Skills, Tasks and Technologies
Beyond the Canonical Model

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Skills Task and Technologies
Beyond the Canonical Model

- **Canonical model** — Elegantly, powerfully operationalizes supply and demand for skills
  - A formalization of Tinbergen’s “Education Race” analogy
  - Two distinct skill groups that perform two different and imperfectly substitutable tasks.
  - Technology is *factor-augmenting*—Always raises productivity/wages

- Model is a theoretical and empirical success
But model largely silent on some central empirical facts of last three decades:

1. Falling real wages of low-skill workers (at least in U.S.)
2. Non-monotone shifts in inequality, despite rising ‘return to skill’
3. Widespread ‘polarization’ of employment across advanced economies
4. Directly skill-replacing (not augmenting) technologies

Needed: Model with richer interplay between skills, tasks, technologies

1. Distinguish between ‘skills’ and ‘tasks’
2. Endogenize assignment of skills to tasks: Comparative advantage
3. Direct competition between skills, techs, trade in performing tasks
4. Nest canonical model as one possible case
What should an amended model offer?

Objectives

1. Explicit distinction between *skills* and *tasks*
   - Tasks—Unit of work activity that produces output
   - Skill—Worker's endowment of capabilities for performing various tasks

2. Allow for *comparative advantage* among workers in different tasks
   - Assignment of skills to tasks is *endogenous* (as in Roy, 1951)

3. Allow for multiple sources of competing task ‘supplies’
   - Workers of different skill levels
   - Machines—Task can be routinized/automated
   - Offshoring—As per Grossman, Rossi-Hansberg (2008)

4. Incorporate at least three skill groups—To study polarization

5. Goal: well-defined set of skill demands, as in canonical model

6. Ability to endogenize task-biased technological change
A Ricardian Model of Skills, Tasks and Technologies

- Related models
  - Heckman and Scheinkman (1987)
  - Acemoglu and Zilibotti (2001)
  - Autor and Dorn (2009)
  - Goos, Manning and Salomons (2009)
  - Costinot and Vogel (2010)

- Less general than Costinot and Vogel, but more 'shovel-ready.'
- 'Co-invention' (33 years later): Dornbusch, Fischer, Samuelson (1977)
  - Call tasks 'goods' (continuum)
  - Call skill groups 'countries' (DFS consider only Home and Foreign)
A Ricardian Model of Skills, Tasks and Technologies
Production technology: Tasks into goods

- Static environment with a unique final good, $Y$
- $Y$ produced with continuum of tasks on the unit interval, $[0, 1]$
- Cobb-Douglas technology mapping tasks the final good:

$$\ln Y = \int_0^1 \ln y(i) \, di,$$

where $y(i)$ is the “service” or production level of task $i$.
- Price of the final good, $Y$, is numeraire.
A Ricardian Model of Skills, Tasks and Technologies

Supply of skills to tasks

Three types of labor: High, Medium and Low

- Fixed, inelastic supply of the three types. Supplies are $L$, $M$ and $H$
- We later introduce capital or technology (embedded in machines)

Each task on continuum has production function

$$y(i) = A_L \alpha_L (i) l(i) + A_M \alpha_M (i) m(i) + A_H \alpha_H (i) h(i) + A_K \alpha_K (i) k(i),$$

- $A$ terms are factor-augmenting technologies
- $\alpha_L (i)$, $\alpha_M (i)$ and $\alpha_H (i)$ are task productivity schedules
- For example, $A_L \alpha_L (i)$ is the productivity of low skill workers in task $i$, and $l(i)$ is the number of low skill workers allocated task $i$. 
Role of comparative advantage

- All tasks can be performed by low, medium or high skill workers

\[ y(i) = A_L \alpha_L(i) l(i) + A_M \alpha_M(i) m(i) + A_H \alpha_H(i) h(i) + A_K \alpha_K(i) k(i) \]

- But comparative advantage by skill differs thru \( \alpha_L(i), \alpha_M(i), \alpha_H(i) \)

Comparative advantage schedule

- **Assumption:** \( \alpha_L(i) / \alpha_M(i) \) and \( \alpha_M(i) / \alpha_H(i) \) are continuously differentiable and strictly decreasing

- Higher indices correspond to “more complex” tasks

- In all tasks, \( H \) has absolute advantage relative to \( M \), \( M \) has abs. adv. relative to \( L \)

- But comparative advantage determines task allocations
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**Equilibrium objects: Task thresholds, \( I_L, I_H \)**
- In any equilibrium there exist \( I_L \) and \( I_H \) such that \( 0 < I_L < I_H < 1 \) and for any \( i < I_L \), \( m(i) = h(i) = 0 \), for any \( i \in (I_L, I_H) \), \( l(i) = h(i) = 0 \), and for any \( i > I_H \), \( l(i) = m(i) = 0 \)

**Allocation of tasks to skill groups determined by \( I_H, I_L \)**
- Tasks \( i > I_H \) will be performed by high skill workers (Abstract)
- Tasks \( i < I_L \) will be performed by low skill workers (Manual)
- Middle tasks \( I_L \leq i \leq I_H \) will be performed by medium skill workers (Routine)

**Boundaries of these sets are endogenous**
- Given skill supplies, firms (equivalently workers) decide which skills perform which tasks → *Substitution of skills across tasks.*
Three equilibrium conditions

1. Law of one price for skills
2. No arbitrage between tasks
3. Equal division of labor among tasks within a skill group
Three equilibrium conditions

1. **Law of one price for skills**
   Let $p(i)$ denote the price of services of task $i$. In equilibrium all tasks employing $L$ workers must pay them the same wage, $w_L$, and similarly for $H$ and $L$:
   
   $$w_L = p(i)A_L\alpha_L(i) \text{ for any } i < I_L.$$  
   $$w_M = p(i)A_M\alpha_M(i) \text{ for any } I_L < i < I_H.$$  
   $$w_H = p(i)A_H\alpha_H(i) \text{ for any } i > I_H.$$  

2. **No arbitrage between tasks**

3. **Equal division of labor among tasks within a skill group**
Three equilibrium conditions

1. **Law of one price for skills**

2. **No arbitrage between tasks**
   The threshold task $I_H$ must be such that it can be profitably produced using either $H$ or $M$ workers, and similarly for the threshold task $I_L$:

   \[
   A_H \alpha_H (I_H) w_H = A_M \alpha_M (I_H) w_M \\
   A_L \alpha_L (I_L) w_L = A_M \alpha_M (I_L) w_M
   \]

3. **Equal division of labor among tasks within a skill group**
Equilibrium Task Thresholds: No Arbitrage Across Skill Groups

Figure 22. Determination of Equilibrium Threshold Tasks

No arbitrage between H and M

No arbitrage between M and L
Three equilibrium conditions

1. Law of one price for skills
2. No arbitrage between tasks
3. Equal division of labor among tasks within a skill group

Cobb-Douglas production technology implies ‘equal task shares’:

\[ p(i)y(i) = Y \]
\[ p(i)y(i) = p(i')y(i') \]
\[ p(i)A_La_L(i)l(i) = p(i')A_La_L(i')l(i') \]

For any \( i, i' < I_L \), we conclude that \( l(i) = l(i') \). Which implies:

\[ l(i) = \frac{L}{I_L} \text{ for any } i < I_L, \]

and similarly for \( M, H \).
A Ricardian Model of Skills, Tasks and Technologies

- These three conditions [law of one price, no arbitrage, equal shares] imply that relative wages are solely a function of labor supplies and task thresholds:
  \[ w_J = w_J[H, M, L, I_H, I_L|A_H, A_M, A_L, \alpha_H(\cdot), \alpha_M(\cdot), \alpha_L(\cdot)] \text{ for } J \in [H, M, L]: \]

\[
\frac{w_H}{w_M} = \left( \frac{1 - I_H}{I_H - I_L} \right) \left( \frac{H}{M} \right)^{-1},
\]

\[
\frac{w_M}{w_L} = \left( \frac{I_H - I_L}{I_L} \right) \left( \frac{M}{L} \right)^{-1}
\]

- So, labor supplies \( L, M, H \) plus compare adv. \( \alpha(L), \alpha(M), \alpha(L) \) determine task allocation, \( I_L \) and \( I_H \), and hence wages.

- It’s that simple!
Skill-Biased Technical Change: A Rise in $A_H$

- Rise in productivity of $H$ workers broadens their task set, lowers $I_H$
- Squeezes $M$ workers (excess supply of $M$) so $I_L$ also falls
Some Key Comparative Statics

Consider a rise in $A_H$ (SBTC):
- Increase share of tasks done by $H$
- Raises $W_H/W_m$ and $W_H/W_L$

Consider a rise in high-skilled labor supply $H$:
- Increase share of tasks done by $H$
- Lowers $W_H/W_m$ and $W_H/W_L$
- Lowers $W_M/W_L$ (Rise in $A_H$ is isomorphic to rise in $H$)

Identical comparative statics for rise in $A_L$ or $L$. 
Change in productivity or supply of middle-skill workers
Subtle effects

What happens when either $M$ or $A_M$ rises?
- Depends critically on this term:
  $$|\beta'_L (I_L) I_L| \geq |\beta'_H (I_H) (1 - I_H)|$$
- Measures *comparative advantage* of $L$ versus $H$ workers in $M$ tasks
- If $\beta'_L (I_L)$ is low relative to $\beta'_H (I_H)$, high skill workers have strong comparative advantage for tasks above $I_H$.

**Hence, rise in $M$ displaces $L$ workers more than $H$ iff:**

$$\frac{d \ln (w_H/w_L)}{d \ln M} > 0 \text{ iff } |\beta'_L (I_L) I_L| < |\beta'_H (I_H) (1 - I_H)|$$

- Implicitly $I_L$ falls more than $I_H$ rises.
How Technology Enters

Easy to model a ‘task replacing technology’
- Both $K$ and Labor can supply tasks (all are perfect substitutes)
- $K$ will supply task if can accomplish more cheaply than $L$, $M$, or $H$.

Example: Routine Task Replacing technology
- Capital that out-competes $M$ in a subset of tasks $i'$ in the interval $I_L < i' < I_H$

Own wage effects
- Immediately lowers wage of $M$ by narrowing set of $M$ tasks

Cross-price effects on $W_L$ and $W_H$?
- Again depend on $|\beta'_L (I_L) I_L| \geq |\beta'_H (I_H) (1 - I_H)|$
- If $M$ workers better suited to $L$ than $H$ tasks, then $W_H / W_L$ rises
Routine Task Replacing Technology

Focal case

- Task replacing technology concentrated in middle-skill/routine tasks
- Strong comparative advantage of $H$ relative to $L$ at respective margins with $M$

Leads to wage and employment ‘polarization’

1. Wages:
   - Middle wages fall relative to top and bottom.
   - Top rises relative to bottom

2. Employment:
   - Middle-skill/routine tasks mechanized
   - Declining labor input in Routine tasks
   - Given comparative advantage, middle-skill workers move disproportionately downward in task distribution.
Offshoring works identically to capital that competes for tasks

- In this sense, our model is like Grossman and Rossi-Hansberg (2008)
- But the comparative advantage setup here is more general (plausible)
Two further extensions

**Endogenous choice of skills**

- Workers can have a bundle of $l$, $m$, and $h$ skills
- When comparative advantage of one skill sufficiently eroded, may switch skills
- Example: Former manager, now driving delivery truck

**Endogenous technical change**

- Endogenous tech change favoring *skills* is well understood from Acemoglu (1998, 2007)
- We also consider endogenous technical change *favoring tasks* in this model
Ricardian Model: Summary

Model’s inputs

1. Explicit distinction between skills and tasks
2. Allow for comparative advantage among workers in different tasks
3. Allow for multiple sources of competing task ‘supplies’

What the model delivers

- A natural concept of occupations (bundles of tasks)
- An endogenous mapping from skill to tasks via comparative advantage
- Technical change (offshoring) that can raise and lower wages
- Migration of skills across tasks as technology changes
- Polarization of wages and employment as one possible outcome
Where the Canonical Model is Silent (or Mis-speaks)

Can the Ricardian model rationalize these facts?

1. Wage inequality rises less than predicted
2. *Real wage levels fall* for some groups
3. Wage changes non-monotone in skill
4. Polarization of employment growth across high/low-skill occupations (also non-monotone)
5. Rising importance of *occupation* as a predictor of earnings
6. Casual empiricism only
   - Directly skill-replacing technologies commonplace
   - Offshoring may function like a skill-replacing technology
Some potential empirical directions

Some loose observations only

• Model suggests that we want to relate technical change to prices of skills via *changes in comparative advantage*
  • Measuring comparative advantage is difficult, but not impossible
  • One idea is to look at patterns of occupational specialization from ‘pre-period’ as a measure

• More generally, model makes conceptual link btwn skills, tasks and occupations
  • Occupations *do not really exist* in standard competitive wage models
  • Here, they do exist. But there is *still a ‘law of one price’ for skill*
Conclusions

Canonical model has been a huge conceptual and empirical success

- But not able to shed light on some key phenomena of interest
  - Falling real wages for some groups
  - Non-monotone wage changes
  - Polarization of employment
  - Reallocation of skill groups across occupations
  - Rising power of occupation as predictor of wages

Possible additional insights gained by

1. Distinguishing between skills and tasks
2. Allowing for comparative advantage among workers in different tasks
3. Allowing for multiple sources of competing task ‘supplies’