Agricultural Production and Technological Change

Course Overview and Objectives

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AREC 705: Lecture 1

Colorado State University

Introductions

About this class:

- Syllabus
- Course Webpage
- Grades and Assignment Submissions
- Expectations
- My promises to you
- Questions?

My objectives for you:

- Familiarity with the literature and methods
- Improved ability to develop and solve theoretical models
- Fairly polished research paper
- Ability to write and respond to formal referee reports

Introductions

About me

- Originally from Chicago
- B.S. and M.S. in agricultural economics from UIUC
- Ph.D. in agricultural economics from UC Davis
- Most of my research is on the productivity and labor supply of agricultural workers.

About you:

1. Why are you in this class and what are you hoping to get out of it?
2. What sort of job(s) are you interested in?
3. What software or platforms are you most familiar with?
4. Are there any software or platforms you are interested in learning?
5. What are your current research interests or experiences?
6. Of the topics on the course outline, which are you most and least interested in?

Course Topics

Advanced Producer Theory and Analysis

Technology and Productivity

Efficiency and Productivity Analysis

Contract Theory

Advanced Market Models

Week One: Course Overview

This week we will be glancing at the literature in each of the topic areas.

At the end of the week you should be able to answer the questions:

- How should I read a research paper and what does this imply for how I should write a research paper?
- What characterizes each topic area/field?
- What models will we be learning that are commonly used in each field?
- What are some gaps in the literature?
- What am I most interested in researching?

At the end of next week (9/2) you will be submitting three research ideas for your term paper.

Reading and Writing Academic Papers

Keshav, S. How to Read a Paper. Link:
`https://web.stanford.edu/class/ee384m/Handouts/HowtoReadPaper.pdf`

Three-pass approach:

First –

Second –

Third –

Reading and Writing Academic Papers

The "five C" approach:

Category –

Context –

Correctness –

Contributions –

Clarity –

Reading and Writing Academic Papers

My expectation for every class is that you can answer the following:

Contributions – what question(s) is the paper addressing? –

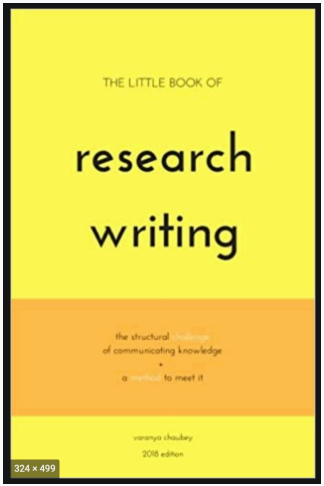
Category – theoretical? empirical? case study? meta-study? –

Conclusions – what are the results? –

Context – what are related papers? who are the authors? –

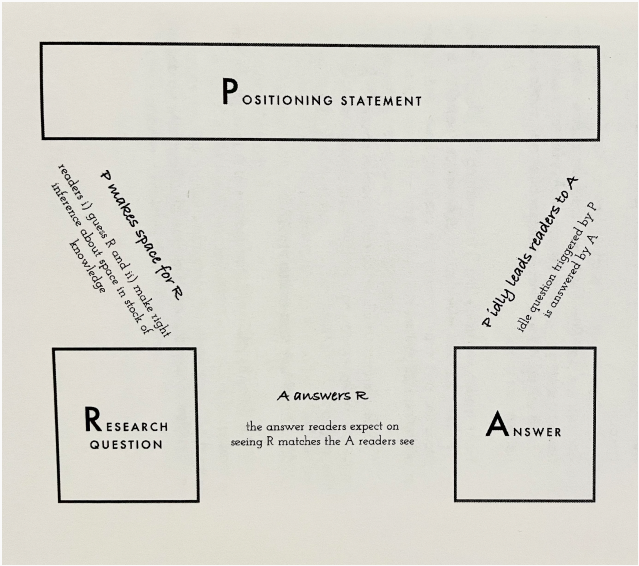
Methods – what methods are used to analyze the problem? –

Reading and Writing Academic Papers



RAP Framework

Overview: Technology and Productivity



A few other resources (in the syllabus):

Cochrane, John H. (2005). Writing Tips for Ph.D. Students. Link: https://faculty.chicagobooth.edu/john.cochrane/research/papers/phd_paper_writing.pdf

Gentzkow, M. & Shapiro, J.M. (2014). Code and Data for the Social Sciences: A Practitioner's Guide. Link: https://web.stanford.edu/~gentzkow/research/CodeAndData.pdf

Head, Keith. The Introduction Formula. Link: http://blogs.ubc.ca/khead/research/research-advice/formula

Overview: Adv. Producer Theory and Analysis

What makes agriculture unique?

Why is agricultural production different from the production of widgets?

How do we go about modeling and analyzing the behavior of agricultural producers given these complexities?

We can begin with a multi-period production function that accounts sequential stages and temporal allocation:

$$y = f\left(f_1\left(\boldsymbol{x}^1, t_1\right), ..., f_m\left(\boldsymbol{x}^m, t_m\right)\right), \tag{1}$$

where y is a single output, $\boldsymbol{x}^i$ is the variable input vector at time t_i, $\boldsymbol{x}^m$ are harvest inputs applied at time t_m, and there are m-production stages.

How do we go about modeling and analyzing the behavior of agricultural producers given these complexities?

We could alternatively represent this production function problem as a function of intermediary outputs, y_i:

$$\begin{aligned} y &= f_m\left(\boldsymbol{x}^m, t_m, \left(f_{m-1}\left(\boldsymbol{x}^{m-1}, t_{m-1}, f_{m-2}\left(\boldsymbol{x}_{m-2}, t_m, ..., f_1(\boldsymbol{x}_1, t_1, y_0), ...\right)\right)\right)\right) \\ &= f^*\left(f_1\left(\boldsymbol{x}^1, y_0\right), ..., f_m\left(\boldsymbol{x}^m, y_{m-1}\right)\right) \end{aligned} \tag{2}$$

where y_0 are initial conditions, y_i is the output at stage i, and the efficient production is such that the producer applies inputs $\boldsymbol{x}^i$ to maximize y_i at each stage i.

Overview: Adv. Producer Theory and Analysis

How do we go about modeling and analyzing the behavior of agricultural producers given these complexities?

Given commonly available data (annual), we tend to proxy this as:

$$y = f^0(\boldsymbol{x}) \approx f^0(\boldsymbol{x}, y_0) \approx \max_{\{x_i\}} \{f^*(.) \mid \sum_{\forall i} x_i = \boldsymbol{x}\} \tag{3}$$

Why is this representation problematic and what data might be usable to improve the estimation of y?

Overview: Adv. Producer Theory and Analysis

How do we go about modeling and analyzing the behavior of agricultural producers given these complexities?

Given commonly available data (annual), we tend to proxy this as:

$$y = f^0(\boldsymbol{x}) \approx f^0(\boldsymbol{x}, y_0) \approx \max_{\{x_i\}} \{f^*(.) \,|\, \sum_{\forall i} x_i = \boldsymbol{x}\} \tag{4}$$

An example in recent literature:

McArthur, J.W. & McCord, G.C. (2017). Fertilizing Growth: Agricultural Inputs and their effects in Economic Development. *Journal of Development Economics*.

$$a_{it} = \beta_0 + \beta_1 f_{it} + \delta' X_{it} + \eta_t^a + \varepsilon_{it}^a$$

$$\varepsilon_{it}^a = \mu_i^a + \nu_{it}^a$$

Overview: Adv. Producer Theory and Analysis

How do we go about modeling and analyzing the behavior of agricultural producers given these complexities?

There are far too many sub-topics within "producer theory" to cover them all. In this course we will go in depth in a few:

1. Theory: Production Decisions
   - Optimal planting of perennials
2. Empirical: Modeling supply
   - Assumptions on expected prices
   - Nerlovian supply response
   - Applications on perennials
3. Theory and empirical: Subsistence and economic production
4. Theory and empirical: Producer decision-making under risk

Overview: Technology and Productivity

Why does technological innovation occur?

Overview: Technology and Productivity

Induced Innovation Hypothesis

"A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind directed to economizing the use of a factor which has become relatively expensive." (Hicks 1932)

Publicly Funded Innovations

Public spending for research and development in agriculture yields high rates of returns. These are justified in agriculture due to the public-good nature of many of these activities (e.g., De Gorter & Zilberman 1990)

Institutional Policies

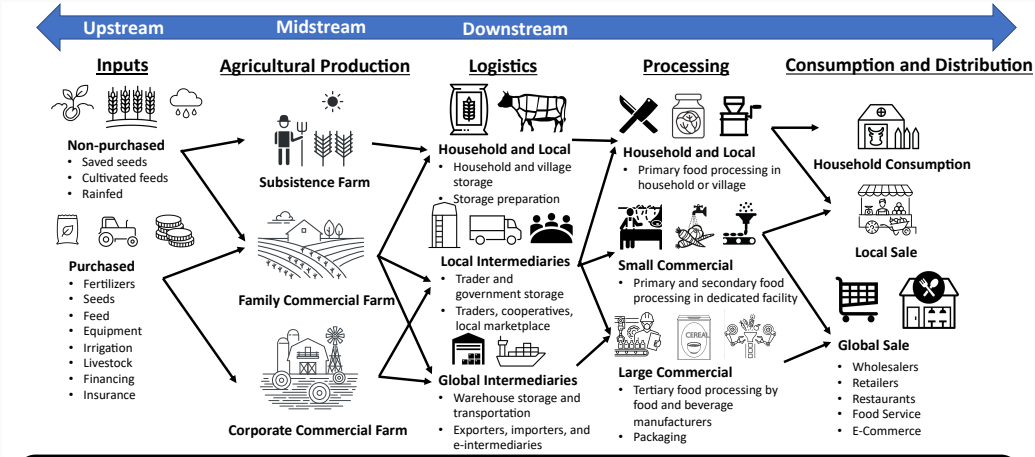
A variety of institutional policies can encourage (patents) or discourage (protectionism policies) technological innovation.

Overview: Technology and Productivity

Why does technological innovation occur?

Is there anything novel about technological innovation in agriculture compared with other industries?

Overview: Technology and Productivity



Change in Labor Demands after Farm Adoption of Automation Technologies

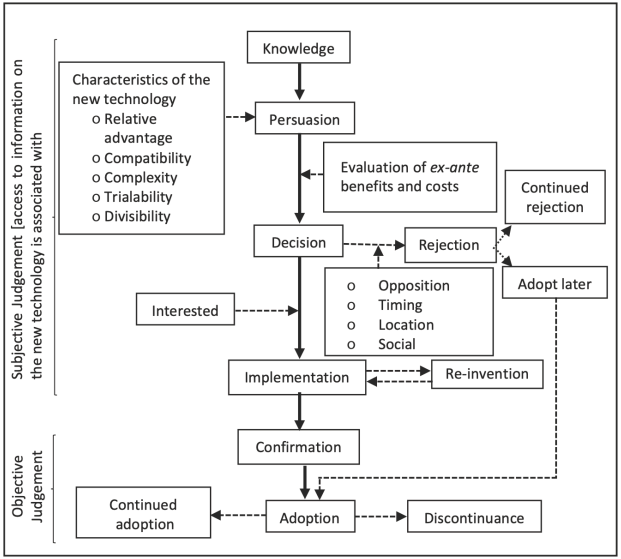
Overview: Technology and Productivity

Why does technological innovation occur?

Is there anything novel about technological innovation in agriculture compared with other industries?

Why would agricultural producers choose to adopt (or not) a new technology?

Overview: Technology and Productivity



Source: Ugochukwu, A.I., Phillips, P.W.B. (2018)

Overview: Technology and Productivity

What we will cover:

1. Theoretical: Technology generation, adoption, and diffusion

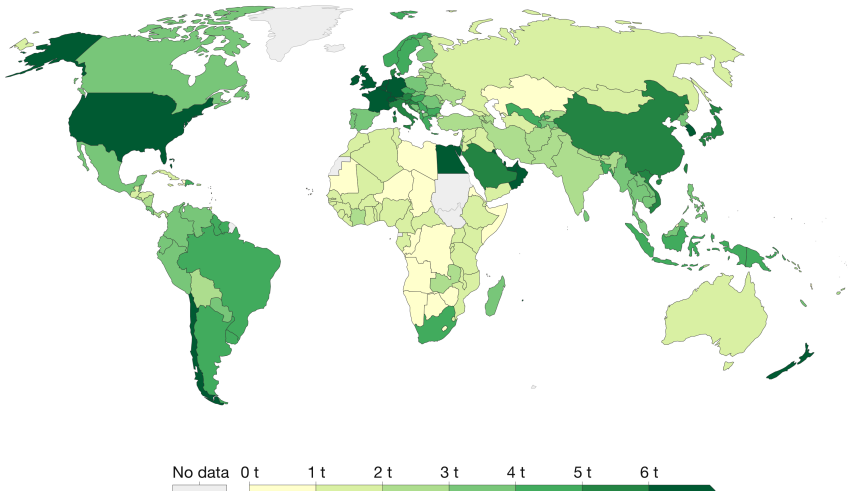
2. Theory and Empirical: The role of new technologies in producer decision-making
   - Technology adoption decision
   - Perennial planting decision
   - Learning about the new technology
   - Impacts of technology adoption on other production decisions

Overview: Efficiency and Productivity Analysis

Cereal yield, 2010

Cereal yields are measured in tonnes per hectare. Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains.

Our World in Data



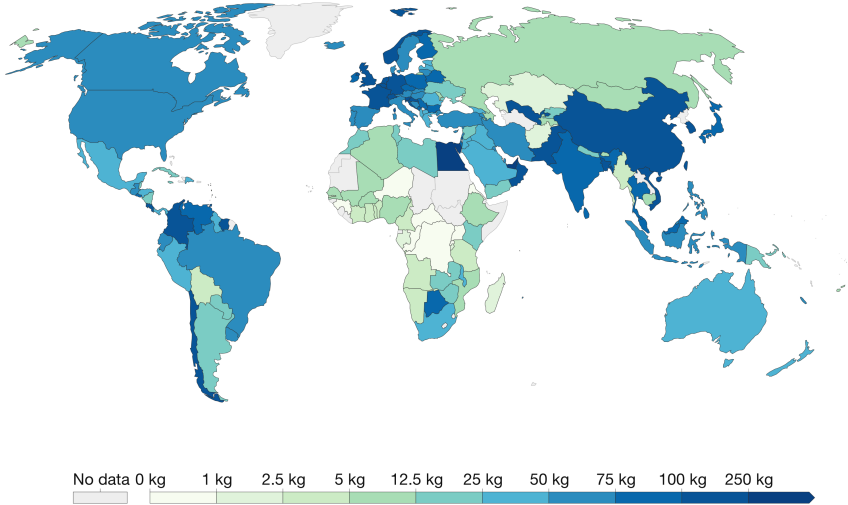
Source: UN Food and Agriculture Organization (FAO)

OurWorldInData.org/crop-yields • CC BY

Nitrogen fertilizer use per hectare of cropland, 2010

Application of nitrogen fertilizer, measured in kilograms of total nutrient per hectare of cropland.

Our World in Data



Source: UN Food and Agricultural Organization (FAO)

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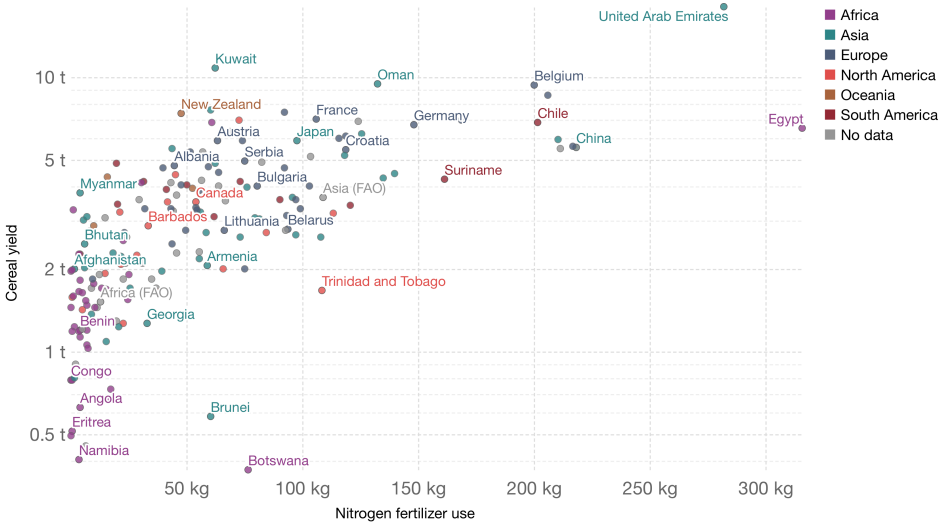
Cereal yield vs. fertilizer use, 2010

Cereal yields are measured in tonnes per hectare. Fertilizer use is measured in kilograms of nitrogenous fertilizer applied per hectare of cropland.



Source: UN Food and Agriculture Organization (FAO)

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Overview: Efficiency and Productivity Analysis

What (other) factors can explain heterogeneous yields?

Overview: Efficiency and Productivity Analysis

What (other) factors can explain heterogeneous yields?

Why do we often include a vector of farmer covariates in our regression equations for yields?

$$Y_{it} = \beta_0 + \beta_1 \mathbf{X_{it}} + \beta_2 \mathbf{Z_i} + \mu_t + \varepsilon_{it}$$

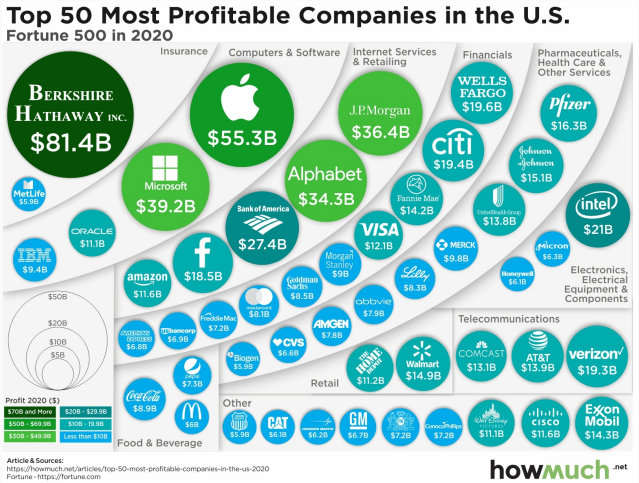
Where,

$\mathbf{X_{it}}$ = soil characteristics, fertilizer, irrigation, pesticides, etc.

$\mathbf{Z_i}$ = operator gender, education level, location, etc.

Overview: Efficiency and Productivity Analysis

In the broader economy, what factors explain differences in profits across firms?



Overview: Efficiency and Productivity Analysis

Productivity

is the ratio of output to input.

Productivity Growth

is the *difference* between the growth in outputs and the growth in inputs.

Variation in Productivity

is a residual.

> *"... a measure of our ignorance."*
>
> *(Abramovitz 1956)*

What constitutes the residual?

- Production technology
- Scale of operation
- Operating environment
- **Efficiency**

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- Production technology
- Scale of operation
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The comparison between observed and optimal values of output and input.

Overview: Efficiency and Productivity Analysis

What constitutes the residual?

- Production technology
- Scale of operation
- Operating environment
- **Efficiency**

The comparison between observed and optimal values of output and input.

1. Which outputs and inputs should be included in the comparison?
   - How do we separate efficiency from other components of the residual?
2. How are multiple outputs and inputs to be weighted?
   - How do we account for differences in prices across time and firms?
   - How do we account for missing market prices (e.g., externalities)?
3. How are the optimal values determined?

What constitutes the residual?

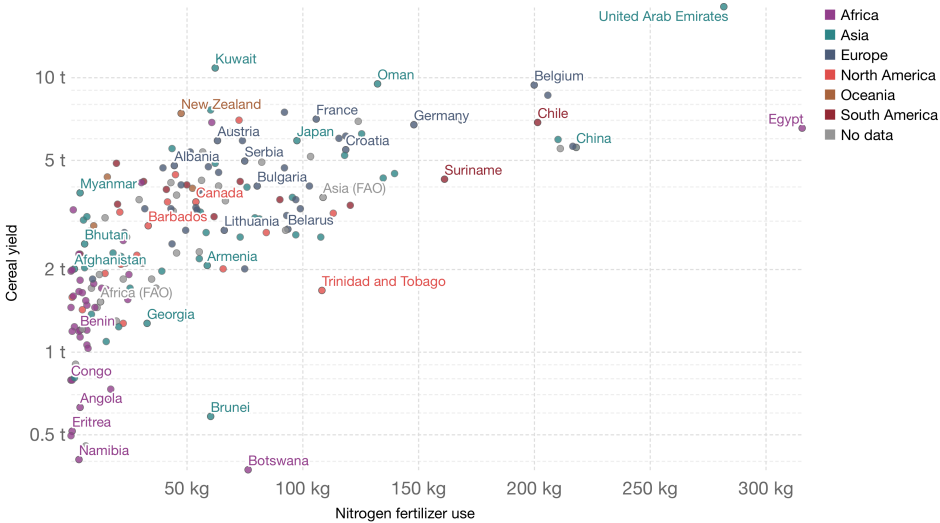
- Production technology
- Scale of operation
- Operating environment
- **Efficiency**

Why tease out these components of the residual?

> *"Only by measuring efficiency and productivity, and by separating their effects from those of the operating environment so as to level the playing field, can we explore hypotheses concerning the sources of efficiency or productivity differentials. Identification and separation of controllable and uncontrollable sources of performance variation is essential to the institution of private practices and public policies designed to improve performance."*
>
> *(Fried, Lovell & Schmidt)*

Cereal yield vs. fertilizer use, 2010

Cereal yields are measured in tonnes per hectare. Fertilizer use is measured in kilograms of nitrogenous fertilizer applied per hectare of cropland.



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Cereal yield vs. fertilizer use, 2019

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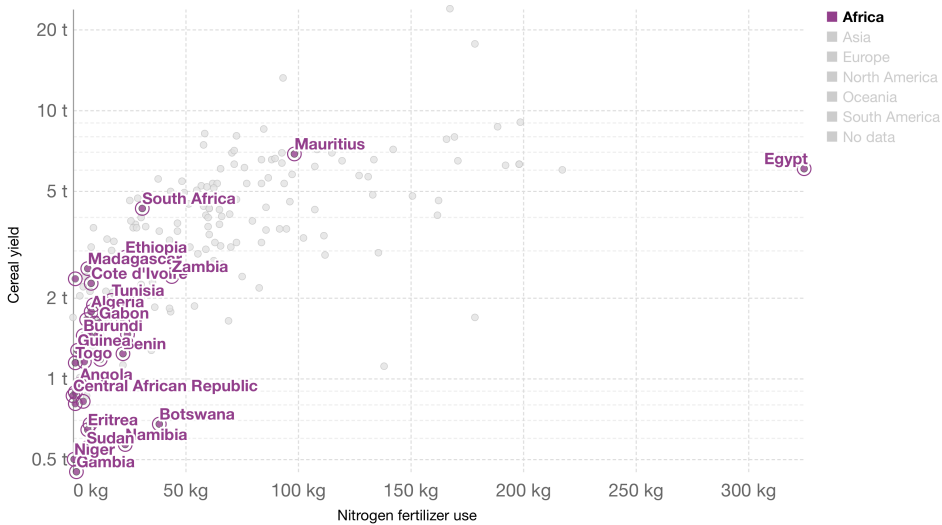

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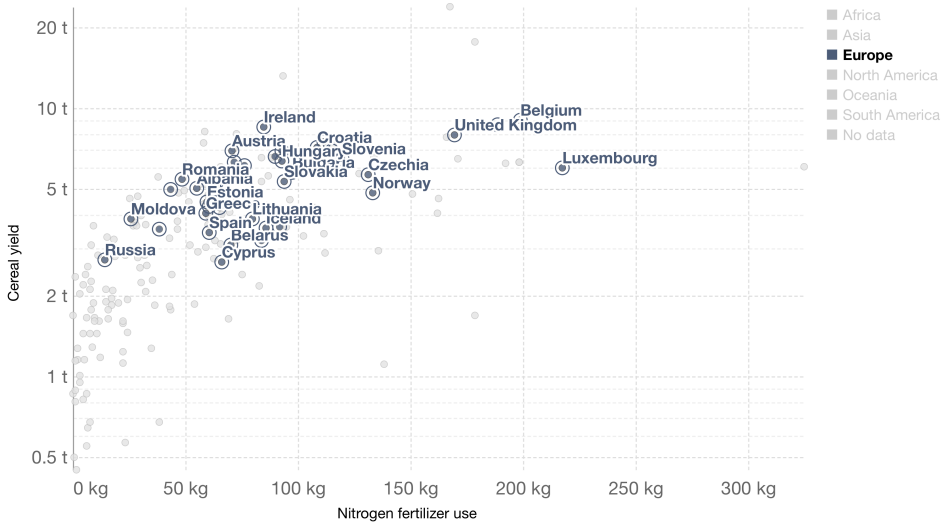

Source: UN Food and Agriculture Organization (FAO)

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How do we study efficiency?

Let's define a set of inputs used by producers as $x = (x_1, ..., x_N) \in R_+^N$ and a set of outputs produced by those inputs as $y = (y_1, ..., y_M) \in R_+^N$. Then production technology can be represented by a set of inputs and outputs:

$$T = \{(y, x) : x \text{ can produce } y\}.$$

We can also define technology by input (or level) sets

$$L(y) = \{x : (y, x) \in T\},$$

which for every $y \in R_+^M$ have input isoquants

$$I(y) = \{x : x \in L(y) \text{ and } \lambda x \notin L(y) \text{ if } 0 \leq \lambda < 1\}.$$

Could inefficiency explain any of these differences?

These input isoquants define the production function. We can then define the input efficient subsets in terms of the level sets:

$$E(y) = \{x : x \in L(y), x' \notin L(y) \text{ for } x' \text{ when } x'_k \leq x_k \forall k \text{ and } x'_k < x_j \text{ for some } j\}.$$

Then we can see that the three sets will satisfy: $E(y) \subseteq I(y) \subseteq L(y)$.

Overview: Efficiency and Productivity Analysis

What methods will we use in this class?

- Theoretical underpinnings
- Data Envelopment Analysis (DEA) – non-parametric production frontiers
- Stochastic Frontier Analysis (SFA) – parametric/ some semi-parametric
- Alternative measures and analyses of firm productivity

Overview: Agricultural Contracts

Overview: Agricultural Contracts

Three typical contracts between farmers and downstream buyers

Resource-Providing Contracts

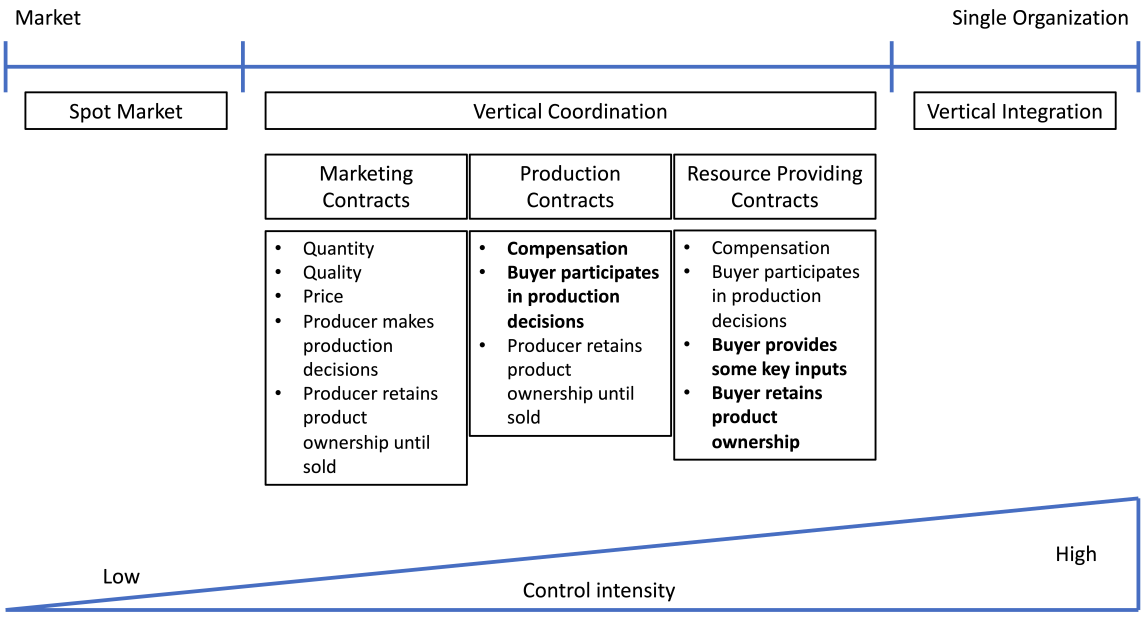
Buyer provides one or more production inputs and participates in management decisions.

Production-Management Contracts

Agreements (typically formal) between a buyer and a grower that specify at least some aspects of the production process as well as compensation.

Marketing Contracts

Formal or informal agreements between a buyer and a grower that set conditions of sale — price determination, quantity, and quality.


Market
Single Organization
Spot Market
Vertical Coordination
Vertical Integration
Marketing Contracts
Production Contracts
Resource Providing Contracts
• Quantity
• Quality
• Price
• Producer makes production decisions
• Producer retains product ownership until sold
• Compensation
• Buyer participates in production decisions
• Producer retains product ownership until sold
• Compensation
• Buyer participates in production decisions
• Buyer provides some key inputs
• Buyer retains product ownership
Low
High
Control intensity

Overview: Agricultural Contracts

Two types of theoretical approaches are used to understand contracting choices:

Agency Theory

Asymmetric information, moral hazard, and risk sharing.

Transaction Cost Economics

Characteristics of transactions defining a production process to explain why specific transactions are organized within a firm or through some method of coordination.

Overview: Agricultural Contracts

Some potential opportunities in contract agriculture...

Hop Contracting:
https://midwesthopproducers.com/brewer-connection-2/hop-contracting/

PACA rules, retail refusals, and strategic behavior of retail firms in fresh strawberry production (talk to me if interested!)

Overview: Agricultural Contracts

What we will cover:

1. Theory and Empirical: Labor Contracts
2. Theory and Empirical: Quality Contracts in the Output Market
3. If time and interest: Input Contracts

Overview: Advanced Market Models

How do producers and consumers interact and what are the implications for producer welfare?

How do we model the interplay between market agents?

Overview: Advanced Market Models

Consider a demand equation for agricultural economists at universities:

$$q_t^d = \beta_1 + \beta_2 U_t + \beta_3 W_t + e_t$$

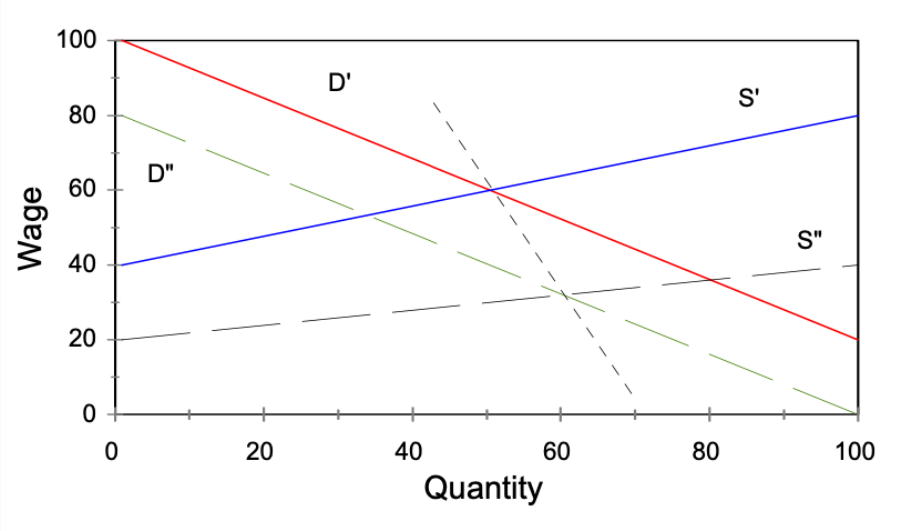
Where,
$U_t = \#$ of undergraduate students and
$W_T =$ wage rate

Consider a supply equation for agricultural economists at universities:

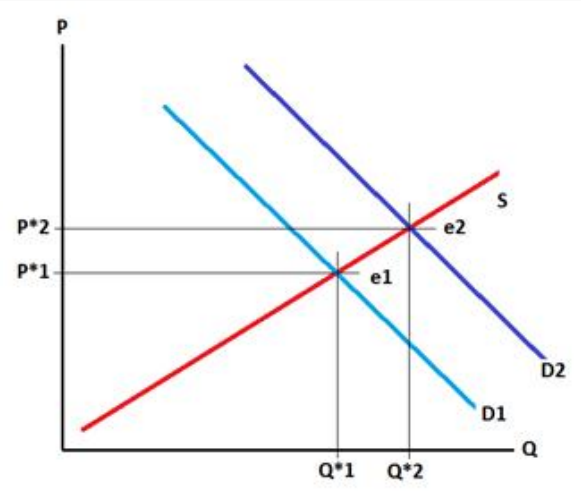
$$q_t^s = \alpha_1 + \alpha_2 R_t + \alpha_3 W_t + e_t$$

Where,
$R_t =$ mean wage rate in competing industries

Overview: Advanced Market Models



Overview: Advanced Market Models



Overview: Advanced Market Models

What we will cover:

1. Theory and Empirical: Systems of Simultaneous Equations
2. Theory and Empirical: Equilibrium Displacement Models
    - Single market models
    - Trade models
    - Multiple market models
    - Examples in recent literature
3. If time and interest: CGE Modeling

Assignments for Next Time

Advanced Producer Theory and Analysis I: Perennials

1. French, B.C. & Matthews, J.L. (1971). A Supply Response Model for Perennial Crops. *American Journal of Agricultural Economics, 53(3)*: 478–490. https://www.jstor.org/stable/1238225
2. Wickens, M.R. & Greenfield, J.N. (1973). The Econometrics of Agricultural Supply: An Application to the World Coffee Market. *The Review of Economics and Statistics, 55(4)*: 433–440. https://www.jstor.org/stable/1925665
3. Arak, M. (1968). The price responsiveness of Sao Paulo coffee growers. Food Research Institute Studies 8, 211-223. https://ideas.repec.org/a/ags/frisst/134980.html