Use of Computational Tools to Support Planning and Policy

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Four main messages

1. Information and communication policy faces grand challenges that require a dynamic systems approach to be addressed effectively
2. Big data analytics can contribute greatly to improve policy analysis, design, implementation, and monitoring
3. Because public policy often seeks to change the system it is interacting with, big data analytics also has limitations
4. Computational methods and integration with other types of social scientific analysis can help overcome these shortcomings

Plan for today

- Big data analytics and ICT policy
- Group discussion: succeeding in the race to advanced mobile broadband
- Application #1: Overcoming digital divides
- Application #2: Designing 5G markets to promote investment and innovation
- Application #3: Mitigating the power of digital platforms
- Recap and conclusion

Big data analytics and ICT policy

Grand challenges of information policy

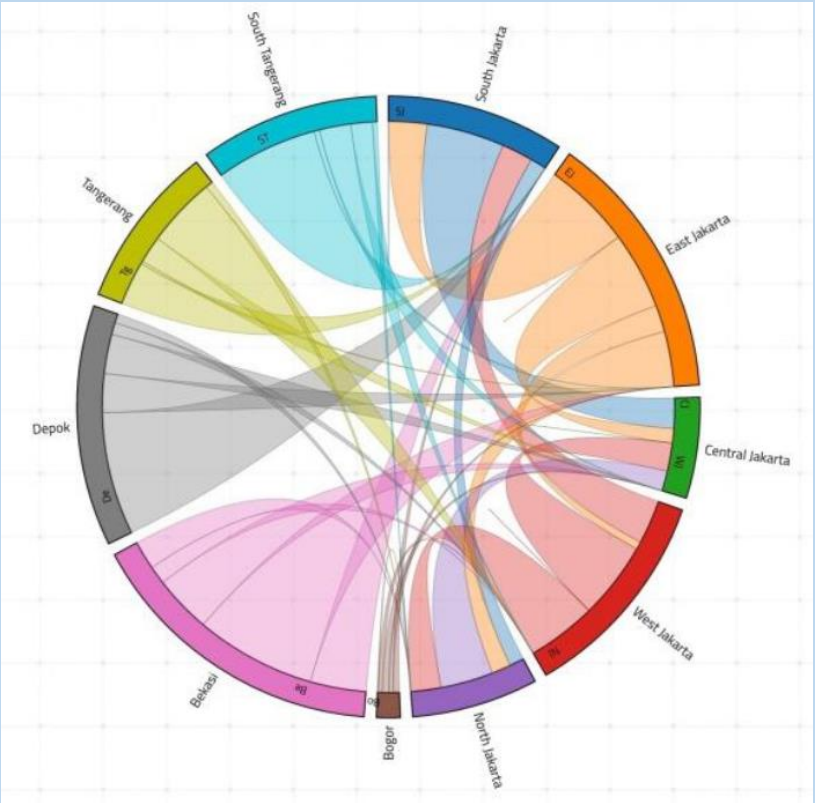
- Increasing digital literacy and reducing digital inequalities
- Harnessing the benefits of next-generation technologies
  - Internet of Things (IoT), Internet in Everything
  - 5G wireless and ubiquitous connectivity
  - Robotics and pervasive automation
  - Big data analytics, machine learning, and artificial intelligence (AI)
- Development of culturally and socially sensitive, transparent algorithms
- Utilization of data while protecting sensitive data, privacy, and information security
- Mitigating the power of digital platforms without harming innovation

Big data and policy

- Two types of policy: improving the performance of a given system (incremental policy) versus policy aimed at changing the structure and trajectory of the system (architectural policy)
- Past behavior and policies may not be good predictors for the consequences of interventions. They also have limitations in deciding what <u>should</u> happen
- However, big data is invaluable in building models to analyze options
  - Scenario building and system dynamic models
  - Computational, numeric models
  - Agent-based models, evolutionary models, genetic learning algorithms
- Big data analysis is a complement to other methods and an important tool to improve policy design and implementation

Promises

- More accurate data documenting availability and adoption of ICTs
- Better understanding of ICT adoption, uses, and effects (e.g., Blumenstock et al., 2015)
- Design of efficient policy responses (e.g., Twitter data on urban commute data, cyber-physical systems in smart cities)
- Effective monitoring of policies
- Examples of projects collected at https://unstats.un.org/bigdata/inventory/



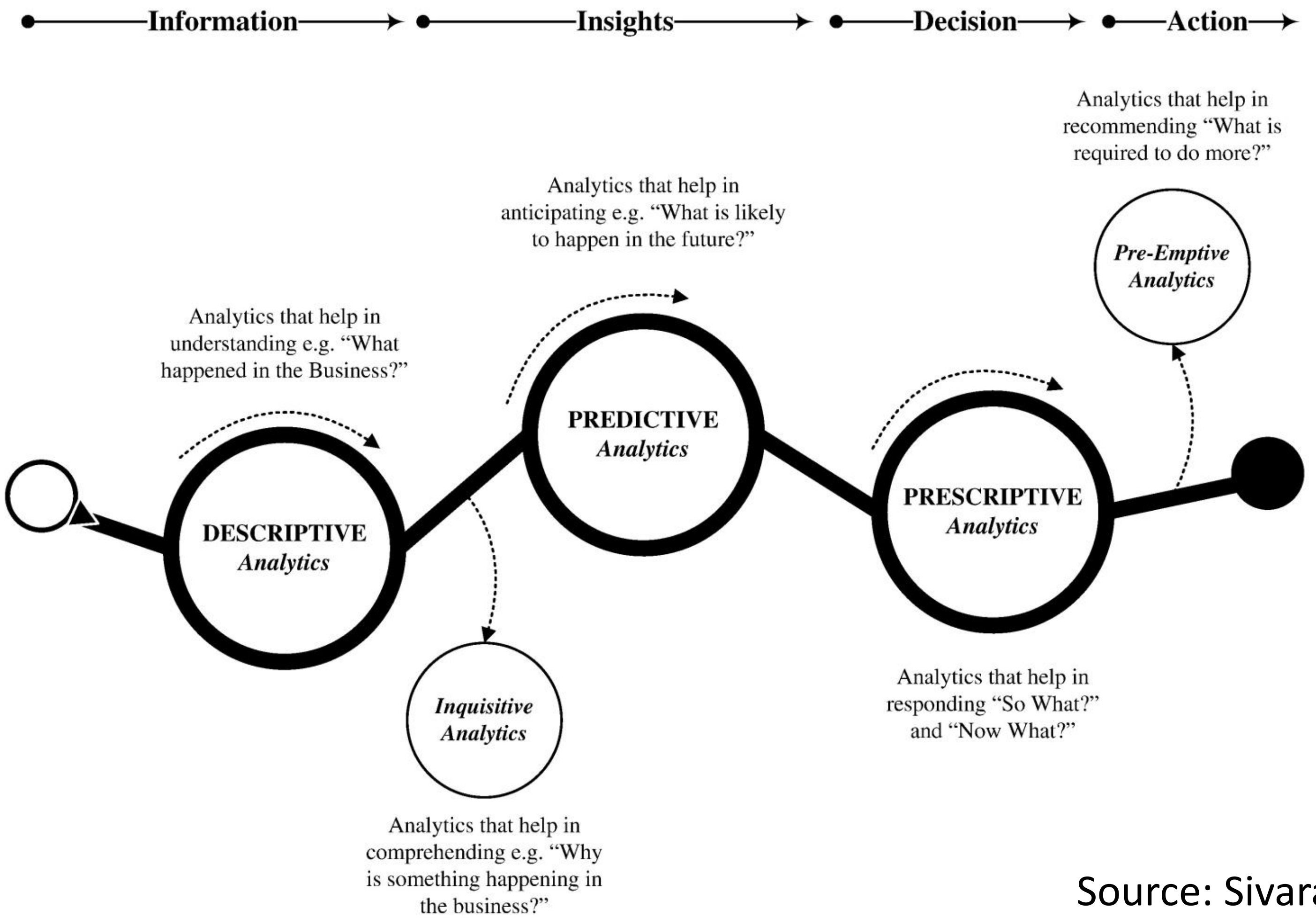
Improved commute statistics using social media data in Jakarta

Concerns

- Big data may change the nature of "knowledge"
- Claims to objectivity and accuracy can be misleading
- Bigger data is not always better
- Data may lose its meaning if taken out of context
- Inherent biases of algorithms and machine learning
- Proprietary data and algorithms create new digital divides
- See boyd & Crawford (2012)

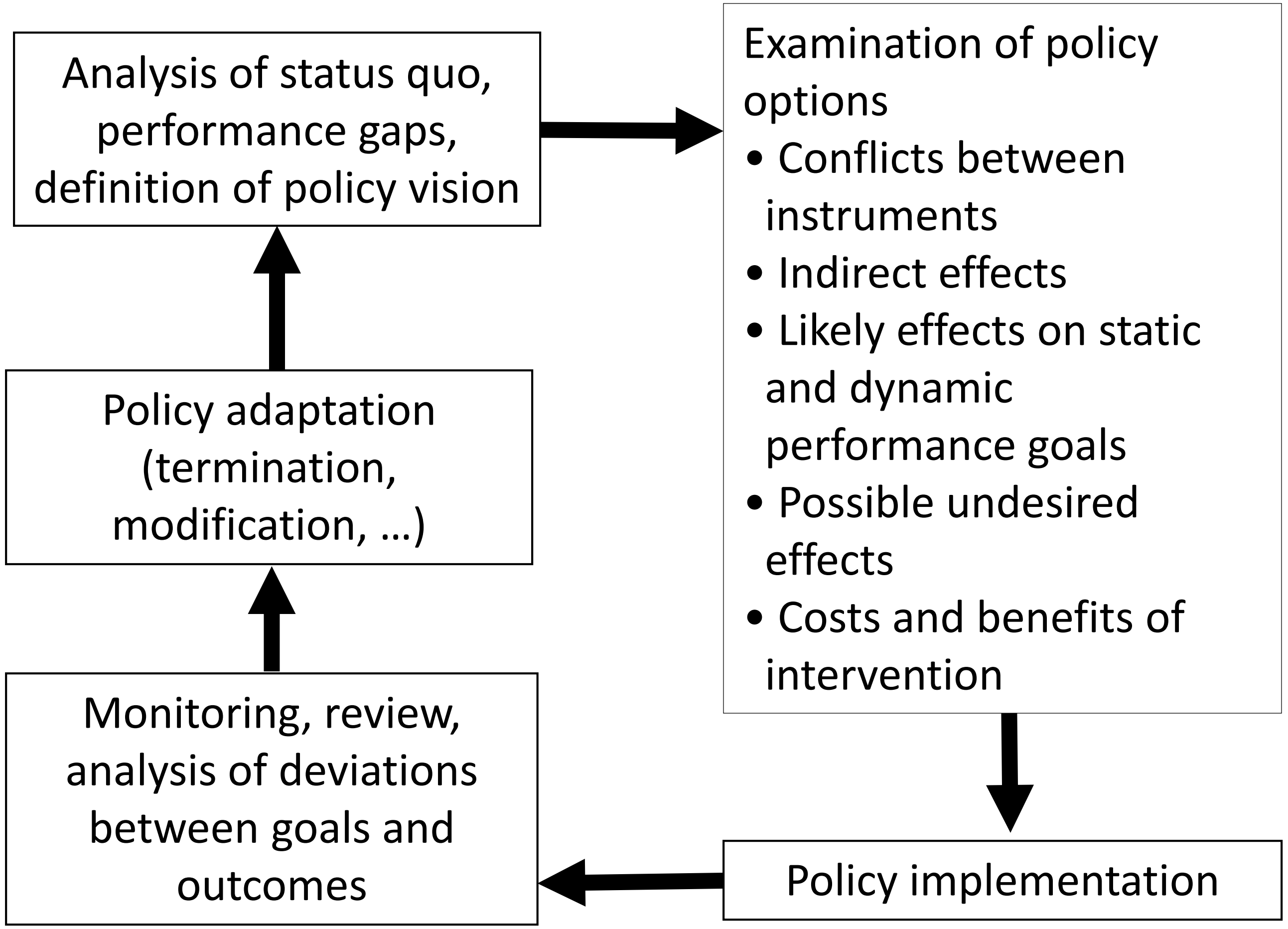
- COMPAS
  - Widely used in U.S. courts since 2000
  - Uses 137 features to determine risk of recidivism
  - Close examination revealed strong biases against black men and in favor of white men
- Virginia Eubanks (2018)
  - *Automating Inequality* examined algorithms intended to support programs fighting homelessness, child abuse, and determine eligibility for public assistance
  - Case studies reveal that they create "digital poorhouses"

Types of big data analytical methods



Source: Sivarajah et al. (2017).

Informing all stages of policy development



A digitally connected world

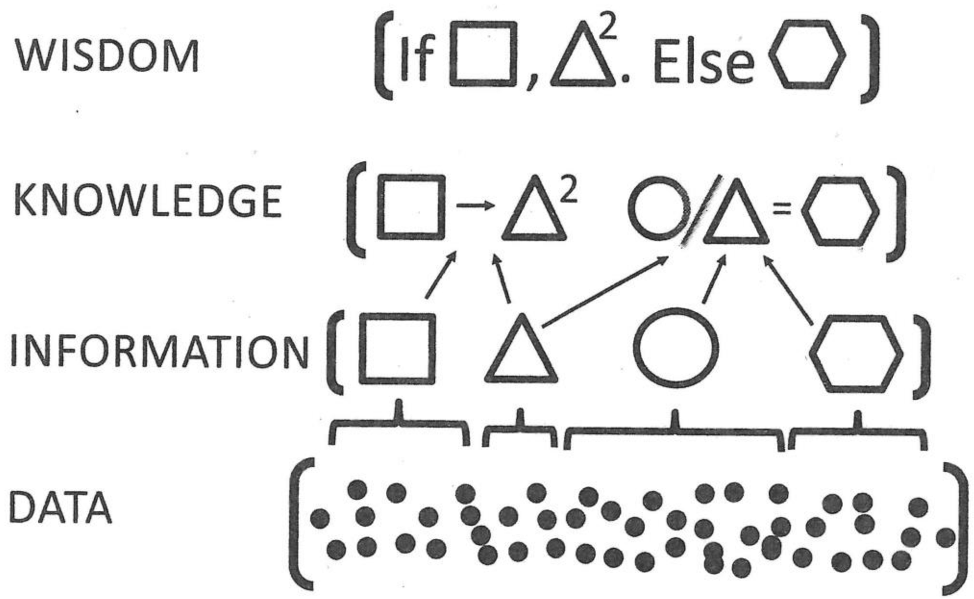
- Characteristics of our connected life
  - "Exponential technologies" accelerate diffusion and widespread use
  - Near-ubiquitous connectivity amplifies interdependencies in work, innovation, political movements, environment, …)
  - As digital technology permeates nearly in all aspects of life and work, it increasingly becomes a "black box" for users (many features are hidden and/or unknown)
- A dynamic, adaptive system
  - Interdependencies create new non-linear dynamics (e.g., network effects, contagion, "butterfly effect")
  - Systems may have multiple equilibria ("attractors"), each representing different performance attributes
  - Initially small differences may lead to major differences in outcomes and path dependencies (e.g., Schelling, 1969, racial segregation model)
  - Diversity increases the performance and resilience of a system up to a point (but excessive diversity may eventually reduce them again)

Policy in dynamic adaptive systems

- The dominant view: public policy as control
  - Abba P. Lerner, *The Economics of Control,* Macmillan, 1944
  - Government can influence outcomes of economy to enhance welfare
- Governance: limits of the state, policy process, and policy-makers
  - Policy makers face many limitations such as incomplete information, feasibility constraints, self-interested players (e.g., Dixit, 1996)
  - Other forms of governance (e.g., networks such as IETF, IGF), voluntary coordination (e.g., 3GPP, W3C), and emergent norms are critically important
- Bottom-up policy for our connected world: active laissez-faire
  - Markets need appropriate rules and policies to work well
  - David Colander & Roland Kupers, *Complexity and the Art of Public Policy*, Princeton University Press, 2014

Many model-thinking (Page, 2018)

- Applying multiple lenses increases our understanding
- Examples include
  - Network models
  - Diffusion and contagion models
  - Game theoretical models
  - Path dependence models
  - System dynamic models
  - Threshold models with feedback
  - Collective action problems
  - Rugged-landscape models
- Can contribute to better policy



Transforming data into wisdom

From: Scott E. Page, *The Model Thinker, What You need to Know to Make Data Work for You*, New York: Basic Books, 20018, p. 7.

Group discussion

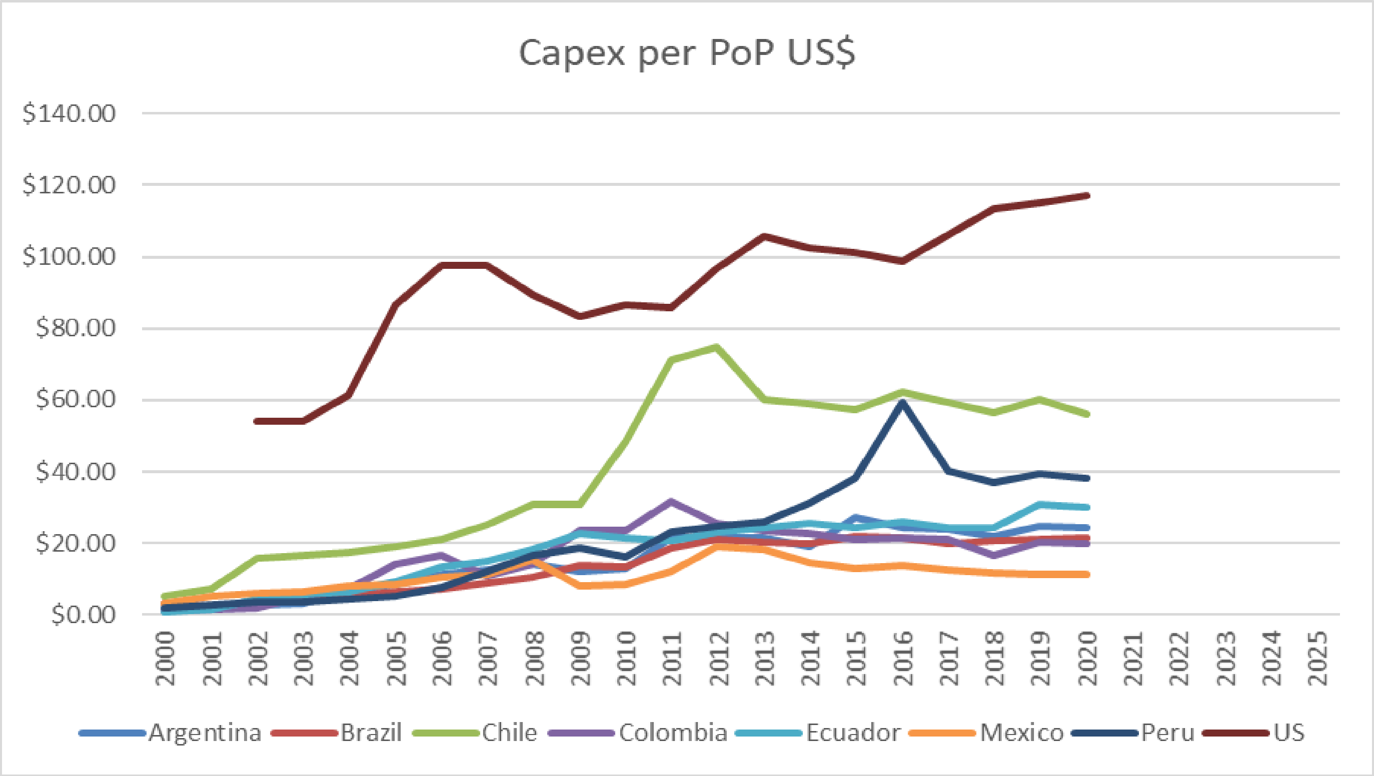
Succeeding in the race to advanced mobile broadband

Promises of advanced broadband

- Advanced broadband connectivity promises innovative services for consumers, support for the Internet of Things (IoT) and seamless specialized services for sectors such as manufacturing, transportation and health care
- Advanced wireless services (e.g., LTE, 5G) will constitute an integral part of the future gigabit communication network infrastructure. Its technical attributes, such as high bandwidth and low latency, will enable a wide range of innovations
- Worldwide, countries are positioning themselves to take advantage of 5G services but policy models vary widely from hands-off entrepreneurship (e.g., U.S.) to regulated competition (e.g., EU) to state-led rollout (e.g., China)

Concerns about infrastructure deployment

- High capital requirements (e.g., antennas, backhaul, spectrum, rights-of-way)
- High innovation potential but no clear use cases yet, hence revenue potential uncertain



Capex for wireless networks (2019-2020 estimated), based on GSMA market information

The Interamerican Advanced Wireless Task Force

- Founded to utilize big data to design effective policies for advanced wireless markets
- Hearing with major stakeholders (network operators, consumers, industry users, …)
- All made recommendations on universal connectivity and which market design would be most conducive to achieve it

- Your tasks:
  - Review the handout and the recommendations by the player assigned to your group
  - Discuss the questions with your group
  - Write outcomes of your discussion on the posters
  - Determine one or more speakers who will share your findings with the other participants (if selected)

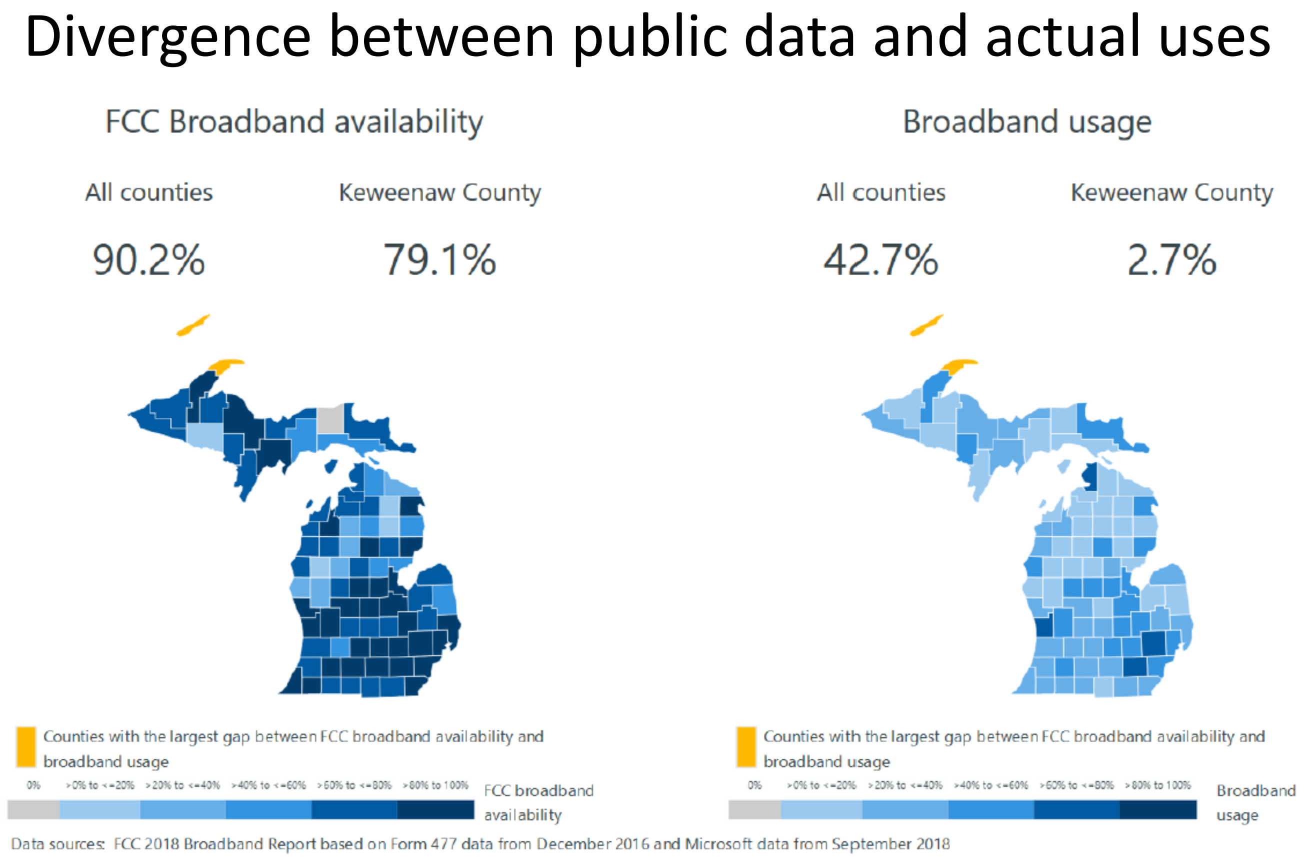
Approximate timeline

- Review the handout (5 minutes)
- Discuss the questions (10 minutes)
- Put your key points on the posters (5 minutes)
- Report back to all (10 minutes)

Application #1:
Overcoming digital divides

The “homework gap” challenge

- “Homework gap” refers to disadvantages of students from kindergarten to high school (K-12) who do not have sufficient access to Internet connectivity and hence fall behind in school
- One of the digital divides
- Extent of problem is not well known, although there is reason to believe that existing data grossly underestimate it



Source: https://www.govtech.com/biz/Microsoft-Speeds-Show-Broadband-Use-Is-Far-Lower-than-Access.html

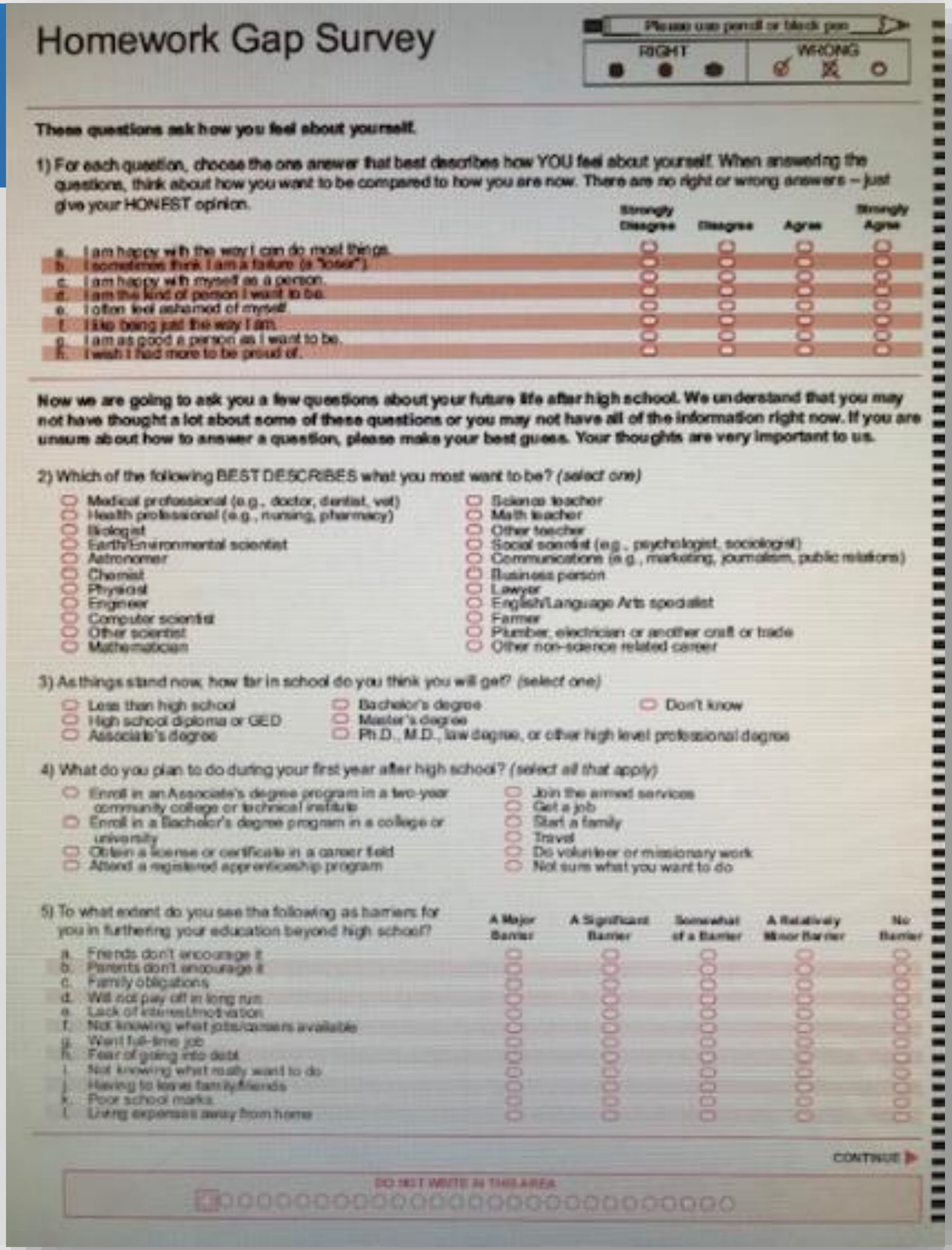
Big data complemented by surveys

- Numerous initiatives to measure network speeds (e.g., Akamai, Ookla, …), each with unique strengths and weaknesses, and examine their social and economic effects
- However, network access and quality is only one among many factors shaping digital divides
- Just examining network access/speeds samples on the dependent variable (does capture variations of access but not those without access)
- Michigan Moonshot Project (Merit Network + Quello Center + MLab)
  - Crowdsourced network quality data to overcome inaccuracies of existing, public domain broadband maps
  - Paper-based survey in schools across the state (pilot study in 202 classrooms in three school systems across the State of Michigan)
  - Allows granular understanding of problem and the targeting of remedial measures (e.g., subsidies, PPPs) to specific locations and populations
  - Unique ID allows linking information to other databases but numerous challenges to protect identity of participants

Survey in a box

Turnkey Kits

- Leadership & Admin Introduction & Overview
- Parental Letter
- Teacher Instructions
  - Video/lesson
  - Paper in-Classroom survey (MSU)
  - Homework Assignment Instructions (Merit)
  - Student Key
- Collection Instructions



Homework Gap Survey

Please use pencil or black pen

RIGHT WRONG

These questions ask how you feel about yourself.

1) For each question, choose the one answer that best describes how YOU feel about yourself. When answering the questions, think about how you want to be compared to how you are now. There are no right or wrong answers – just give your HONEST opinion.

	Strongly Disagree	Disagree	Agree	Strongly Agree
a. I am happy with the way I can do most things.				
b. I sometimes think I am a failure (a "loser")				
c. I am happy with myself as a person.				
d. I am the kind of person I want to be.				
e. I often feel ashamed of myself				
f. I like being just the way I am.				
g. I am as good a person as I want to be.				
h. I wish I had more to be proud of.				

Now we are going to ask you a few questions about your future life after high school. We understand that you may not have thought a lot about some of these questions or you may not have all of the information right now. If you are unsure about how to answer a question, please make your best guess. Your thoughts are very important to us.

2) Which of the following BEST DESCRIBES what you most want to be? *(select one)*

- Medical professional (e.g., doctor, dentist, vet)
- Health professional (e.g., nursing, pharmacy)
- Biologist
- Earth/Environmental scientist
- Astronomer
- Chemist
- Physicist
- Engineer
- Computer scientist
- Other scientist
- Mathematician
- Science teacher
- Math teacher
- Other teacher
- Social scientist (e.g., psychologist, sociologist)
- Communications (e.g., marketing, journalism, public relations)
- Business person
- Lawyer
- English/Language Arts specialist
- Farmer
- Plumber, electrician or another craft or trade
- Other non-science related career

3) As things stand now, how far in school do you think you will get? *(select one)*

- Less than high school
- High school diploma or GED
- Associate's degree
- Bachelor's degree
- Master's degree
- Ph.D., M.D., law degree, or other high level professional degree
- Don't know

4) What do you plan to do during your first year after high school? *(select all that apply)*

- Enroll in an Associate's degree program in a two-year community college or technical institute
- Enroll in a Bachelor's degree program in a college or university
- Obtain a license or certificate in a career field
- Attend a registered apprenticeship program
- Join the armed services
- Get a job
- Start a family
- Travel
- Do volunteer or missionary work
- Not sure what you want to do

5) To what extent do you see the following as barriers for you in furthering your education beyond high school?	A Major Barrier	A Significant Barrier	Somewhat of a Barrier	A Relatively Minor Barrier	No Barrier
a. Friends don't encourage it					
b. Parents don't encourage it					
c. Family obligations					
d. Will not pay off in long run					
e. Lack of interest/motivation					
f. Not knowing what jobs/careers available					
g. Want full-time job					
h. Fear of going into debt					
i. Not knowing what really want to do					
j. Having to leave family/friends					
k. Poor school marks					
l. Living expenses away from home					

CONTINUE

DO NOT WRITE IN THIS AREA

THE MICHIGAN MOONSHOT

MERIT'S COMMITMENT TO ENDING THE DIGITAL DIVIDE

merit | MICHIGAN STATE UNIVERSITY | quello center | MLAB

More than 380,000 homes in rural Michigan do not have access to broadband. Accurate connectivity data is the first step in assessing community needs and building support for funding sources. Current FCC data aggregation processes may misrepresent broadband availability. These can be overcome by collecting consumer-sourced data through surveys such as this one.

The Measurement Lab (M-Lab) platform is run by the scientific community. We make all test results publicly available via the MeasurementLab.net website to help promote Internet research. M-Lab's Network Diagnostic Tool collects a number of measures of different facets of your Internet connection. The information published includes each device's IP address, but does not include personal identifying information about you as an Internet user.

Learn more about the Michigan Moonshot

+ Data Privacy FAQ

Where are you completing this survey from?

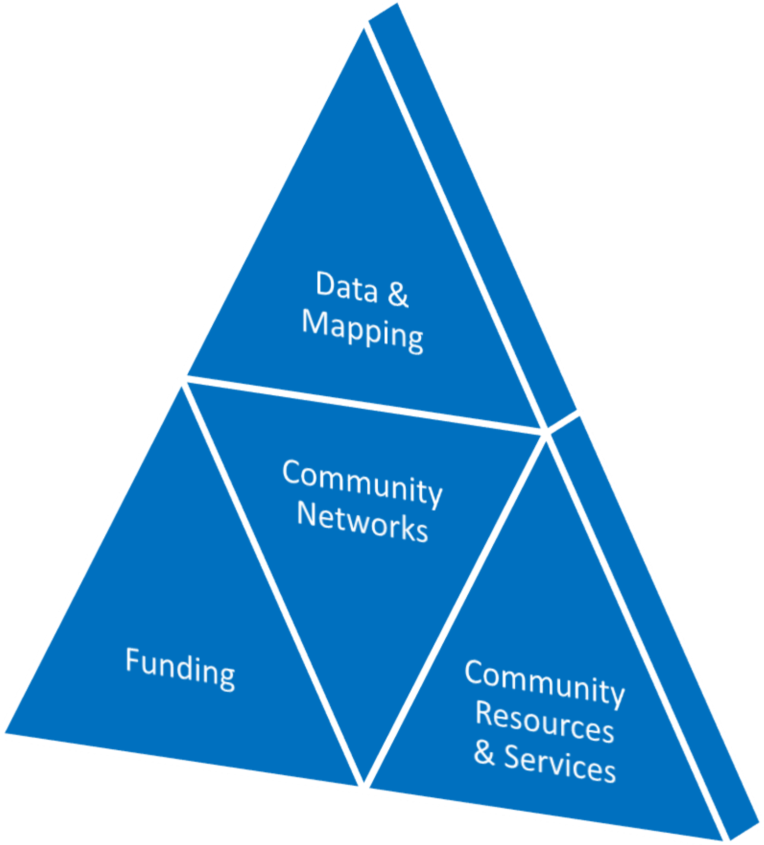
Including yourself, how many of those living in your home are under the age of 18?

Does your family own or rent the place where you live?

Do you have problems using the internet at home to do any of the following? (Check any that apply)

- [ ] Homework (if applicable)

Contribution of big data analytics



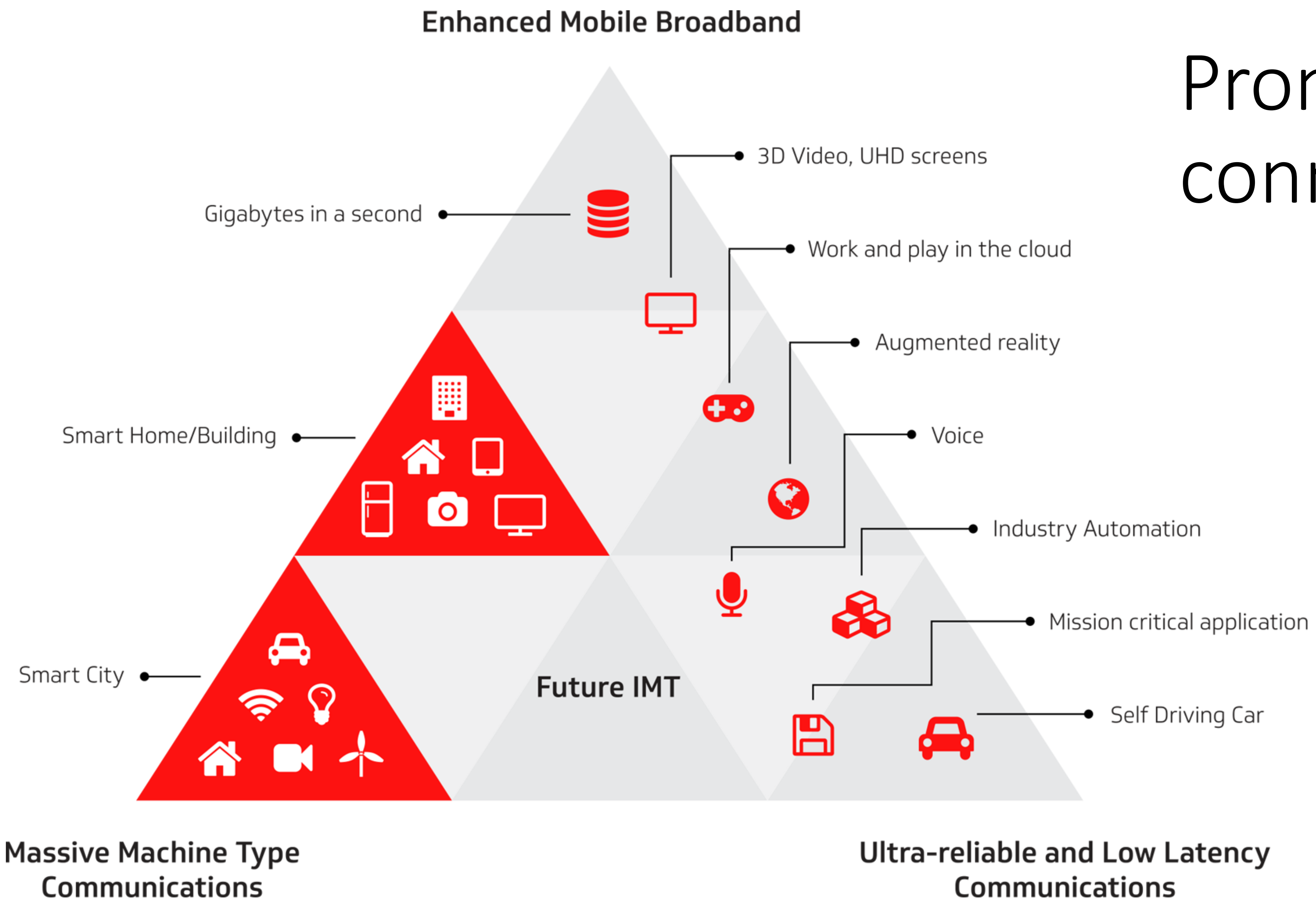
Phase I

- Develop citizen-science/crowd-sourcing techniques to assess the "***homework gap***" in a more granular manner
- **Share information** statewide and become active nationally
- Foster public-private **partnerships**
- Broadband **EDU Series**

Phase II

- Establish **community connectivity teams** to provide expertise in data analysis, broadband technologies, financing, sustainability, project management and network construction
- Assist in navigating **community planning grants** through state or philanthropic means; help communities acquire one-time **construction subsidies**

Application #2:
Designing 5G markets to promote investment and innovation

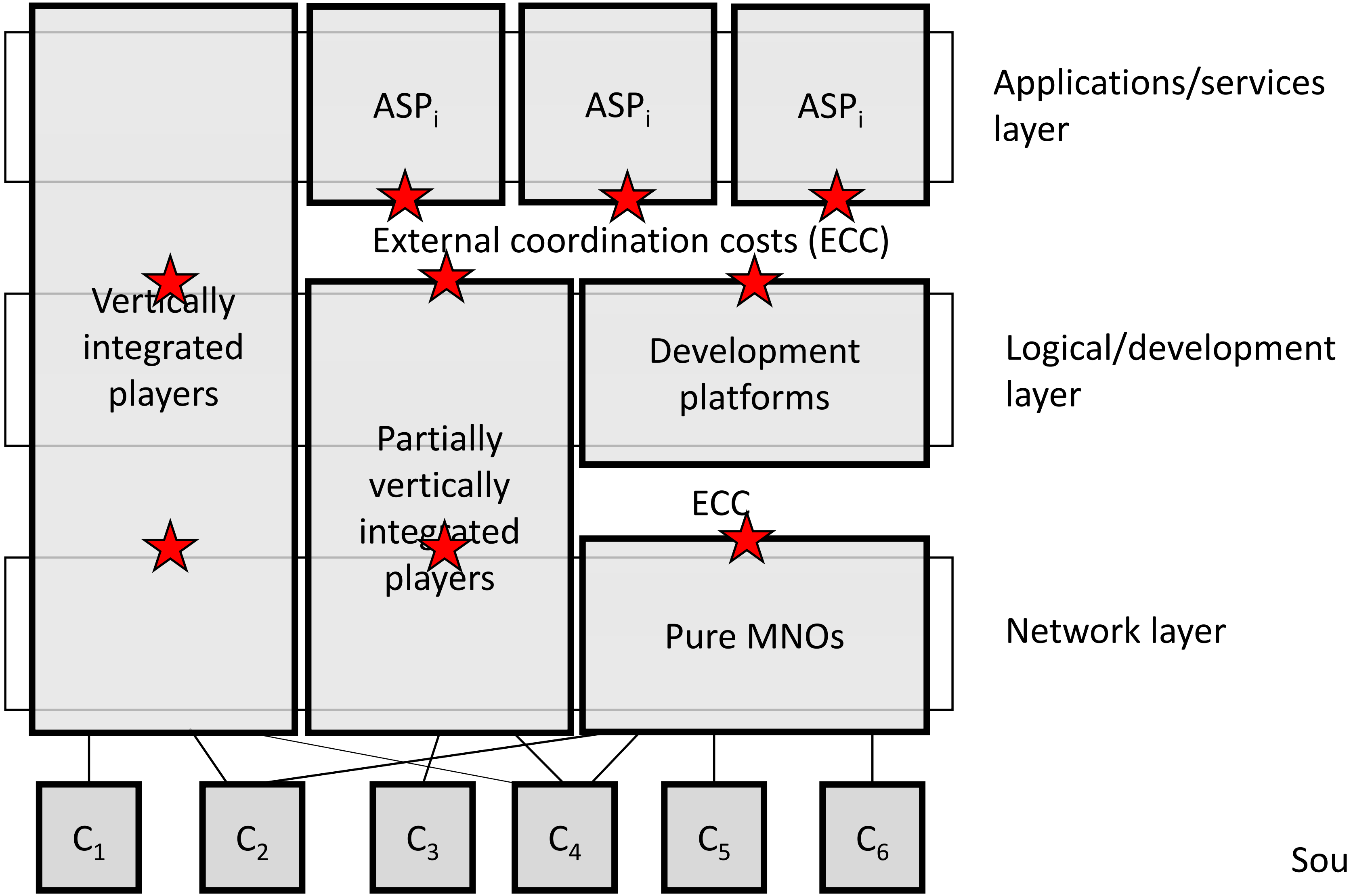


Promises of 5G connectivity

- Part of future seamless gigabit network infrastructure
- Enables numerous new services for consumers, businesses, government

Source: https://www.cablelabs.com/insights/cable-5g-wireless-enabler

The 5G value system



Areas of concern are:

- Access bottlenecks
  - Fixed network backhaul
  - Rights of way
  - Data
- Coordination costs
  - Transaction costs
  - Adaptation costs
- What is the appropriate role of policy and regulation?

Source: Bauer & Bohlin, 2019

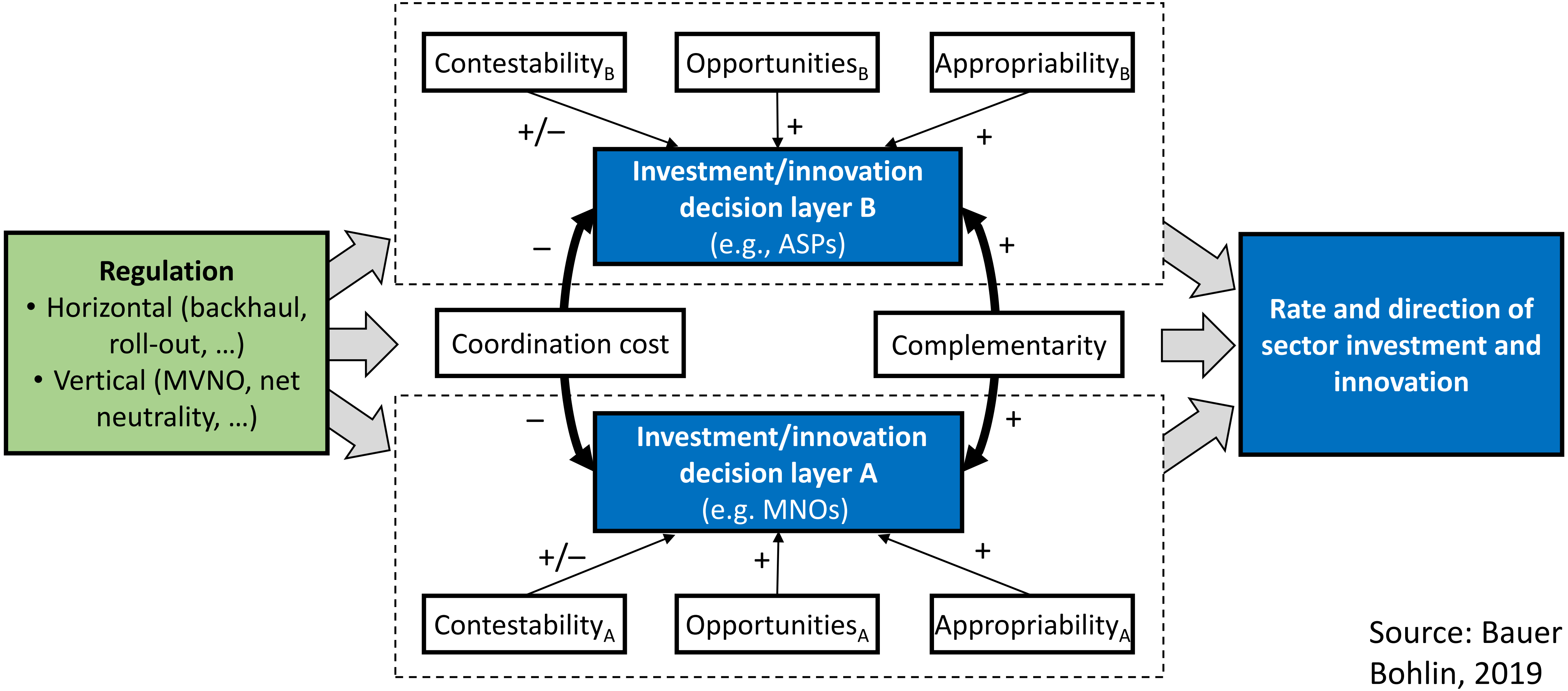
Can/should policy support 5G?

- Should access to network transportation services be regulated?
  - Mobile virtual network operator (MVNOs) access to MNO networks (e.g., regulated reference offer)
  - Access by application and service providers (ASPs) and content providers (CPs) to networks and end users (e.g., mobile network neutrality)
- Should public policy mitigate the market power of digital platforms and facilitate coordination among players?
  - Interoperability (e.g. open and transparent standards)
  - Open application programming interfaces (APIs)
- How should access to resources be organized?
  - Spectrum management (initial allocation, secondary markets)
  - Rights of way (outdoors antenna locations, access to buildings)
  - Data about network, users, …
- How can public interest goals (e.g., universal coverage, service, public interest innovations) be supported?

Emerging 5G market designs

- Regulated competition (e.g., dominant in European countries)
  - Ex ante regulation to neutralize market power and dominance, typically after detailed examination of market structure and conduct
  - Might use backhaul regulation, mobile virtual network operator (MVNO) access, regulation of rights of way (ROW), network neutrality
- Policy-push (e.g., some Asian and a few European countries)
  - Proactive policy intervention to accelerate infrastructure rollout and service innovation
  - Typically includes infrastructure rollout targets (possibly public investment), mandatory MVNO access, open network provisions (e.g., mobile network neutrality, mandatory open APIs), open data, industrial policy programs
- Entrepreneurship (e.g., United States)
  - Strong reliance on private sector and entrepreneurship to advance 5G rollout and innovation
  - Minimal ex ante regulation and intervention; market failure to be addressed by competition policy (and possibly ex post regulation)

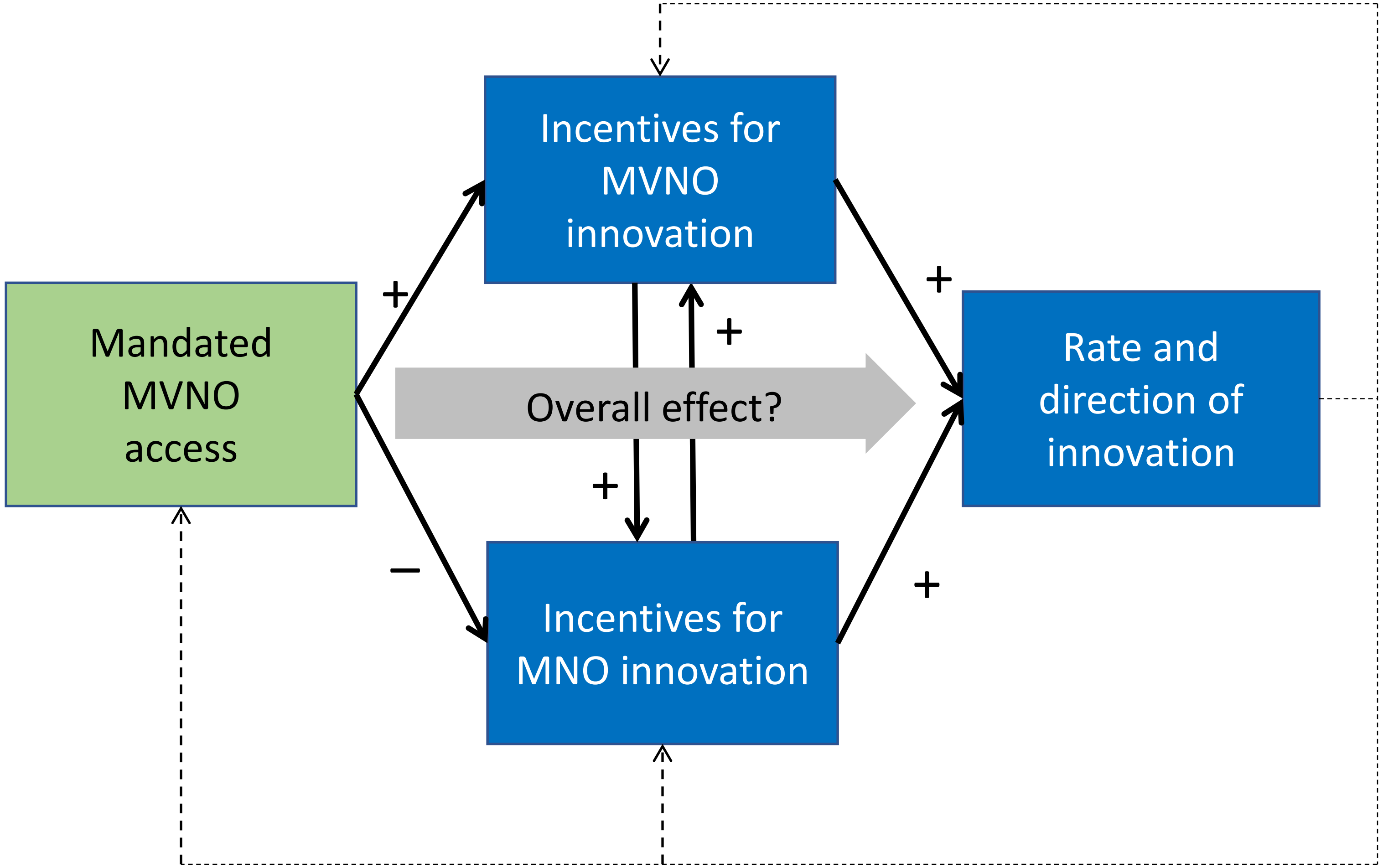
Complexity of non-linear dynamics



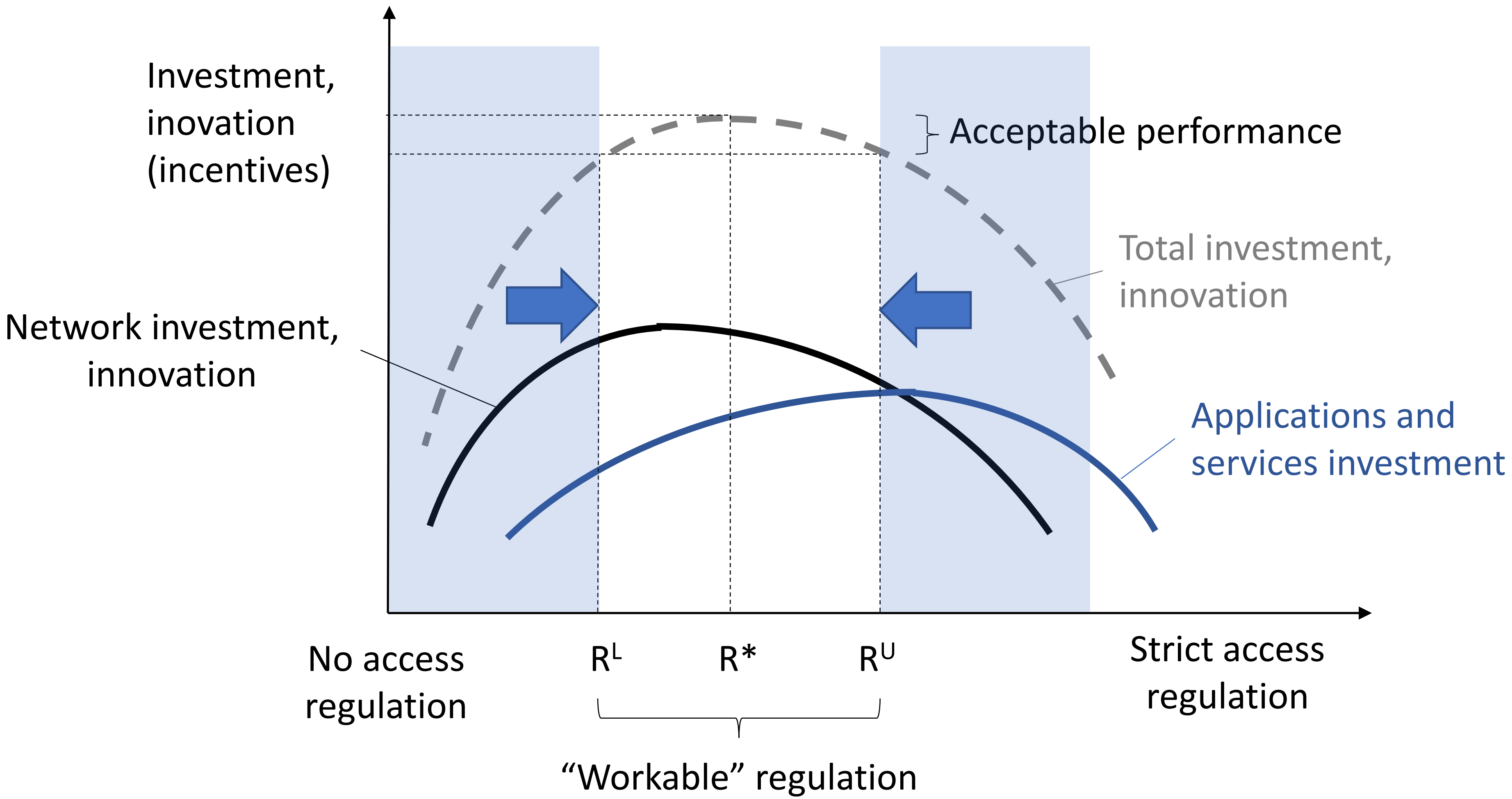
Source: Bauer & Bohlin, 2019

+ … variables move in same direction, – … variables move in opposite direction, +/– … ambiguous

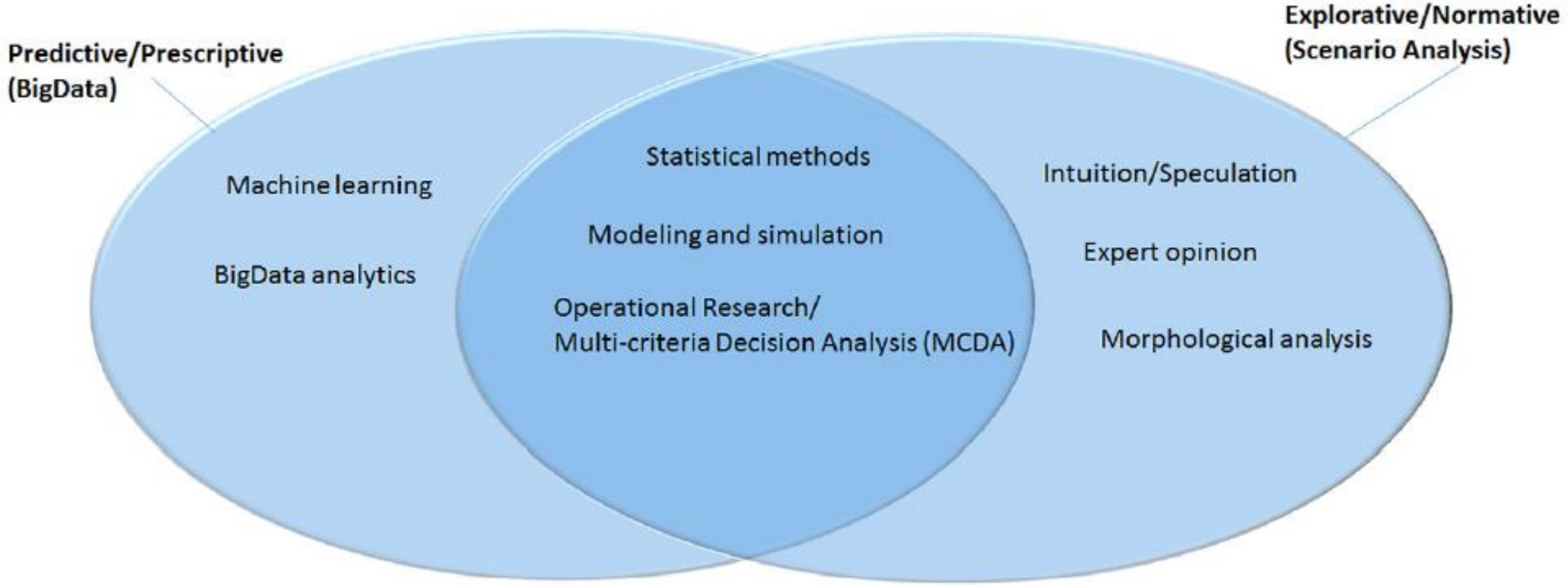
Positive and negative feedbacks



Regulation does not control, but „tune“ the system

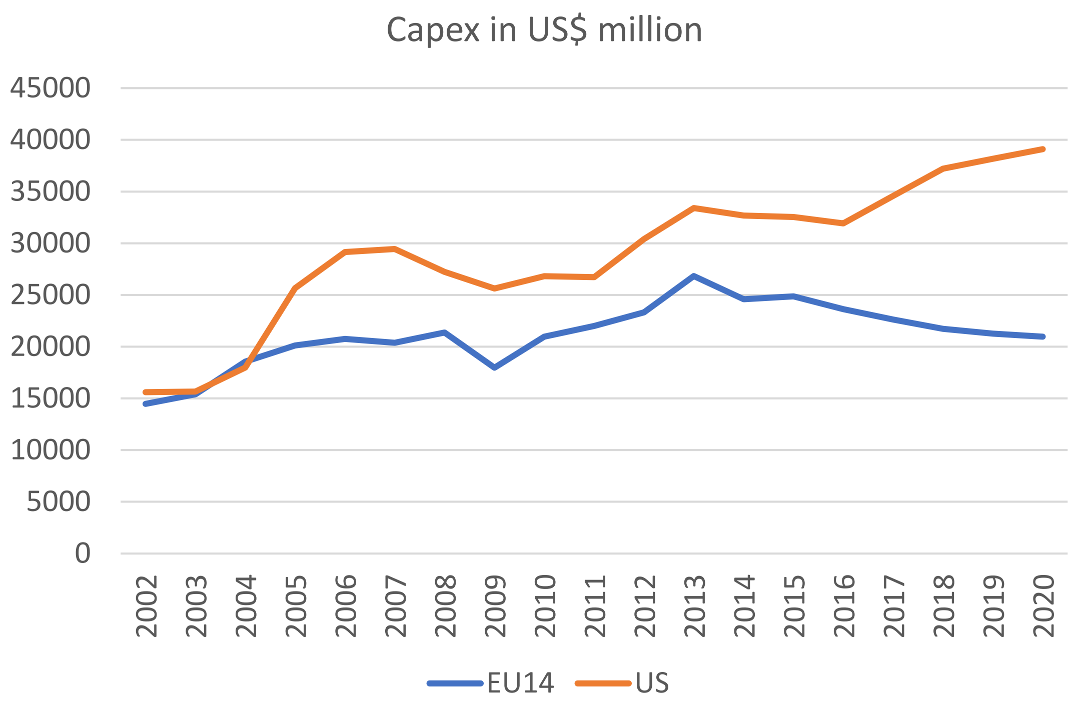


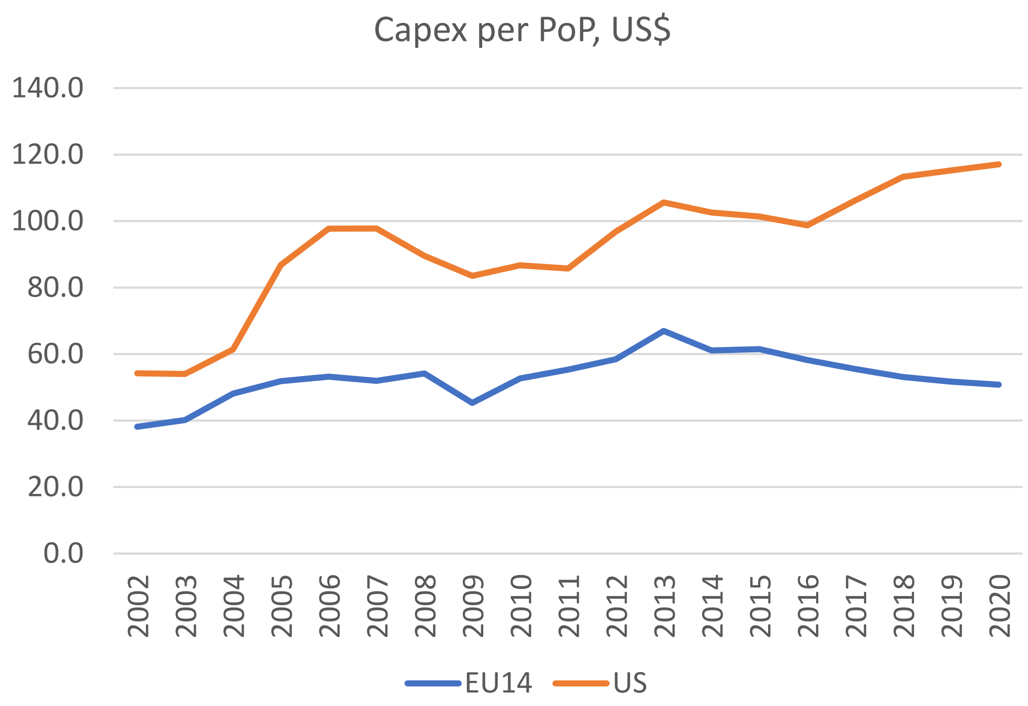
Granular data and scenario analysis allow exploring possible futures



Source: Batrouni et al. (2018)

Scenarios for 5G capex in the EU-14 and U.S.





Source: Bauer & Bohlin, 2018

Contributions and limits of big data analytics

- Contributes to building better models of the underlying non-linear dynamics
  - Establish directionality of relations
  - Calibrate effect sizes
  - Better and more accurate measures of outcomes
- Allows better monitoring of effects of policy changes
  - Provisions for data collection and data sharing needed (e.g., data trustees)
  - Needs to be complemented by analytical, causal models of underlying processes
- Can provide limited advice as to how policy changes will affect overall system and what the preferred course of action is

Application #3:
Mitigating the power of digital platforms without harming innovation

Increasing concerns about platform power

- Economic and technological attributes of digital markets contribute to enormous market concentration
  - Supply-side economies of scale and economies of scope
  - Demand-side economies of scale (network effects)
  - Positive feedback effects in platform ecosystems
  - Winner-takes-all dynamics
- Concerns include
  - Ability to manipulate digital markets (e.g., design algorithms that favor own products/affiliated partners)
  - Increasing control over data that are not accessible to competitors (but an essential input to competitors)
  - Ability to influence and potentially manipulate information flows with broad effects on political system

Policies to mitigate platform power

- Network neutrality
  - Strict neutrality: each datagram needs to be treated alike ("a bit is a bit is a bit")
  - Weak neutrality: differentiation of quality of service (QoS) allowed, but needs to be done in non-discriminatory fashion
- Open network requirements
  - Interconnection and interoperability
  - Open data, open APIs, open algorithms
- Vertical (structural) separation
  - E.g., *Open Reach* in the United Kingdom
  - Platform providers (e.g., networks, providers of logical platforms) cannot also be present in applications, services, and content markets
- Competition policy measures
  - E.g., EU cases against Google; U.S. cases against Microsoft, Facebook
  - Often works slow and faces tremendous challenges producing compelling evidence

Contribution of computational methods

- All these policies generate differential, positive and negative feedback effects on players in the digital ecosystem (see above)
- Net effects depend on initial conditions, strength of interdependencies, and behavior of players
- Difficult, if not impossible to model analytically (non-linearities, multiple equilibria (“attractors”), fast-paced change)
- Some challenges can be overcome by computational methods
  - System dynamic simulation models (e.g., Sterman, 2000)
  - Generative social science, especially agent-based models (e.g., Epstein, 2006)

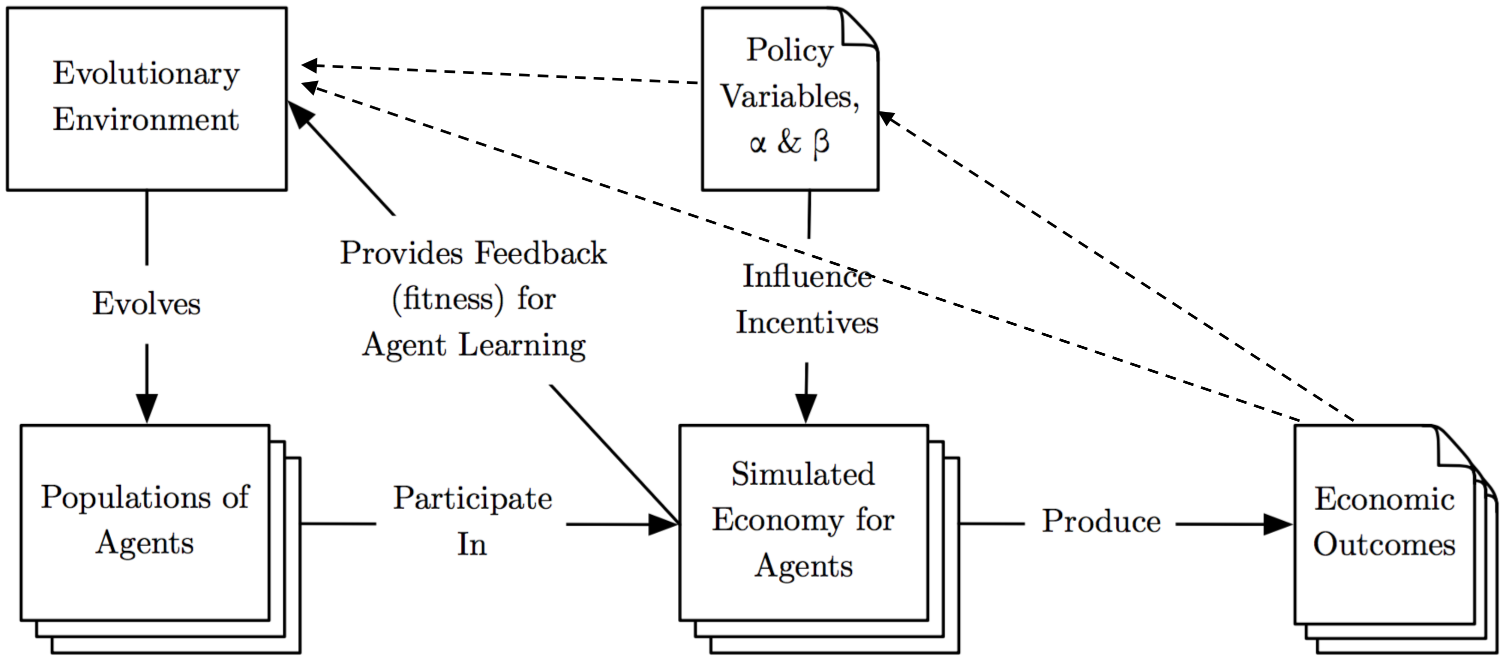
Agent-based modeling (ABM)

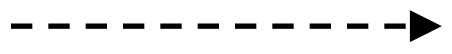
- Simulate the actions and dynamic interactions of agents (individuals, groups, organizations) with the goal to assess their effects on the system
- Components include
  - Agents that act based on rules (ranging from simple to rich specifications)
  - Relationships between the agents
  - An environment in which the agents interact
- Computational modeling frameworks (e.g., Swarm, NetLogo, RePast, AnyLogic) allow analyzing the emergent properties of such interactions
- Allow examining the consequence of changing the rules and/or structure
- Models need to be verified (testing whether the model works correctly) and valid (checking whether the right model has been built)
- Examples at http://ccl.northwestern.edu/netlogo/models/

ABM applied to vertical integration

- Kendall J. Koning, *An agent model of vertical integration in tele-communications and content,* Ph.D. Dissertation, 2017
- Models ICT value system as an interaction of heterogeneous agents (ISPs, consumers, content providers). Individual agents seek to optimize their profits (utility) following a decision heuristic and adapt their strategies based on the outcomes (“fitness”)
- Over many generations, agent decisions improve and adapt to the parameter setting of the model, which include regulatory and policy dimensions (e.g., whether vertical integration is permitted, whether network neutrality is mandated) and economic/technical conditions
- Policy parameters and environmental settings can be mapped to outcomes

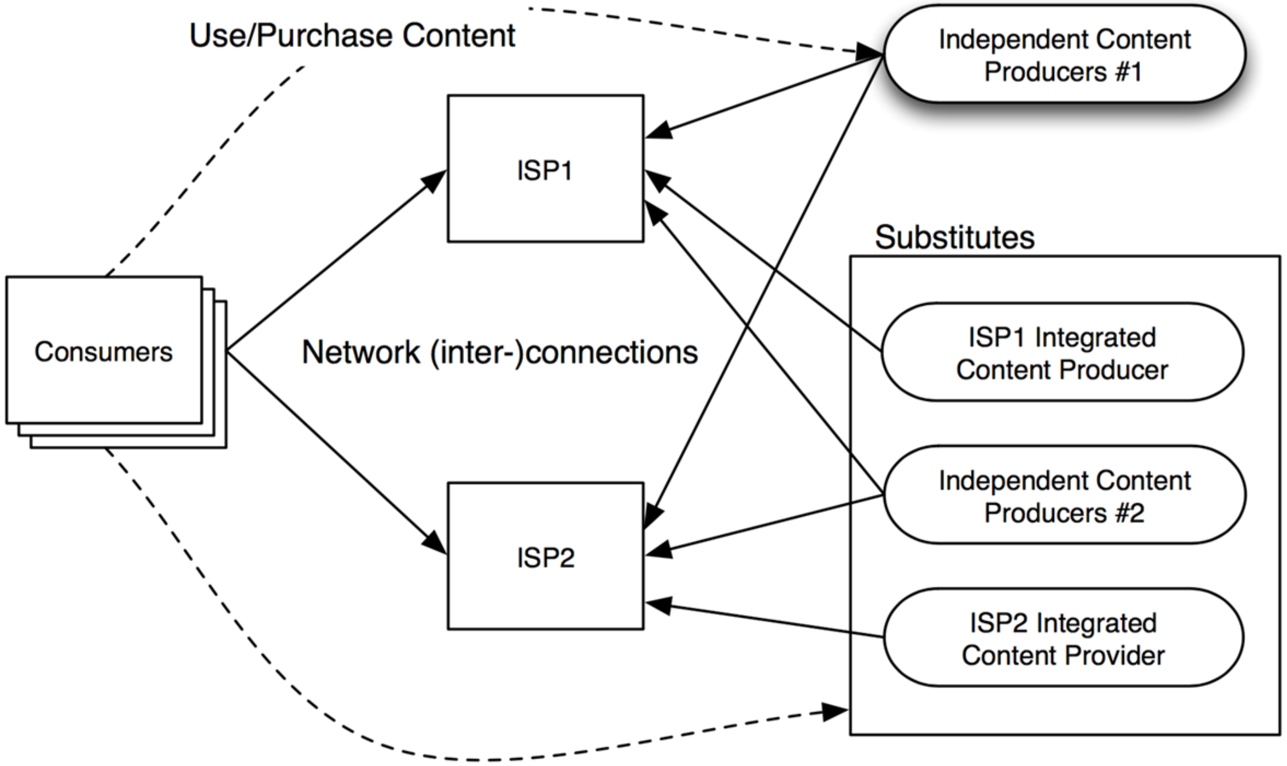
Overall model structure




Not examined in this model

Source: Koning, 2017

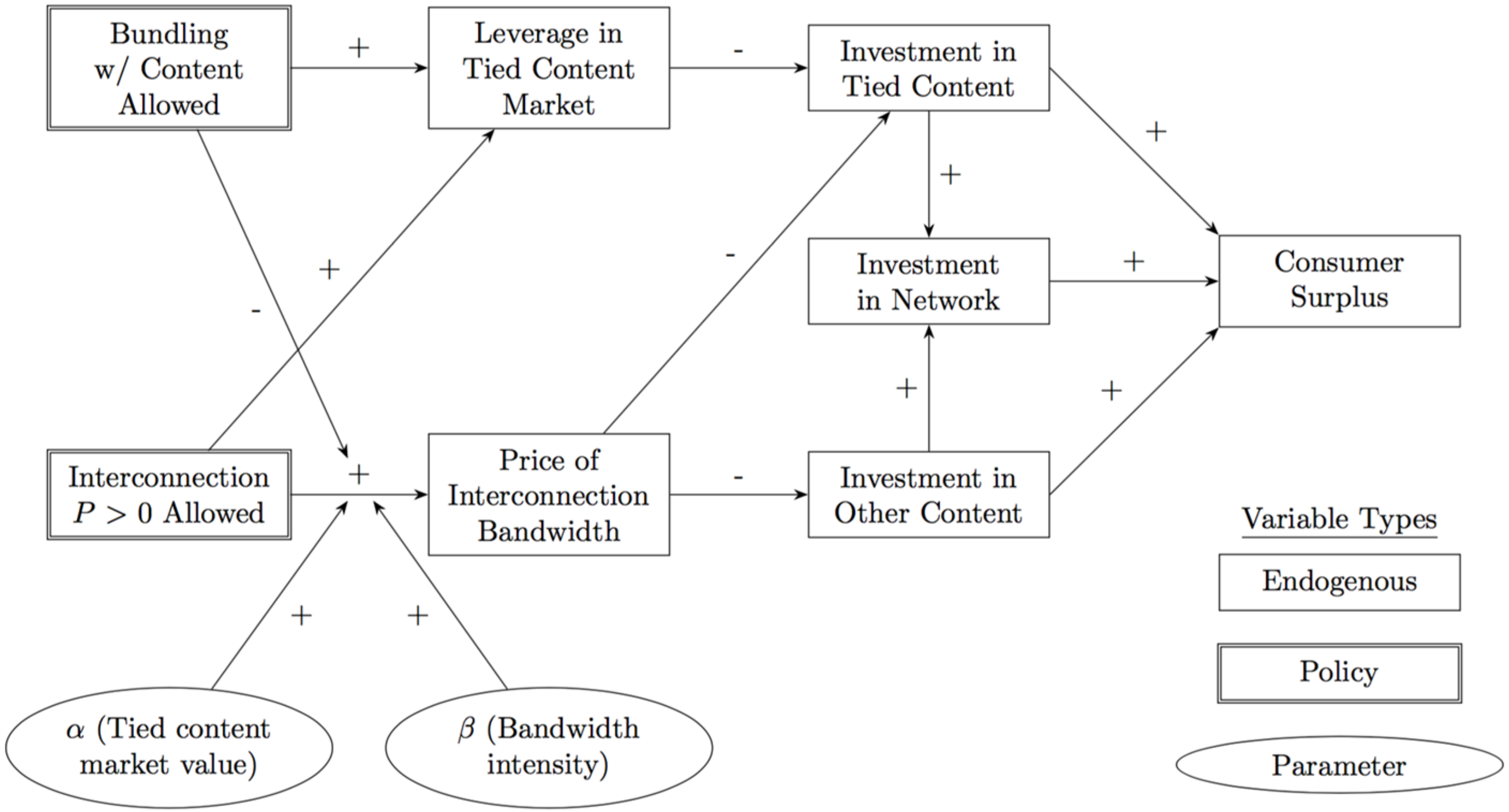
The simplified agent model



Source: Koning, 2017

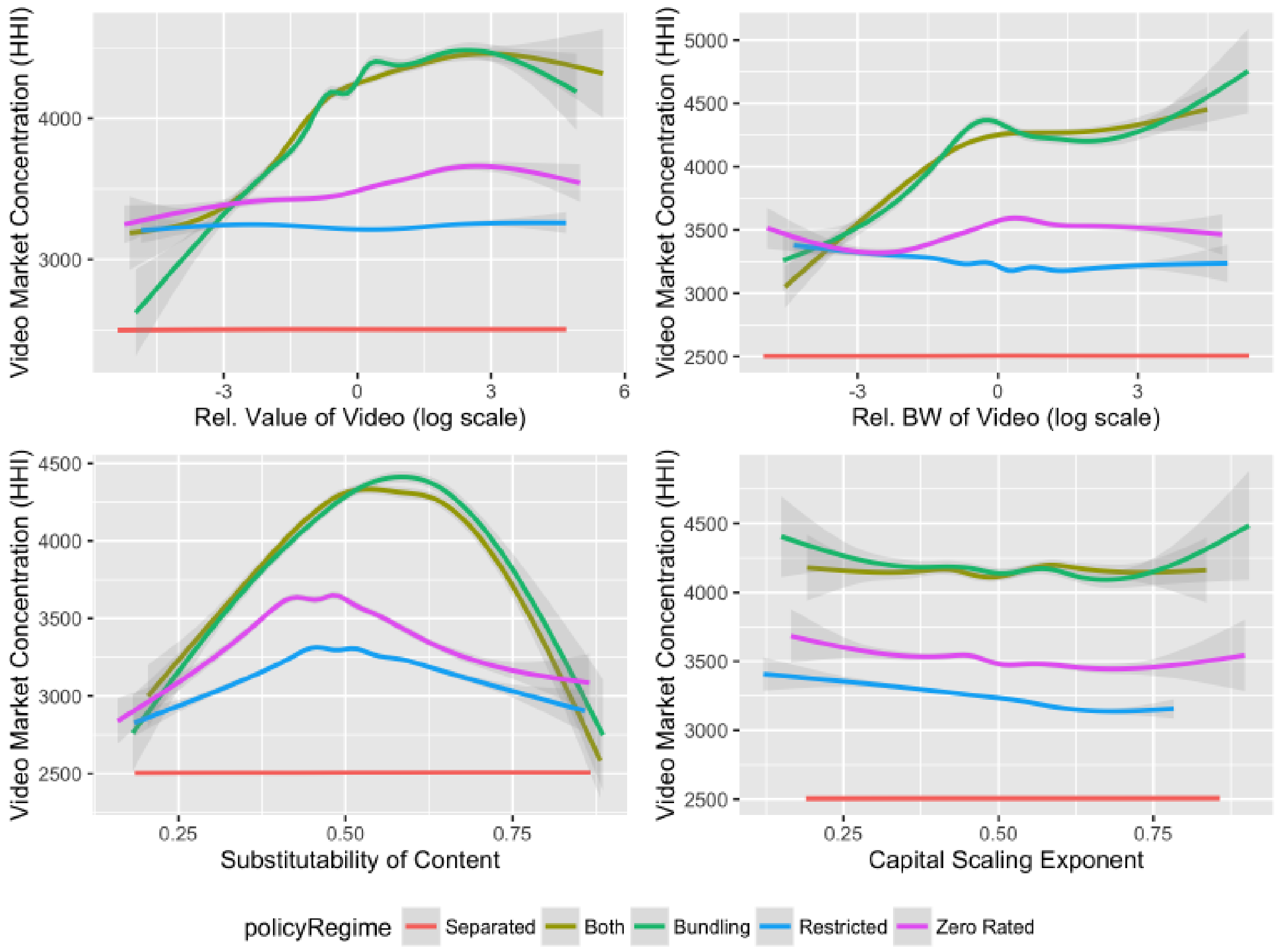
- Consumers optimize utility
- Internet Service Providers (ISPs) and content producers optimize profits
- Regulatory variables
  - Structural separation (Y/N)
  - Bundling allowed (Y/N)
  - Zero rating allowed (Y/N)
  - Ability of ISPs to charge content providers (Y/N)
- Factorial design, model runs generate empirical data on outcomes

Relations among major variables



Source: Koning, 2017

Selected findings for market concentration



Source: Koning, 2017

Big data analytics and ABM

- Big data analytics can help to build better agent-based models
  - Calibration of effect sizes
  - Assessing the validity of model (e.g., by replicating outcomes using past data)
- Big data can improve monitoring of effects of policy changes
  - Provisions for data collection and data sharing needed (e.g., data trustees)
  - Needs to be complemented by analytical, causal models of underlying processes
- ABM allows evaluating potential effects of structural policy changes on overall system and in selecting a preferred course of action
- However, ABM needs considerable refinement before robust recommendations can be derived

Recap and conclusion

Recap of main points

1. Information and communication policy faces grand challenges that require a dynamic systems approach to be addressed effectively
2. Big data analytics is a promising tool that can help improve policy analysis, design, implementation, and monitoring
3. However, because policy often seeks to change the system it is interacting with, big data analytics has limitations
4. Computational methods and integration with other types of social scientific analysis can help overcome these shortcomings

Obrigado!
Thank you!

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