Sufficient Statistics and Policy Evaluation

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- Counterfactual/causal/what-if questions:
  - What are the effects of trade liberalization, or the recent US-China trade war?
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  - Do transportation infrastructure investments justify their astronomic price tags?

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  - Is urban gentrification leading to spatial inequalities and an erosion of opportunities for economic mobility?
  - Do transportation infrastructure investments justify their astronomic price tags?
- What role does data play in answering those questions? Why do we need theories?
  - Economic theory alone does little to narrow the range of quantitative answers: policy relevance in question
  - Usually nature does not grant us sufficiently rich quasi-experimental serendipity which can deliver answers from data alone
  - The only option on the table is to combine the lessons of economic theory with what we can glean from empirical patterns

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  - Additional information in need: modeling assumptions and the logical deductions
- Formalize these assumptions and deductions: structural (empirical) model:
  - A clear mapping of assumptions to answers
  - *Minimize* the need for theoretical assumptions through **the use of facts that can be extracted from the available data**
  - Bridge the gap between **what is identified** and **what is desired**

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- Quasi-experimental variations to identify $X \Rightarrow Y$: an instrument Z that affects Y merely through X

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- Interpretation: predictions on the effects of a large-scale traveling subsidy to migrants?

Quasi-Experiment: A Less Ideal Case

- Suppose that:
  - θ is known: *e.g.* $Y = W$
  - X is not random: *i.e.* $X \neq Z$
- Example: How much would the GDP of a typical country be harmed if it were less open to trade? Feyrer (2021)
  - W is observed: GDP
  - X (trade flows) is not random
  - Instrument Z: Variation in the exposure of countries to the increase in shipping distances caused by the Suez Canal blockade

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    - Direct effect: trade elasticity (θ) estimated by gravity equation
    - Indirect effect: tariffs (t) $\Rightarrow$ wages (w) $\Rightarrow$ trade flows (λ)
    - A model on how wages and trade flows are determined in a general equilibrium system:

$$f(w, t; \theta) = 0, \quad \lambda = \lambda(w, t; \theta) \tag{1}$$

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- In this case, even when W is observed, we still need a model to evaluate the **overall** effects of X on W
  - In general, evaluating overall effects of X on W requires additional assumptions, in particular about **indirect effects**
  - Another example is Adao et al. (2022) on how the China shock affects the U.S. local labor markets

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  - X (regional exposure to tariff liberalization) may not be random: utilize Bartik IV
  - W (the real income of households) is unobserved: utilize Engel-like curve relates the hard-to-measure desired outcome (real income, W) to the easy-to-measure surrogate (meat expenditure shares within food, Y)

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- Sometimes the surrogate is nonlinear but direct:
  - Explicit $W = g(Y, \theta)$
  - Assumption: X has no effect on the difference between W and $g(Y, \theta)$

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    - X (changes in the US protectionism tariffs) is plausibly exogenous
    - $X \Rightarrow$ four key auxiliary outcomes (Y): **prices and quantities** of products coming into the US from tariff-hit countries relative to others; similar prices and quantities for products leaving the United States for retaliating countries relative to others
    - General equilibrium model of entire US production and consumption is needed to answer the researchers' question about **aggregate real income** (W):

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- The model (implicitly) specifies
  1. Surrogacy function $g(Y, \theta)$
  2. How θ can be pinned down by available data

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  - The logical essence of the model changes as we condition on a different set of auxiliary outcomes

  - The parameters θ of the model $g(Y, \theta)$ are specific to that model: *Borrowing parameters from microeconomic models forgets that parameters do not have a life of their own as some kind of platonic entity. Instead, parameters have meaning only within the context of a particular model*

  - We write down models that strike a balance between plausibility, parsimony, and (statistical) precision, but always **relative to the question of interest and the data available**

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  - We write down models that strike a balance between plausibility, parsimony, and (statistical) precision, but always **relative to the question of interest and the data available**
- *Different* models may agree on their answers to $X \Rightarrow W$, **once we condition on features of the available data**
  - These data features are called sufficient statistics
  - Marschak's Maxim: low-dimensional combinations of model elements (observable in the data) could suffice for answering a given policy question

Sufficient Statistics

- Example: When local governments offer subsidies and other incentives to attract large businesses, are their residents better off? Greenstone and Moretti (2003)
  - X (subsidies) $\Rightarrow$ Auxiliary outcome Y (observed change in land values) $\rightarrow_{\text{sufficient statistics within a class of models}}$ W (local residents' welfare)
  - A class of models: (1) workers are mobile and have identical preferences; (2) local land is in fixed supply; (3) other factors (such as labor and capital) are mobile; and (4) land markets are competitive

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- Sufficient statistics is context-specific: **asking models to agree when they are being used to answer a specific question**

Necessary Statistics

- Find data on the sufficient statistic variables and make the model discrepancy go away
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- **Envelope theorem**: any indirect effects due to the agent changing its behavior are zero to first order

$$V(\alpha) = \sup_{x \in \mathcal{X}} f(x, \alpha); \mathcal{X}^*(\alpha) = \{x \in \mathcal{X} : f(x, \alpha) = V(\alpha)\} \Rightarrow V'(\alpha) = f_\alpha(x, \alpha), \forall x \in \mathcal{X}^*(\alpha) \quad (3)$$

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- Assumption: the consumer under study is optimizing her consumption bundle, given prices

Necessary Statistics

- Example: a rise in American tourists $(X) \Rightarrow$ individual's welfare (W) Allen et al. (2021)
  - $X \Rightarrow Y$ (changes in prices and wages): instrument Z (exogenous variation in the timing and neighborhood concentration of certain tourists)
  - W is simply a function of that individual's budget shares on each price and earnings shares on each type of income

Unnecessary Statistics

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  - Simpler data requirements: the long vector of micro data includes **a set of unnecessary statistics**, once we condition on observing the shorter vector of **macro data**

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- Example: How much does a country gain from the trading it does with the wider world? Arkolakis, Costinot, and Rodríguez-Clare. (2012)
  - A large class of gravity models: (1) consumers have constant-elasticity of-substitution preferences; (2) firms have heterogeneous but constant marginal costs of selling to any country; (3) firms use one factor that is in fixed supply to each location; and (4) firms compete either perfectly competitively or monopolistically competitively
  - The welfare cost of autarky for a given "Home" country is a function of just two statistics: (1) the value of the trade elasticity and (2) the current share of imports in Home's total consumption
  - Underlying micro data (*e.g.* that on the sets of firms, products) are **unnecessary statistics** for the question at hand and within the class of models considered

Unnecessary Statistics

- Armington model without tariffs: $\lambda_{in} = \frac{\left(\frac{w_i \tau_{in}}{A_i}\right)^{1-\sigma}}{\sum_{k=1}^{N}\left(\frac{w_k \tau_{kn}}{A_k}\right)^{1-\sigma}} = \left(\frac{w_i \tau_{in}}{A_i}\right)^{1-\sigma} P_n^{\sigma-1}$
  - Welfare changes led by changes in trade costs: $\hat{W}_i \equiv \frac{\hat{w}_i}{\hat{P}_i} = \hat{\lambda}_{ii}^{\frac{1}{1-\sigma}}$

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- Spatial model: $\lambda_{in} = \left(\frac{w_i \tau_{in}}{\bar{A}_i L_i^{\alpha}}\right)^{1-\sigma} P_n^{\sigma-1}$
  - Welfare changes led by changes in trade costs:

$$\hat{W} \equiv \left[\sum_{i=1}^{N} \iota_i \left(\frac{\hat{w}_i}{\hat{P}_i}\right)^{\frac{1}{\beta}}\right]^{\beta} = \left[\sum_{i=1}^{N} \iota_i \left(\hat{\lambda}_{ii}^{\frac{1}{1-\sigma}} \hat{L}_i^{\alpha}\right)^{\frac{1}{\beta}}\right]^{\beta}$$

Sufficient Functions

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- Example: How much does a country gain from the trading it does with the wider world? Adao, Costinot, and Donaldson (2017)
  - A class of models with **arbitrary** preferences and **arbitrary** technologies used under competitive conditions

  - The trade model is isomorphic to one in which countries instead merely trade the services of their (geographically immobile) factors: any country has a set of well-behaved but "reduced" preferences over the factor services (**reduced factor demand functions**)

  - To the extent that there are **fewer factors than goods**, the summary offered by reduced preferences is **dimension-reducing**

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- When the goal is to design optimal policies, the role that theory and data play is purely to provide **a measure of the magnitude of market failures** and of the consequences of real-world **limits on lump-sum transfer** schemes

- Under a wide range of assumptions, designing optimal policies depends intimately on the size of wedges
  - Some wedges are direct to quantify (*e.g.* 10% tariffs); others are not, e.g. pollution
  - X (observed measure of the private benefit or cost) $\Rightarrow$ Y (observed measure of the social benefit or cost of an agent's actions): a measure of the ratio of marginal social benefit to marginal social cost (exactly the wedge we seek to understand)
  - *e.g.* The firm's markup: (1) the marginal social value of this action, per unit produced, is simply the price it charges to consumers; and (2) the marginal private cost, to the firm, of producing is simply the cost of producing an additional unit.

Wedges and Optimal Policies

- Example: Where should place-based policies and infrastructure investments be optimally placed to maximize national output? Kline and Moretti (2014)
  - Place-based policies only make sense if there are local positive externalities of production in the region—which would drive a wedge between private and social values of production and result in inefficiently low levels of output

  - Understand the optimal place-based policies requires the estimation of the shape of the local spillovers: a nonlinear relationship between local productivity (Y) and local production size (X), using features of the TVA program as instruments (Z)

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- More plausibly, a government can levy taxes in relation to a household's earnings only
- What are the optimal policies then? Challenge: What actually are the government's objectives? *e.g.* Weights across households/firms
- Example: How should import tariffs be designed to achieve redistributional objectives? Costinot and Werning (2022)
    - Assumption 1: the government's redistributional objective is a function of incomes (rather than the identities of taxpayer identities per se)
    - Assumption 2: the observed income tax schedule is being used by this government in reflection of whatever those objectives may be
    - The optimal tariff on Chinese imports is a function of four sufficient statistics: (1) the marginal income tax schedule; (2) the income distribution; (3) elasticities of labor supply at each income level; and (4) estimates of the impact of Chinese imports on wages at each quantile of the income distribution

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- Hulten's theorem: an economy-wide application of the envelope theorem
  - The first-order benefits of a shock X in an efficient economy are simply given by the vector of "Domar weights" (which are simply the value of production as a share of GDP) on all activities that are directly affected by X

  - The second-order benefits are given simply by the changes in the Domar weights of directly-affected activities

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- Quantify the impacts of X in the absence of market failures:
  1. The size of the direct productivity changes caused by X
  2. The size of the Domar weights on those directly affected activities (first-order)
  3. The effects of X on the changes in the Domar weights (second-order)

Impacts of Shocks in the Presence of Market Failures

- In the presence of market failures, a first-order component of $X \Rightarrow W$ will hinge on two additional mechanisms:
    1. The extent to which the shock to X causes reallocations of primary factors towards those activities that have large positive wedges (social value $>>$ private value): a fortunate benefit of X that could not happen in an efficient economy (Baqaee and Farhi (2020))
    2. The extent to which the shock actually changes the wedges themselves: additional benefits

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- Example: Can an export demand shock improve allocative efficiency? McCaig and Pavcnik (2018)
  - Formal firms face greater taxation and regulation: larger value marginal products of labor $\rightarrow$ labor productivity wedge

  - Vietnamese manufacturing industries that saw relatively large reductions in US import tariffs exported more to the United States and expanded employment, and they did so relatively more among the formal-sector firms within such industries

  - Quantify the effect of the trade agreement (X) on labor reallocation (Y) and multiply this estimated effect by the labor productivity wedge

Concluding Remarks

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- To extrapolate from the **estimated effects** to the **counterfactual questions**, it is vital that researchers understand the **data-assumptions frontier** in which
  - they invoke only the most plausible theoretical assumptions necessary to map the data they have to the questions at hand
  - they seek to *minimize* reliance on modeling assumptions by drawing on data that can resolve model ambiguities to the greatest extent possible

Readings

- More details on sufficient statistics: Henrik J. Kleven (2021)
- General tips on economic research: Simon W. Bowmaker (2012) “The Art and Practice of Economics Research: Lessons from Leading Minds”