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 should 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/](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

- Examination of policy options
  - Conflicts between instruments
  - Indirect effects
  - Likely effects on static and dynamic performance goals
  - Possible undesired effects
  - Costs and benefits of intervention

- Policy implementation

- Monitoring, review, analysis of deviations between goals and outcomes

- Policy adaptation (termination, modification, ...)

- Analysis of status quo, performance gaps, definition of policy vision
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
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

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 per PoP US$

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

![Divergence between public data and actual uses](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
More than 300,000 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 Networks 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)
- Work
- Browse the web
- Watch video
- Use social media
- Use virtual conferencing services
- Use a gaming service
- Other (please specify)
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
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

- Contestability_B
- Opportunities_B
- Appropriability_B
- Contestability_A
- Opportunities_A
- Appropriability_A

Investment/innovation decision layer B (e.g., ASPs)
Investment/innovation decision layer A (e.g. MNOs)

Rate and direction of sector investment and innovation

Regulation
- Horizontal (backhaul, roll-out, …)
- Vertical (MVNO, net neutrality, …)

Coordination cost
Complementarity

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

Source: Bauer & Bohlin, 2019
Positive and negative feedbacks

Mandated MVNO access

Incentives for MVNO innovation

Overall effect?

Incentives for MNO innovation

Rate and direction of innovation

Overall effect?
Regulation does not control, but „tune“ the system

Investment, innovation (incentives)

Network investment, innovation

"Workable" regulation

Applications and services investment

Acceptable performance

Total investment, innovation

No access regulation

Strict access regulation

R^L \quad R^* \quad R^U
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/](http://ccl.northwestern.edu/netlogo/models/)
ABM applied to vertical integration


- 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

Source: Koning, 2017
The simplified agent model

- 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

Source: Koning, 2017
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!
References


References...


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