Market Networks under ZI Traders

Shabnam Mousavi
Max Planck Institute

Shyam Sunder
Yale School of Management

Second ZIMI Conference, 21-23 October 2021

Outline

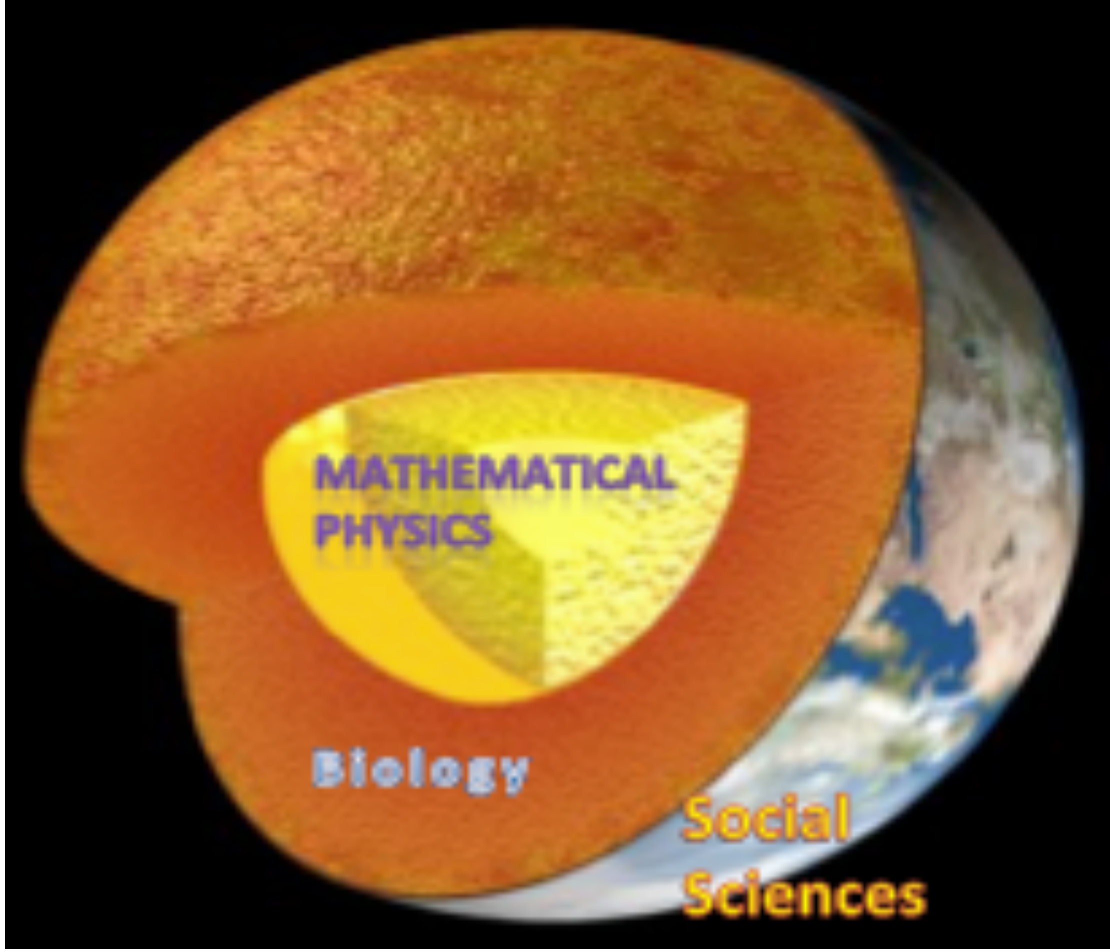
- TTT/3T:
  - Framing observed phenomenon first in physics sans reductionism
- ***Exercise 1:***
  - Principle of least action as a frame for individual behavior
- ***Exercise 2:***
  - Kirchhoff's circuit laws as a frame for network of markets with ZI traders
- *Goal = theory building*

Big Picture: A Schematic of Scientific Inquiry

Domain	Animate	Animate-Inanimate	Inanimate
Discipline	Social Sciences	Biology/Molecular Chem.	Physics/Chemistry
Subject matter	Person/group/institution	Cells/Organism/group	Matter and energy
Principles, concepts and terms	Theories of mind Perception & cognition Nature vs. nurture Demand & supply Behavior, labor, capital, trade, contract, judgment, personality, development State and society…	Evolution by natural selection (Matching) Longevity vs. reproduction Function of organs Anatomy and physiology DNA, RNA, cells, protein, life…	Least action Force fields Chemical binding Inertia & Symmetry Relativity Effort, flow, motion, time …
Shared features	Physical existence in all domains is subject to physical laws. Properties (e.g., efficiency) are assessed conditionally.		

(dis)organized

- As-if v As[it]is
- Intelligence v Structure
- Many millions v Abstracting off
- Trade-off v Less-is-more
- Humans v Bots



- *Physics, biology, psychology, … **as frames**:* *BUILD METHOD*

*Solvability,
decidability,
incompleteness,
algorithms, …*

METHOD: For a phenomenon of interest,

Step1- Choose a physics law to frame the phenomenon

Step2- Develop format for applying law phenomenon

Step 3- Construct operational definitions

IF worked, then compare to extant methods

ELSE, find another law;

RETURN to Step2

DEFINITION:

An ***action is a movement*** *from state A to state B, where A and B are(/not) specified by the actor. A pair of beginning-end states (A, B) constitutes a situation.*

- Think of a **subject matter** in your discipline:
  - Economist--- decision to buy a smart phone
  - Psychologist--- emotions and bonds between friends
  - Biologist--- reproduction or mating
  - Philosopher--- liberty or free will
  - Physicist--- *any* topic in physics

Exercise 1: use principle of least action (explore the scope of framing possibilities)

Proposition: Of all possible paths from a beginning A to an end B, the behaviorally efficient path uses minimal action, where action is a scaler that corresponds to the dimension where value has been conserved.

IMPLEMENTATION: For each phenomenon, configure three elements, Action element, Fixed/exogenous elements, Resulting path from the action

The principle of least action as a structural property of “behavior”: Modeler Perspective

	Description	Fixed/Exogenous	Action Element	Example	Path
1	Going from point A to point B in the Euclidian 2-D space	Beginning and end in Euclidian space	Euclidian distance	Connecting two dots in the 2-D Euclidian space	A straight line
2	Going from A to B involving force fields	Beginning and end in a gravity (or any other force) field	The Physical action	A ball thrown in the air at an angle	A parabola derived from min S
3	Moving from A in one surface to B in a surface with different fabric	Beginning and end in Euclidian space Change in the fabric of space	Time (forth dimension in Minkowski space)	Life guard rescues a drowning swimmer	A broken line, for which the Descartes-Snell’s law holds

The principle of least action as a structural property of behavior-- contd.

	Description	Fixed/Exogenous	Action Element	Example	Path
4	To be at a specific end B at (or before) a fixed time	Time that the ball reaches the catching point no need to know B or time	Keep a fixed angle of gaze	Gaze heuristic: 2 Goals =be there(1:space)+ when(2:time) the ball is	A curved path, depending on when the angle of gaze is first fixed
5	"Save wire" organization principle*	Location of ganglia in a combinatorial space	Min cost (length) of connection among ganglia	Ganglia connections in the brain	A path of fiber connections with minimal length of connections
6	Use the simplest model necessary for action	One cue is valued more than others	Use only the cue Maximum validity	One-reason decision making	A non-compensatory structure: 1, ½, ¼, ….

[1] This does not include the possibility that the location of ganglia and connections are co-determined. (Cherniak 1994)

Compare to Extant Methods

	Method of modeling	WHAT: Given variables	HOW: Action element	Path of Action
To catch a fly ball	*Current Method: Inward approach with three-tiers*	Time a fly ball takes to reach ~1.5 m above ground	Use the evolutionary capacity of holding gaze on a moving object	A curved path, depending on when the angle of gaze is first fixed
	Proposed method: In the first physics tier only	Same as above	Keep a *fixed angle* of gaze (change=0)	Same as above
Arrange nervous system network	*Current method: Inward approach in the second tier*	Location of ganglia in a combinatorial space	Economize the use of biological resources for connecting (ganglia)	A path of fiber connections with minimal length of connections
	Proposed method: In the first physics tier only	*Number of ganglia*	Minimize distance among ganglia and position them concurrently	*Same as above*

Summary of insights from *Exercise 1*:

A: beginning / *B*: end	**Specified**	**Non-specified**
Specified	Actions correspond to observable paths (A = B: deliberate inaction)	May never start (wishes and dreams)
Non-specified	Acting under unknowable consequences (Modeling involves reduction)	Habits, customs, rituals (A = B: unconscious inaction)

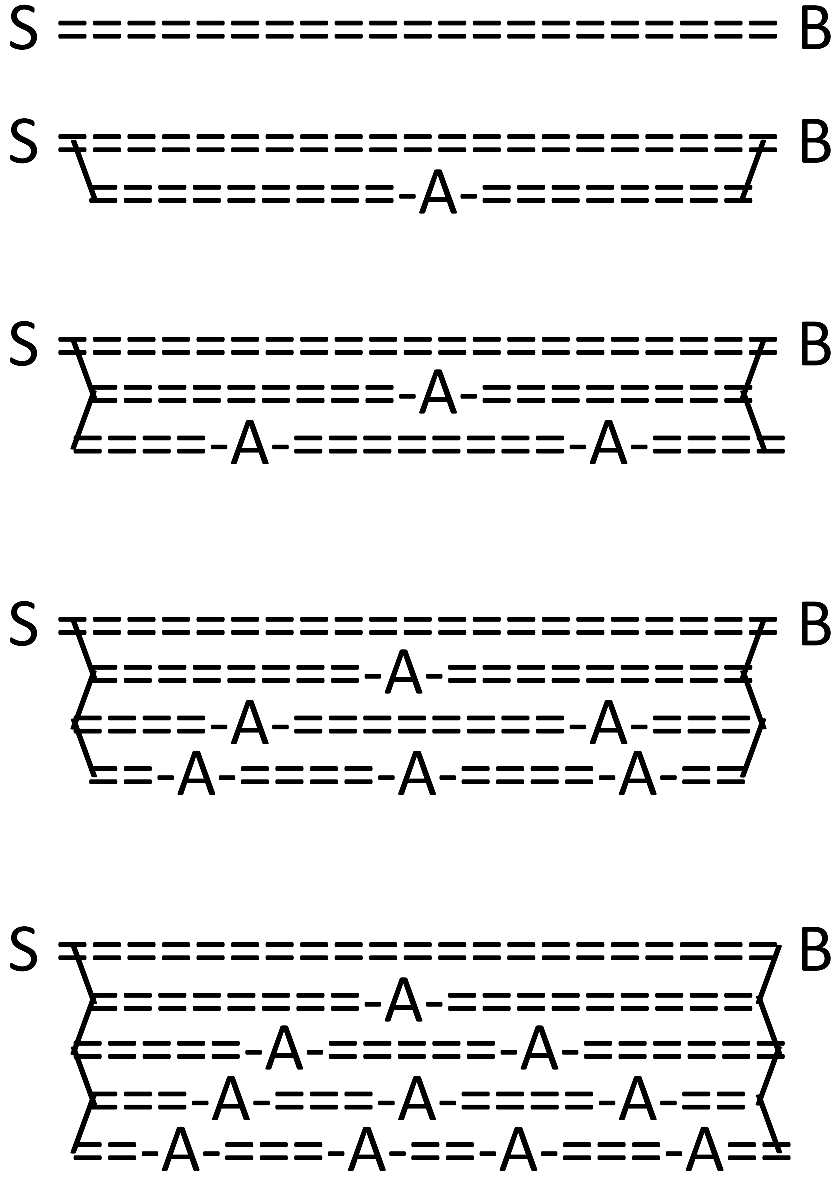
Exercise 2: MarketNet

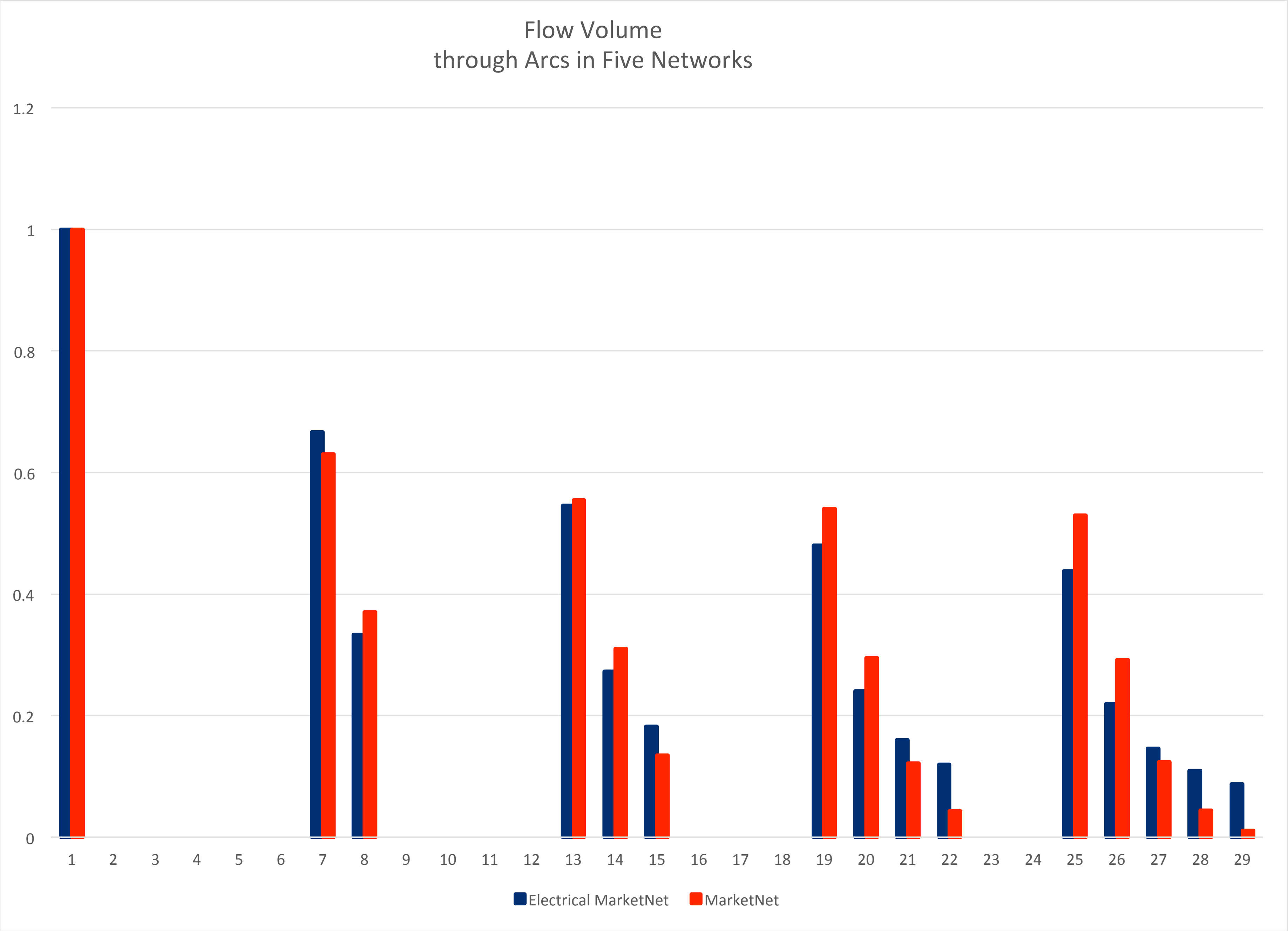
- Platform to explore structural properties of networked markets
- Zero/minimal intelligence agents
  - Exogeneous sellers & buyers, arbitrageurs (and producers)
- Random bids/asks with no-loss constraint
- Properties: allocative efficiency, prices, volume, distribution of surplus, etc.

STEP1:

USE **Kirchhof’s Circuit Laws** to frame a network of markets

- N paths indexed by k
- r_k resistance in path k=1,2,..
- v_{SB}=1 voltage diff
- v/r_k flow/current in path k
- $\Sigma\, v/r_k$ total flow on all paths
- $(1/r_k)/\Sigma(1/r_k)$ flow on path k




Flow Volume
through Arcs in Five Networks
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Electrical MarketNet
MarketNet

analogy of electrical networks

- the proportion of total volume of transactions in any market in the network can be thought of as the the current in the corresponding link of a similar electrical network.
- We fixed the potential difference between A and B, correspondingly, the value to exogenous buyer at 1 and cost to exogenous seller at 0 so the total surplus to be extracted on each unit is also 1.
- We use the proportion of units traded because we keep the number of units of endowment of exogenous agents a free parameter in order to obtain sufficient transactions data for estimating the statistical patterns in the simulation data.

Comparison of Flows in Electrical and Market Network Test 5, 10, 15, 20

Electrical (Blue), Market Model (Orange) and Simulated Market (Gray)

Y axis on Log scale

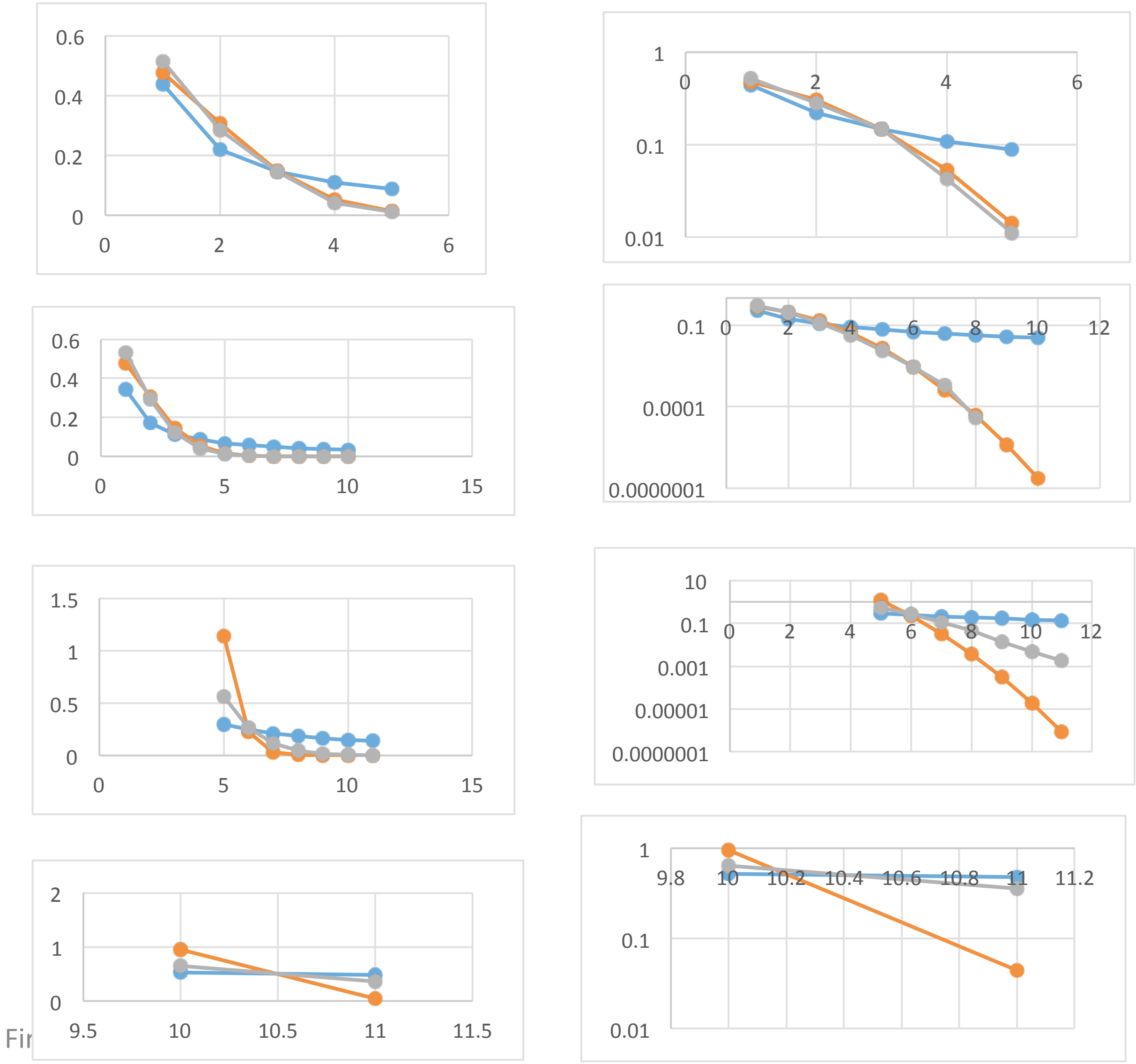
m_i : "resistance" of path *i*

$1/m_i$: volume of trade in path

Like electrical circuits, the proportion of total volume that flows through each trading path in the market network:

$$g_i = (1/K)(HarmonicMean\ of\ m)/(m_i)$$

Where A and B can also trade with each other along *K-1* other paths, numbered from 2 to *K*



FINDING: Kirchhoff's circuit laws do not work for framing network of markets!

- What to consider next?
  - Demand as a dynamic concept (v static)
  - Turning focus from price to efficiency (a ZI turn)

INSIGHT: Electric circuits gives us a platform for exploring market netwroks, but the theory doesn't carry over **because** of the requirement for simultaneous clearing across all markets.

…ZI agents as electrons could still work!

…

ELSE,

Pick another physics principle

Frame again

…

There are two basic kinds of variables that describe the action of a physical system. ***Effort variables*** *are those things that cause an action to occur**.*** ***Flow variables*** *are the responses to effort variables, usually involving movement but not always. For the simple case of a running animal, the effort variable is the force required to propel the animal; the flow variable is the velocity of movement. Heat loss from that same animal, which is the flow variable, occurs in response to a temperature difference, an effort variable. Sexual attraction to an animal of the opposite sex (effort variable) can result in a wide range of activities, including copulating (a flow variable). Hunger (an effort variable) can result in feeding (a flow variable). Thus, there are a wide variety of causes and effects related to biological activity, and these can be thought about in terms of effort and flow variables, which tend to simplify the concepts of biological activities. For any activity of a biological organism or system, searching for the effort variable, the flow variable, and relationships between these two can make it easier to comprehend not only how and why the activity occurs, but also the intensity of the activity (1941-Biology for Engineers, A.T. Johnson- pp. 32-33).*