Becker Meets Ricardo:

Multisector Matching with Social and Cognitive Skills

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Introduction

- social skills are important in education, labor and marriage
  - market participants value and screen for social skills
  - social skills affect market outcomes in all three sectors
- why are social skills valued?
  - need a model of social interaction where individuals have heterogenous social skills
  - it should also differentiate cognitive skills from social skills

This Paper

- develops a theory of social and cognitive skills, and a tractable multisector matching framework
- builds on several classical ideas:
  - cognitive skills are complementary in production: Becker
  - there are gains to specialization: Smith
  - task assignment based on comparative advantage: Ricardo
- assumes a common team production for all three sectors
  - output is produced by completing two tasks
  - specialization improves productivity, but needs costly coordination
  - individuals differ in communication/coordination costs (social skills)
  - individuals with higher social skills are more efficient in coordination

Results Overview

- full task specialization in labor, but partial specialization in marriage
- many-to-one matching in teams in the labor market, a commonly observed organizational form
- matching patterns differ across sectors:
  - labor market: managers and workers sort by cognitive skills
  - marriage market: spouses sort by both social and cognitive skills
  - education market: students with different social and cognitive skills attend the same school
- equilibrium is a solution to a linear programming problem
  - great for simulation and estimation

Closely Related Work

- Garicano (2000), Garicano and Rossi-Hansberg (2004, 2006)
  - study how communication costs affect organization design, matching, occupation choice etc., where individuals differ by cognitive skills only
- using a different production technology, we extend them by:
  - adding another dimension of heterogeneity: communication costs
  - studying multisector (school, work and marriage) matching

Model Setup

- risk-neutral individuals live for two periods
  - enter education market as students; then work and marry as adults
  - one unit of time endowment for each sector
  - free entry of firms and schools
- individuals are heterogenous in two dimensions
  - (fixed) gross social skill η, with $\eta \in \left[\underline{\eta}, \overline{\eta}\right]$
  - initial cognitive ability a, with $a \in [\underline{a}, \overline{a}]$
  - education transforms a into adult cognitive skill k, with $k \in \left[\underline{k}, \overline{k}\right]$
- individuals' net payoff: wage (ω) $+$ marriage payoff (h) $-$ tuition (τ)
  - individual decision: who to match with in each sector

Single Agent Production

- output is produced by completion of two tasks, I and C
  - θ_i^I, θ_i^C: times i spent on task I and C respectively
  - time constraint in each sector: $\theta_i^I + \theta_i^C \leq 1$
- single agent production:

$$\beta k_i \min\left\{\theta_i^I, \gamma\theta_i^C\right\} \qquad \text{(Single)}$$

  - $\beta < 1$: potential gain to specialization
  - $\gamma > 1$: task C takes less time to complete
  - no need for coordination: gross social skill η_i does not enter production

Team Production

- consider a two-person team with (η_i, k_i) and (η_j, k_j)
  - θ_i^I, θ_j^C: times i and j spend on task I and task C respectively
- specialization needs coordination
  - only individual on task C bears (one-sided) coordination cost:
  - $(1-\eta_j)\,\theta_j^C$ for coordination, remaining time $\eta_j\theta_j^C$ for production
- team output:

$$\sqrt{k_i k_j}\,\min\left\{\theta_i^I, \gamma\eta_j\theta_j^C\right\} \qquad \text{(Team)}$$

- compared to single agent production: $\beta k_i \min\left\{\theta_i^I, \gamma\theta_i^C\right\}$
  - we drop $\beta < 1$: gains to specialization (Smith)
  - $\sqrt{k_i k_j}$: complementarity in cognitive skills (Becker)
  - who should do task C: comparative advantage (Ricardo)

Social Skills and Team Production

- team production technology: $\sqrt{k_i k_j}\min\left\{\theta_i^I, \gamma\eta_j\theta_j^C\right\}$
- define social skill n: $n \equiv \gamma\eta_j$
- team production technology: $\sqrt{k_i k_j}\min\left\{\theta_i^I, n_j\theta_j^C\right\}$
  - individuals with higher n, when assigned to C, are more productive
- assume team production is always superior to working alone

Labor Market Specialization and Task Assignment

Proposition. Full task specialization is optimal, i.e., an individual is assigned to task I or C throughout.

- many-to-one matching: one member on task C (manager, with social skill n) "supervises" n other members on task I (workers)
- workers' social skills have no value for team production

Proposition. Task assignment according to comparative advantage: there is a cutoff $\widehat{n}(k)$ such that a type-(n,k) individual does task C if and only if $n \geq \widehat{n}(k)$.

- individuals with higher social skills become managers/teachers

Sorting in the Labor Market

- problem of a type-(n_m, k_m) manager:
  - choose n_m worker types to maximize

$$\max_{(k_1,\ldots,k_{n_m})} \sum_{i=1}^{n_m} \left[\sqrt{k_m k_i} - \omega(k_i)\right]$$

  - in optimum, workers have the same k_w
  - manager earns $n_m \phi(k_m) = n_m \max_{k_w} \left[\sqrt{k_m k_w} - \omega(k_w)\right]$
- define equilibrium matching $\mu(k_m) \in \arg\max_{k_w} \left[\sqrt{k_m k_w} - \omega(k_w)\right]$

Proposition. Equilibrium exhibits positive assortative matching (PAM) along cognitive skills: $\mu'(k) > 0$

Marriage Market

Assume monogamy: Spouses devote all their time in the marriage market with each other

Proposition. Full specialization is not optimal.

Proposition. Equilibrium sorts in two dimensions: individuals marry their own type.

Education Market

- task assignment is exogenous
  - teachers do task C
  - students do task I
- team production function: $\sqrt{a_i k_t}\min\left\{\theta_i^I, n_t\theta_t^C\right\}$
  - in equilibrium, a type-(n_t, k_t) teacher can manage n_t students
  - input: student's initial cognitive skill a_i
  - output: student's adult cognitive skill k_i
- better schools (teachers with higher k_t) will charge higher tuition

Equilibrium Education Choice

- choose education/school (k_t) to maximize future net payoff
  - return on education depends on future occupation choice
- conditional on occupation choice, equilibrium exhibits PAM
  - students with higher a_s or n_s attend better schools (higher k_t)

Proposition. There is an educational gap: a student who has marginally more a_s or n_s and switches from being a worker to being a teacher/manager will discretely increase his or her schooling investment

General Equilibrium and Linear Programming

- equilibrium equivalent to a utilitarian social planner solving a linear programming problem
  - chooses number (measure) of (n_m, k_m, n_w, k_w) firms and number of (n_t, k_t, n_s, a_s) schools to maximize:

$$\sum_{\text{firm types}} \#\text{ firm type } (n_m, k_m, n_w, k_w) \times \left(n_m \sqrt{k_m k_w}\right)$$

$$+ \sum_{\text{marriage types}} \#\text{ marriage type } (n, k, n, k) \times \left(\frac{2n}{n+1} k\right)$$

  subject to, for each adult type (n, k),

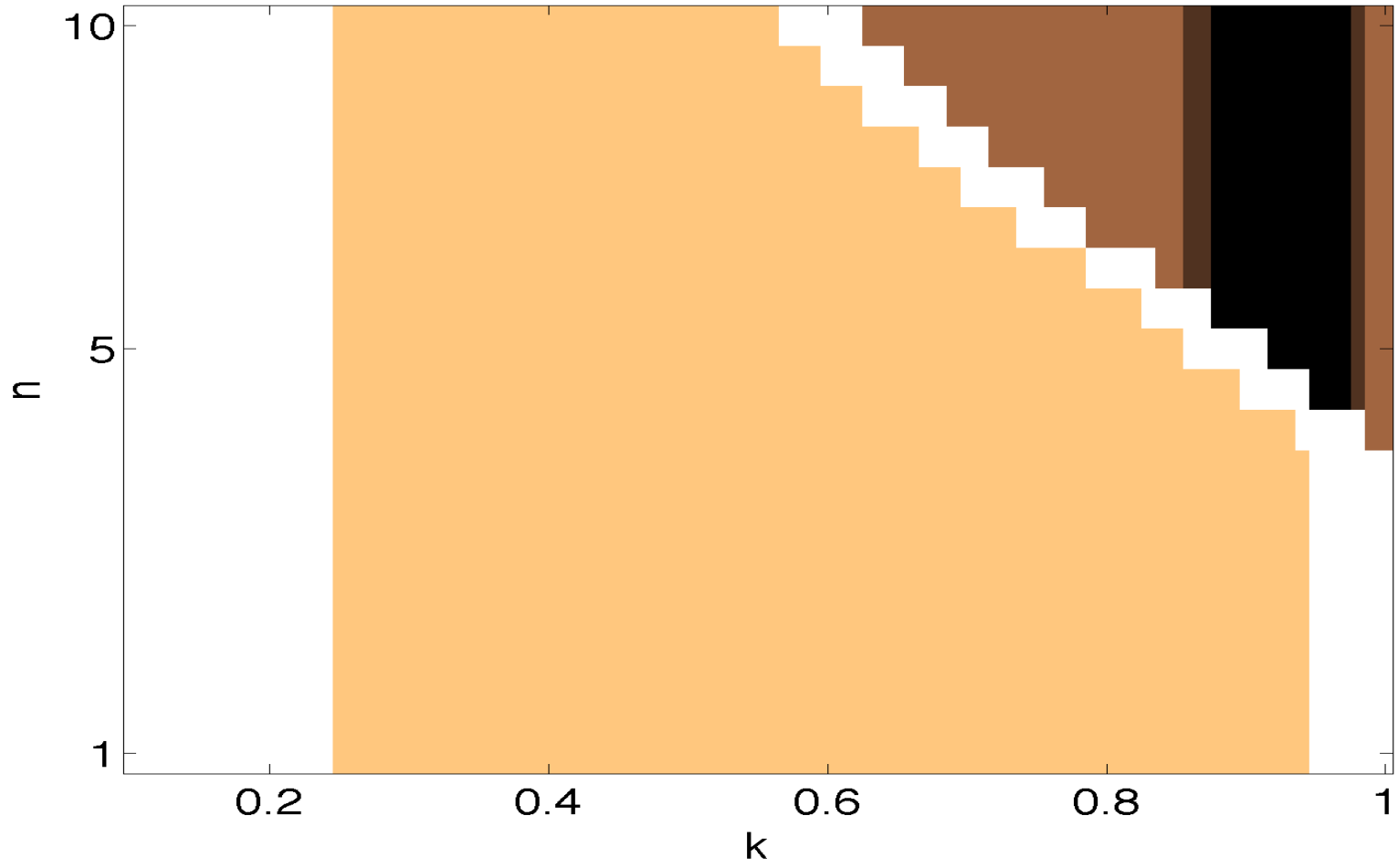
$$\text{demand by firms + schools} \leq \text{supply of adults}$$

  and for each student type (n, a),

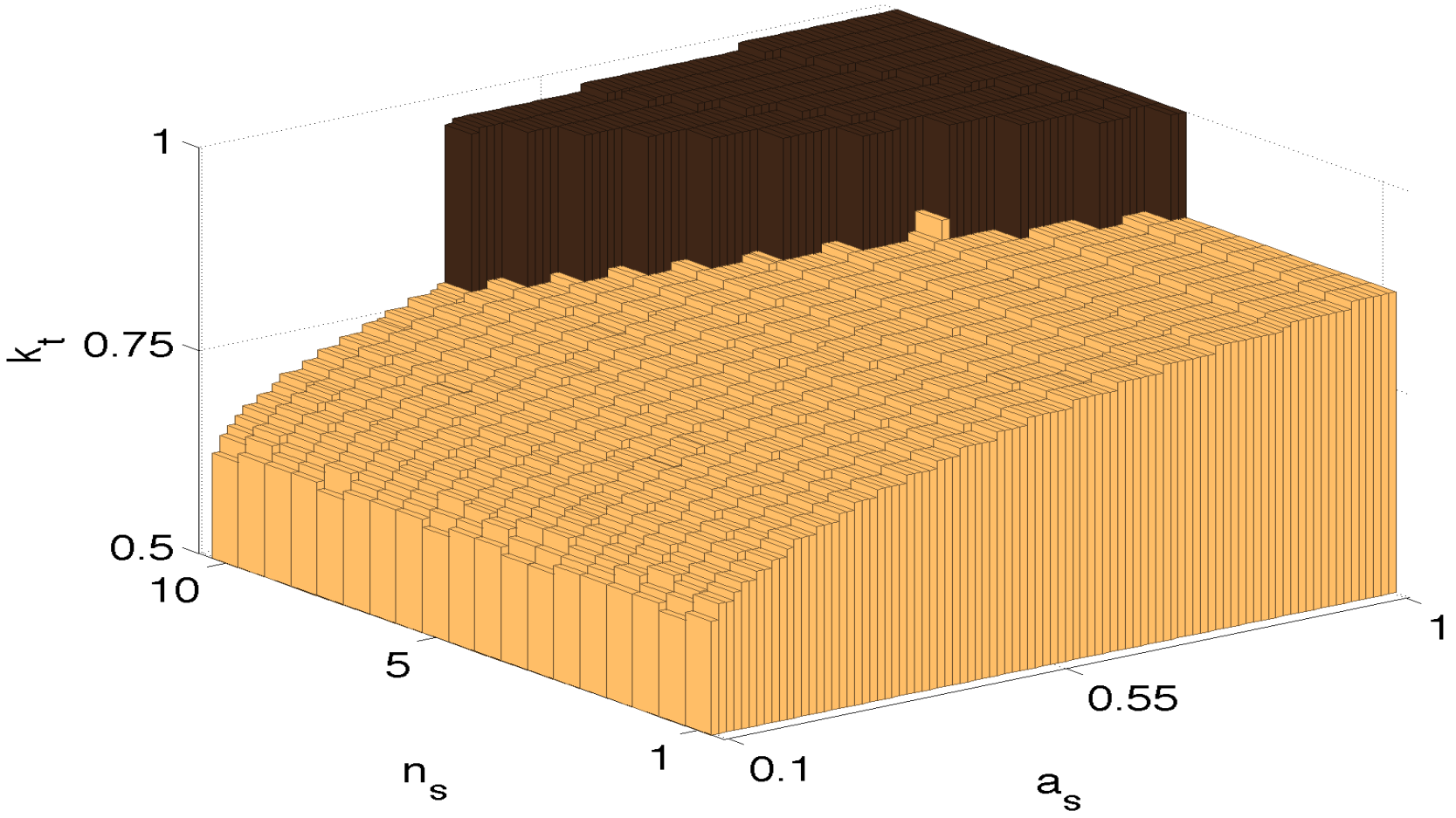
$$\text{school slots for students} \leq \text{supply of students}$$

- wages and student payoffs: multipliers attached to the constraints

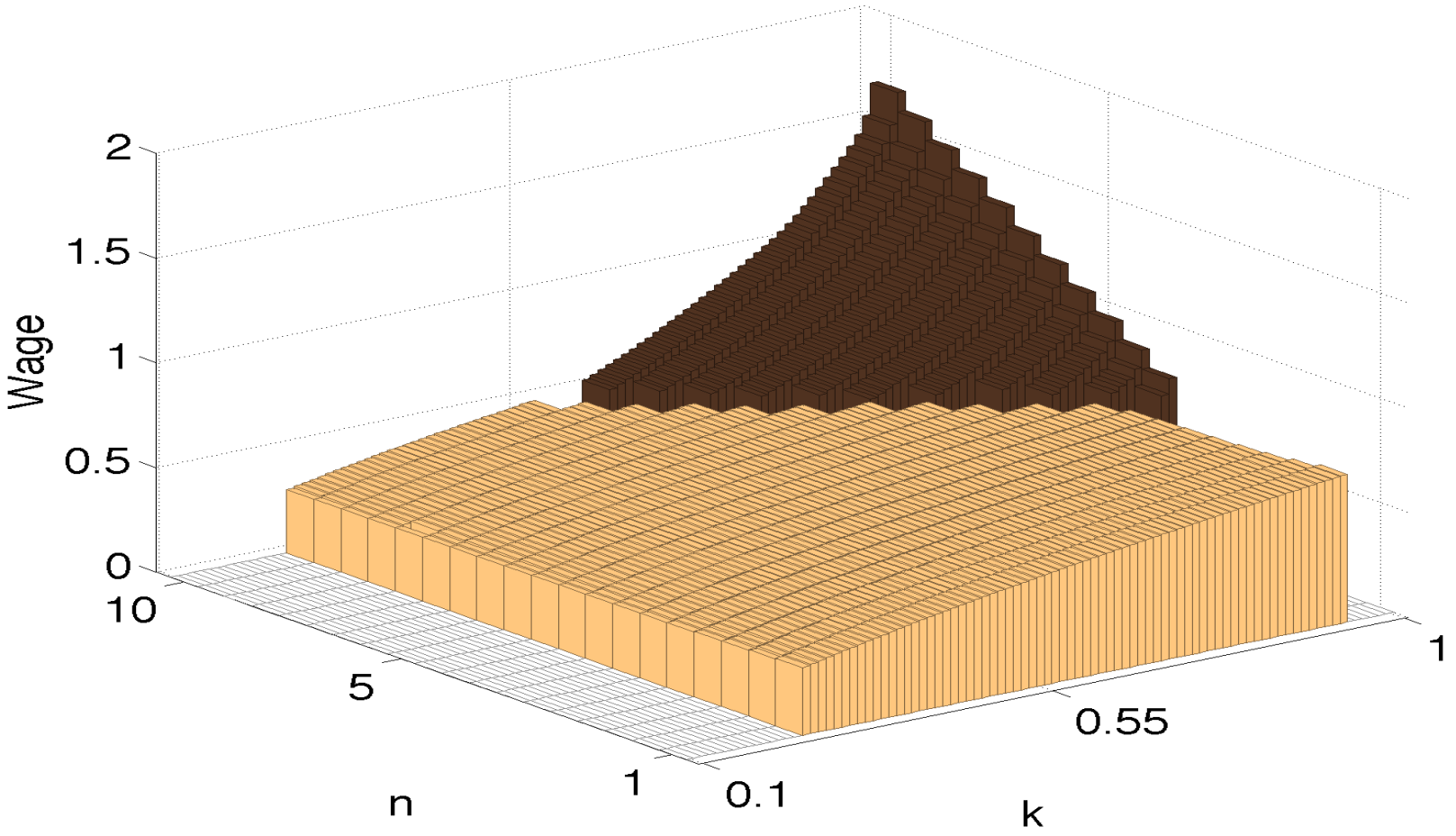
Numerical Simulation: Occupation Choice



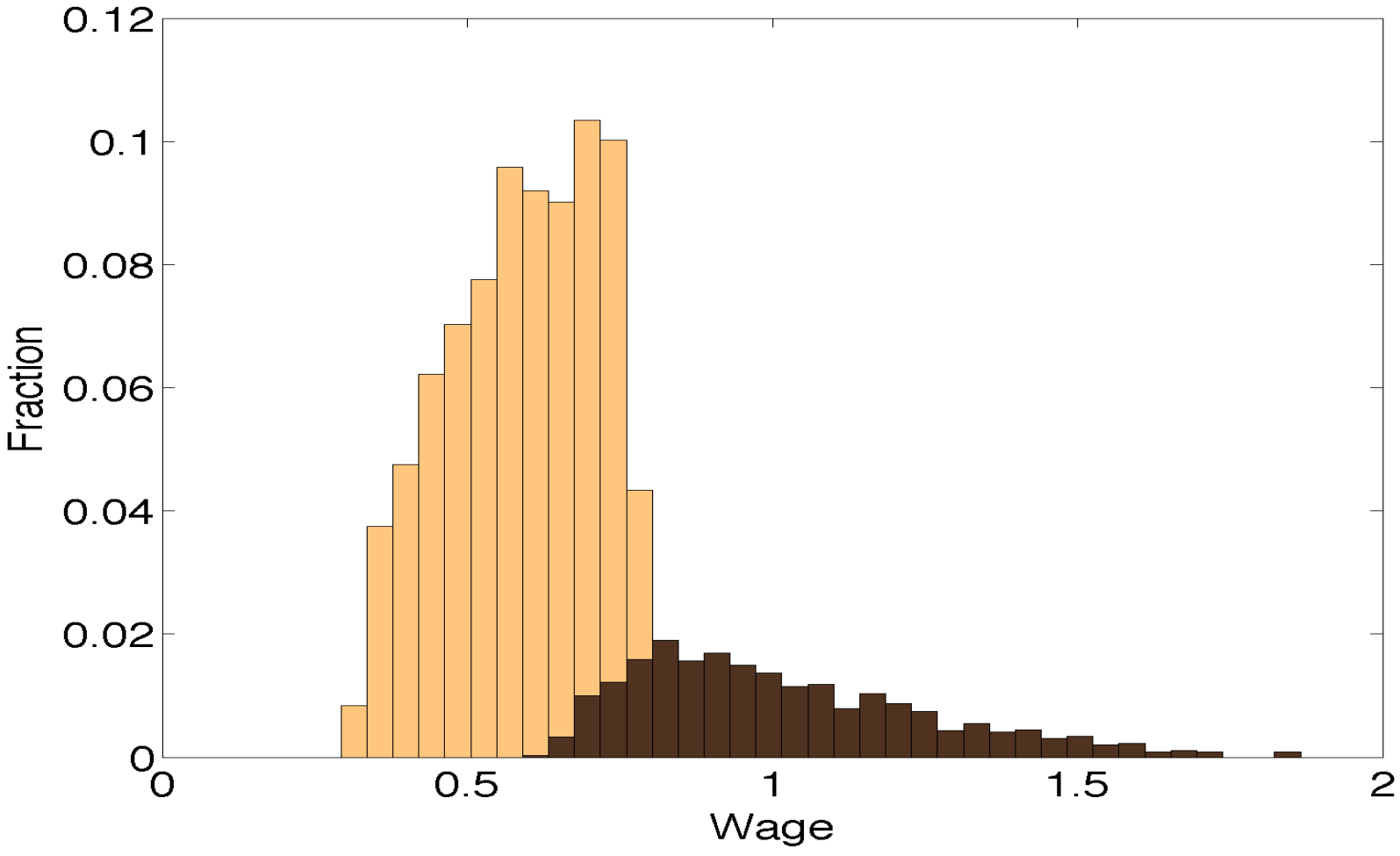
Numerical Simulation: Education Choice



Numerical Simulation: Equilibrium Wage



Numerical Simulation: Wage Distribution



Related Literature (Partial List)

- importance of non-cognitive (including social) skills
  - Almlund, Duckworth, Heckman and Kautz (2011), Heckman, Stixrud and Urzua (2006) ...
- frictionless transferable utility model of marriage
  - one factor: Becker (1973,1974) ...
  - two factors: Anderson (2003), Chiappori, Oreffice and Quintana-Domeque (2010)
- task assignment and hierarchies
  - Roy (1951), Sattinger (1975) ...
  - Lucas (1978), Rosen (1978, 1982), Garicano (2000), Eeckhout and Kircher (2011) ...
- Linear programming model of frictionless multifactor marriage matching model
  - Chiappori, McCann and Nesheim (2010)

Conclusion

- we present a tractable framework for multisector matching
  - all three sectors share qualitatively the same team production function
  - team production function incorporates specialization and task assignment
  - specify an explicit role for social skills in production
- capture matching patterns in each of the three sectors
- generate predictions consistent with empirical observations
- a first pass theory of social and cognitive skills
  - many possible extensions