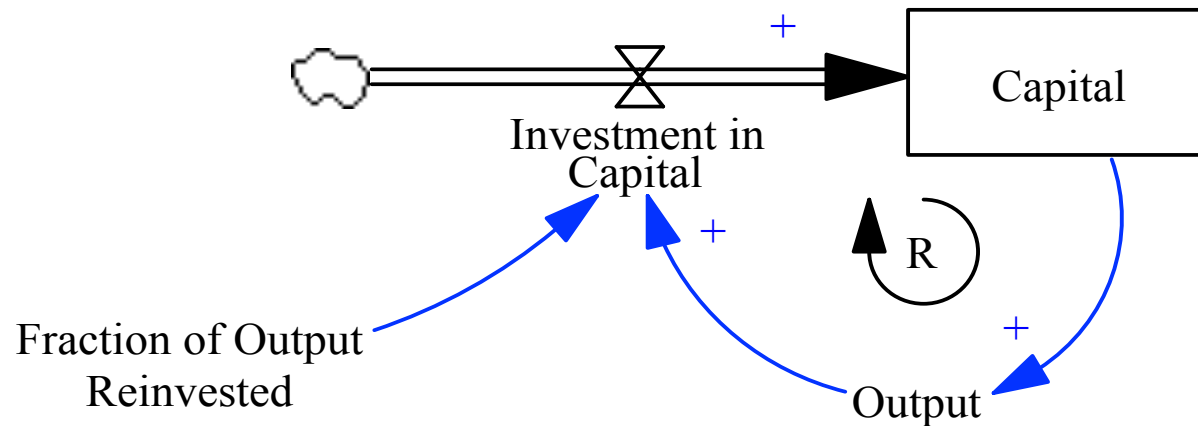
Balancing feedback loops are goal-seeking structures in systems and are:

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





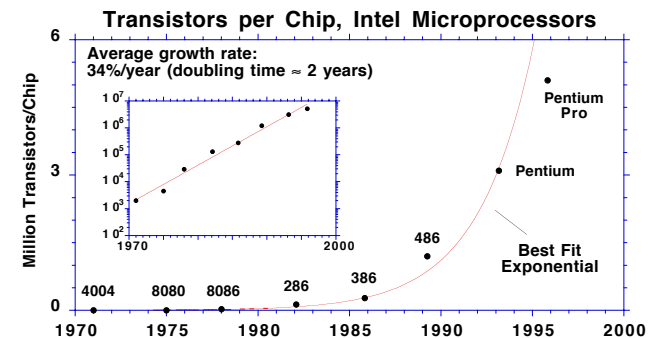
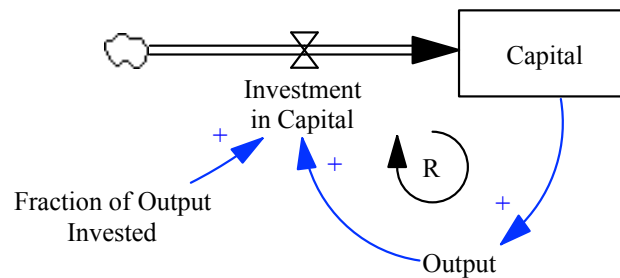
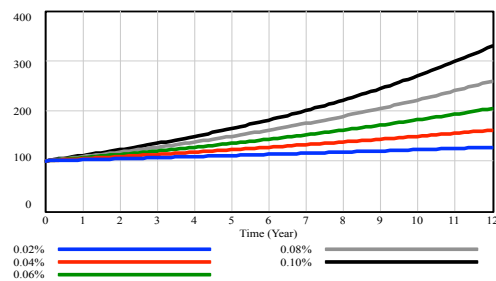
# Another type of feedback...



<b>Capital</b>	↑	Output	↑
Output	↑	Investment in Capital	↑
Investment in Capital	↑	<b>Capital</b>	↑

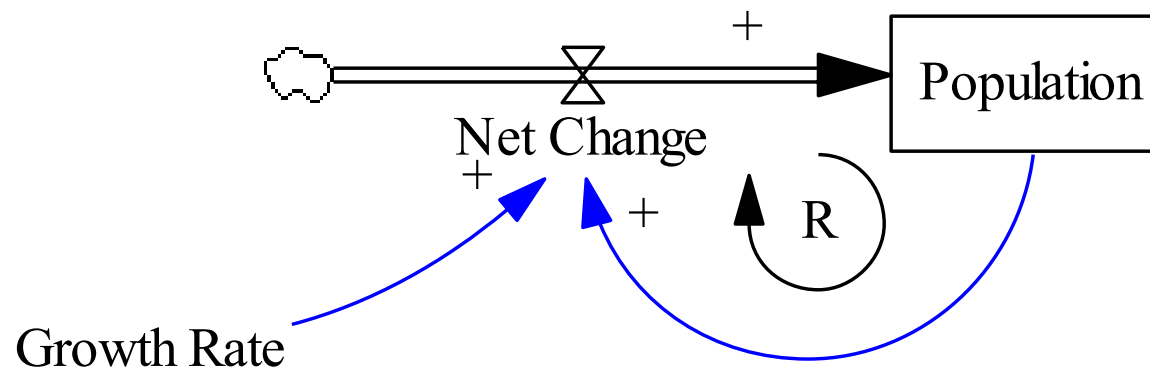
# Reinforcing Loops

- “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.”



# Population Growth Example

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)

# Positive Feedback (Sterman 2000)

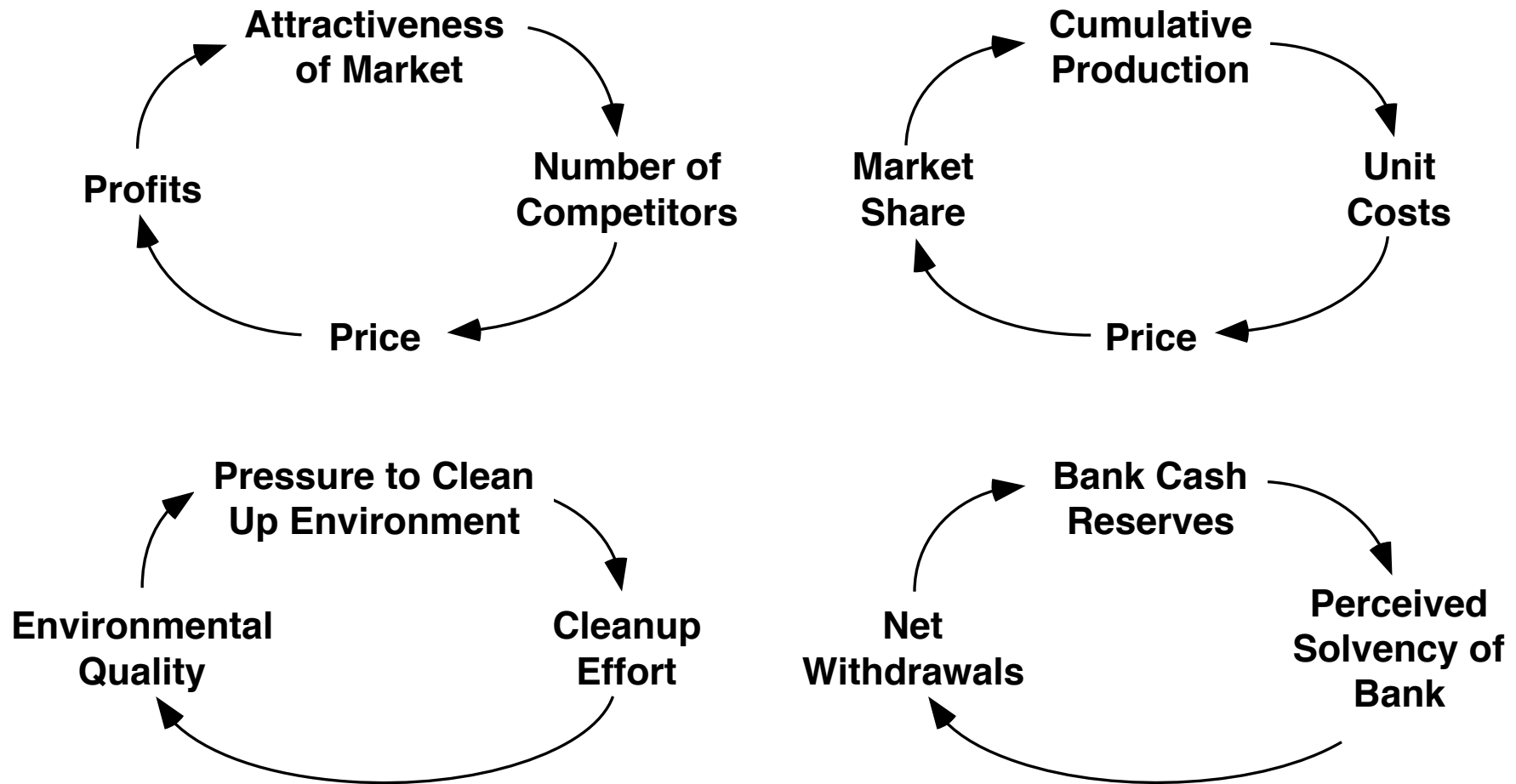
*Bill Gates quotes...*

- “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]



# Challenge 3.2

## *Calculate Link and Loop Polarity*



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# Feedback Summary

- A complex system is an interlocking structure of feedback loops, and this loop structure is found many real-world processes (Forrester 1969).
  - A feedback loop is a closed chain of causal links from a stock, through a flow, and back to the original stock again.
  - There are two classes of feedback loops. **Negative feedback** counteracts the direction of change, whereas **positive feedback** amplifies change and drives exponential growth.
  - Loop polarity is calculated by examining the individual link polarities in a circular causal chain. If there are an odd number of negative links, the loop polarity is negative, otherwise the loop polarity is positive.



# Challenge 3.3

- Build a stock and flow model of University Competition
- For each University, include:
  - Stocks for Staff and Students
  - Student staff ratios
  - Attractiveness
- Identify feedback loops and speculate on how the system might behave over time

