Sorting, learning, and mobility when jobs have scarcity value

A comment

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Introduction

Jovanovic and Nyarko focus on two classes of models in which learning plays an important role in occupational sorting and mobility behavior. The Stepping Stone model generates an occupational ladder among informationally related activities. The central assumption is that knowledge acquired in the performance of one activity helps to avoid mistakes in related activities. Because foregone output associated with mistakes is relatively small in some activities, they provide a "natural training ground" for other, informationally related activities. Consequently, there is a motive for occupational progression over the life-cycle from less risky to more risky, informationally related activities. As Jovanovic and Nyarko stress, occupational mobility in the Stepping Stone model reflects acquired expertise by the worker.

The Bandit model highlights one type of uncertainty and its implications for occupational choice and mobility. In particular, the young feel greater attraction to risky occupations because they place a higher value on experimentation. If experimentation reveals that ability does not lie in the upper tail of the reward distribution for the risky occupation, the worker can exercise the option to switch to a less-risky occupation. The young face greater uncertainty about own ability and, hence, attach greater weight to outcomes in the upper tail of the reward distribution in the risky occupation. In addition, the young anticipate reaping the rewards of experimentation over a longer horizon. These two effects imply that many individuals will progress
from more- to less-risky occupations over the life-cycle. Occupational mo-
bility in the Bandit model reflects acquired information about the worker’s
innate abilities and suitability for particular jobs.

The Stepping Stone and Bandit models deliver useful and empirically
relevant insights about occupational choice and mobility. But the two models
abstract from features of the real world that strike me as central to the role
of learning in many of the patterns we observe in occupational sorting and
mobility behavior. The features I have in mind are, first, simple experience
effects that involve skill acquisition but no mistake-avoidance motive and,
second, learning about ability when (some) jobs have scarcity value. As
I stress below, when jobs have scarcity value, absolute ability differences
among workers influence occupational sorting patterns, and learning about
ability differences among workers drives mobility behavior.

My objective in this comment is to articulate some observations about
the role of experience effects and the role of learning about worker ability
differences in occupational sorting and mobility behavior. I offer only cursory
remarks about experience effects because my main points are transparent. I
devote more attention to the consequences of learning about ability differ-
cences among workers. My main focus is a simple Team Production model
in which jobs have scarcity value. As in the Bandit model, mobility reflects
acquired information about innate abilities, but experimentation has neither
private nor social value in the Team Production model, and its empirical
implications more closely resemble those of the Stepping Stone model. For
example, in the Team Production model there is a strong motive for oc-
cupational progression over the life cycle from less-risky (low-variance) to
more-risky (higher-variance) activities. I intend my remarks about the role
of experience effects and learning about ability differences among workers to
complement the insights in the paper by Jovanovic and Nyarko.

Simple experience effects

Consider the role of experience in occupational progression over the life-cycle.
Terms like “learning by doing” and “learning on the job” capture a key fact
about individual productivity growth: as a direct consequence of performing
certain tasks, a worker’s productivity improves on the same or other tasks.
The Stepping Stone model captures this idea in the transferability of knowl-
edge about how to avoid mistakes. The accumulation of such knowledge and
its transferability between tasks yields predictions for occupational sorting
and mobility and their relationship to the first and higher moments of the
wage distribution.

“Simple” experience effects, however, need not imply any particular rela-
tionship of higher moments of the wage distribution to occupational sorting
and mobility. By simple experience effects, I mean an additive contribution to future output on a task as a consequence of performing the same task or a related task. Formally, we can think of adding a term to the Jovanovic and Nyarko production functions (1) and (2) for an old person that is independent of the decision variable, z, but that depends on the person's occupation during youth. These terms carry over as career-path-specific constants in the expressions (4) for the maximized value functions. Clearly, without further restrictions on these simple experience effects, one could easily obtain a different prediction from the model about, say, the life-cycle progression from less- to more-risky occupations.

Simple experience effects of this sort are analytically trivial in the Jovanovic and Nyarko context and, without further structure, seemingly devoid of implications that are both interesting and falsifiable. But that does not mean that simple experience effects are unimportant in determining occupational sorting and mobility patterns. It may well be that some occupations (e.g., student, retail clerk, sales person) generate large simple experience effects for many other occupations so that they become natural starting points or "training grounds." In practice, I suspect it will be difficult to distinguish between simple experience effects and the mistake-avoidance effect emphasized by Jovanovic and Nyarko. A model with simple experience effects can reproduce any pattern of occupational sorting, mobility and mean wage behavior generated by Jovanovic and Nyarko Stepping Stone model. Allowing for unobserved worker heterogeneity, a relevant consideration in empirical studies, it is probably not difficult to account for higher moments of the wage distribution in a plausible theory based on simple experience effects.

Sorting, learning, and mobility when jobs have scarcity value

I now turn to the role of learning about ability when ability comparisons among workers are relevant to occupational sorting and mobility patterns. Consider some examples of prototypical career paths: Professor → Dean, Player → Coach, Soldier → General, Engineer → Manager, Dancer → Choreographer, Team Member → Team Leader, and Priest → Cardinal. As remarked upon by Jovanovic and Nyarko, these examples illustrate a natural progression from simpler to more complex and informationally related activities. But, to my eye, they also point to the scarcity value of certain jobs or positions near the top of an organizational hierarchy.

For example, an army has many foot soldiers but few generals and only one commander-in-chief. There is little scarcity value attached to the position of foot soldier, but tremendous scarcity value is attached to the position of top general. While the Stepping Stone model delivers an occupational ladder, it lacks an occupational hierarchy in the sense of Rosen (1982) whereby
individuals at the top of an organization influence the productivity of individuals at lower levels.

Neither does the Stepping Stone model deliver stratification by worker productivity across teams, as in Kremer’s (1993) analysis of O-ring production functions. In his model, complementarity among workers in the production process underlies the scarcity value of jobs. Athletic contests present clear examples of how complementarity generates scarcity value for jobs. For example, a key feature of the production technology for a football team is the dependence of each player’s productivity on the ability of his team mates on the field, and the lack of scope for quantity (more players) to substitute for quality (better players).

Job scarcity value can also arise because of heterogeneity among cooperating inputs in the production process. Consider a world with one machine that can be operated by only one worker at a time. The opportunity cost of assigning worker A to the machine depends on the output foregone by not assigning B to the machine, so that there is scarcity value attached to the job of “machine operator.” This basic idea carries over to more complex situations with a distribution of worker types and machine types.1

We can summarize the central point as follows. According to the Stepping Stone and Bandit models, the opportunity cost of placing worker 1 in occupation A involves that worker’s foregone expected return in occupation B. The expected return of, say, worker 2 in occupation A is irrelevant. In contrast, when jobs have scarcity value, the opportunity cost of placing worker 1 in occupation A depends on worker 2’s expected return in A. Therefore, when jobs have scarcity value, ability comparisons among workers become relevant to occupational sorting and mobility. When jobs lack scarcity value, ability comparisons among workers do not matter.

These remarks suggest that models of learning about ability differences among workers are likely to generate useful and empirically relevant insights into occupational sorting and mobility behavior. I turn now to one such model.

A simple model of production teams with learning about ability

Consider a model of production teams in an overlapping generations environment with \((L/2)\) young people and an equal number of old people. Young persons enter the world with ability \(\alpha\) drawn from distribution function \(F(\cdot)\).

\[\text{See, for example, the discussion of the differential rents model in Sattinger (1993). With suitable assumptions, it would be easy to introduce learning about ability into an overlapping-generations version of Sattinger’s differential rents model. Such a model would generate (a) upward and downward vertical mobility in response to revised assessments of worker ability and (b) a strong tendency for the wage distribution to fan out with age.}\]
The corresponding density function \( f(\cdot) \) has positive support on \([\alpha_{\min}, \alpha_{\max}]\), with \( \alpha_{\min} \geq 0 \). I work with a continuum of agents, so that the entire distribution \( F \) of ability is represented in each generation.

Teams of managers and workers form at the beginning of each period. Ability is initially unknown but learned by all in the course of production during youth. Thus, the ability of old agents is known with certainty, but there is no possibility of distinguishing young agents by ability when teams form. In view of these assumptions, I will think of an allocation as (a) a function for old people that maps \( \alpha \in [\alpha_{\min}, \alpha_{\max}] \) to an occupation in the set \{Manager, Worker\} and to a value in the set of integers that indexes teams, and (b) a rule that specifies the mass of young people allocated to each occupation on each team.

There are \( T = (L/N) \) production teams, each of which has a mass \( N - 1 \) of workers and a unit mass of managers. A feasible allocation of agents to occupations and teams satisfies the technological constraints,

\[
\int_{l \in M_i} dl = 1 \quad \text{and} \quad \int_{l \in W_i} dl = N - 1, \quad \text{for} \quad i = 1, 2, \ldots, T, \tag{1a}
\]

and the aggregate resource constraint,

\[
\sum_{i=1}^{T} \left( \int_{l \in M_i} dl + \int_{l \in W_i} dl \right) = L, \tag{1b}
\]

where \( M_i \) and \( W_i \) denote measurable sets of managers and workers, respectively, on team \( i \).

Team production generates output according to a multiplicative function of average managerial ability and average (transformed) worker ability:

\[
Y_i = \left( \int_{l \in M_i} \alpha(l) dl \right) \left( \int_{l \in W_i} Q[\alpha(l)] dl \right)^\gamma, \quad \gamma \geq 1, \quad i = 1, 2, \ldots, T, \tag{2}
\]

where the parameter \( \gamma \) influences the strength of the complementarity among workers on the same team, and the function \( Q(\cdot) \) governs the sensitivity of productivity to ability in the occupation of "worker." I place more structure on \( Q(\cdot) \) below, but I have in mind that it is always a positive-valued, nondecreasing function of ability. The team-size parameter \( N \) relates to an asymmetry between managers and workers that typifies many productive organizations. In particular, each manager exerts an influence on the productivity of many workers, but each worker influences the productivity of relatively few managers. Hence, I assume \( N > 2 \).

An efficient allocation maximizes total team output \( \sum_i Y_i \) subject to the production functions (2) and the feasibility constraints (1). One might imagine, based on this model's fairly simple structure, that a full characterization of efficient allocations is easily obtained. That turns out not to be the case.
Rather the model admits rich, sometimes complex patterns of efficient allocations, depending on specific assumptions about $N, F(\cdot), Q(\cdot)$ and $\gamma^2$. For this reason, I will seek only to characterize the efficient allocation and a decentralized implementation in some special cases. I will also restrict my attention to allocations in which the old persons in each $W_i$ and $M_i$ form a convex set on $[\alpha_{\min}, \alpha_{\max}]$. Finally, when I treat mobility behavior over the life cycle, I will focus on allocations that rule out pointless mobility between teams. These allocations are the only ones that would survive the introduction of a vanishingly small cost of mobility across teams.

Case 1: Team output insensitive to worker ability

Assumptions:

(a) $Q(\cdot) \equiv 1$,
(b) $\alpha < \alpha_M \equiv F^{-1}(\frac{L}{2} - T)$.

Assumption 1(a) means that only managerial ability influences team output. The regularity condition 1(b) insures that ability levels for the top $T$ persons in each cohort exceed mean ability.

The efficient allocation and mobility behavior are easily characterized in this case. The top $T$ old people with $\alpha \geq \alpha_M$ become managers, and everyone else is a worker. There is no mobility between teams, but a fraction $2T/L = 2/N$ of the workers on each team is promoted to manager at the beginning of old age. Total output under the efficient allocation is given by

$$Y = T(N - 1)^{\gamma} \int_{\alpha_M}^{\alpha_{\max}} \alpha f(\alpha) d\alpha,$$

which is just the product of the aggregate worker input and the aggregate managerial input.

A decentralized equilibrium that implements the efficient allocation is also easy to obtain. Competition generates a uniform wage for workers at, say, the value $\omega_0$. Competition between the marginal manager and the marginal worker implies continuity of the wage schedule at $\alpha_M$. Competition for managers implies that managerial compensation rises in ability with slope $(N - 1)^{\gamma}$ and peaks at $\omega_0 + (\alpha_{\max} - \alpha_M)(N - 1)^{\gamma}$. Lastly, free entry of teams implies that total compensation exhausts output:

$$L\omega_0 + (N - 1)^{\gamma} \int_{\alpha_M}^{\alpha_{\max}} \alpha f(\alpha) d\alpha = Y.$$

Substituting for aggregate output $Y$ and solving for the uniform worker wage

$^2$This richness and complexity is not surprising from the vantage point of previous work on assignment models with important complementarities between managerial and worker ability. See, for example, the discussion in Kremer and Maskin (1996).

$^3$I do not believe this restriction binds in the cases I consider.
level yields
\[ \omega_0 = \frac{(T - 1)(N - 1)^{\gamma}}{L} \int_{\alpha_M}^{\alpha_{\max}} \alpha f(\alpha) d\alpha. \] (5)

The equilibrium wage function is uniform for young people, and it is piecewise linear in ability for old people with a kink at \( \alpha_M \):

\[
\begin{align*}
\omega^y &= \omega_0, \\
\omega^o(\alpha) &= \omega_0, & \alpha &< \alpha_M \\
&= \omega_0 + (\alpha - \alpha_M)(N - 1)^\gamma, & \alpha &\geq \alpha_M.
\end{align*}
\] (6)

The mean and dispersion of wages rise with age and occupational progression.

**Case 2: Limited sensitivity to worker ability**

Assumptions:
(a) \( Q(\cdot) = 1 \) for \( \alpha < \alpha_s \); \( Q(\cdot) = q > 1 \) for \( \alpha \geq \alpha_s \).
(b) \( \bar{\alpha} < \alpha_M \equiv F^{-1}(\frac{L}{2} - T) \).
(c) \( \alpha_s < \alpha_M \).

Worker productivity is now a step function in ability with a jump at \( \alpha_s \). This minor change in specification leads to rich sorting dynamics and a complex wage structure.

The efficient allocation now involves four types of teams and a 5-way partition of old workers by ability. Ignoring integer constraints, the allocation can be described as follows:

\[
\begin{align*}
\alpha \in [\alpha_{\min}, \alpha_s) &: \text{less-able old workers;} \\
\alpha \in [\alpha_s, \alpha_M) &: \text{more-able old workers;} \\
\alpha \in [\alpha_M, \alpha_1) &: \text{managers of less-able old workers;} \\
\alpha \in [\alpha_1, \alpha_2) &: \text{managers of young workers;} \\
\alpha \in [\alpha_2, \alpha_{\max}] &: \text{managers of more-able old workers;}
\end{align*}
\] (7)

where \( \alpha_1 = F^{-1}(\frac{L}{2} - T + F(\alpha_s)/(N - 1)) \) and \( \alpha_2 = \alpha_1 + \frac{T}{2} \).

As before, a fraction \( \frac{N}{N} \) of workers move up to management as they enter old age, but the model now implies a rich pattern of mobility between teams. If \( F(\alpha_s) \) is small relative to \( \frac{L}{2} \), so that most workers have productivity \( q \), the following mobility patterns hold. On most teams, the low-productivity workers leave when they become old to join another team with only low-productivity workers, and most of the other members remain at the organization to become high-productivity workers. The exiting low-productivity workers on these teams are replaced by new high-productivity workers. Most of the remaining teams experience the opposite patterns of mobility (i.e., low-productivity workers remain, and high-productivity workers stay). The top-ability persons on most teams (\( \alpha \geq \alpha_2 \)) remain with the organization.
but are promoted to management. The next most-able group \( (\alpha \in [\alpha_1, \alpha_2]) \) leave to become managers of newly-formed teams of young workers. The weakest managers \( (\alpha \in [\alpha_M, \alpha_1]) \) on most teams leave to join teams with low-productivity workers.

This case also generates entry and exit of teams. No team survives more than 2 generations, and a fraction \( 1/(N-1) \) of new teams disbands after only 1 generation. In contrast, teams never exit in case 1; they simply replenish their old workers with new ones each period.

The equilibrium wage function for old people now jumps discontinuously at \( \alpha_3 \). The wage function is continuous and piecewise linear to the right of \( \alpha_3 \), with kinks at \( \alpha_M, \alpha_1 \) and \( \alpha_2 \). The steepness of the wage function increases at each kink point because of greater productivity of the workers who cooperate with managers. Finally, the wage for young people is uniform at a value that lies between the wages for low-productivity and high-productivity old workers.

**Case 3: Greater sensitivity to worker ability**

Assumptions:
(a) \( Q(\alpha) = \alpha \) for \( \alpha < \alpha_M; Q(\alpha) = \alpha_M \) for \( \alpha \geq \alpha_M \).
(b) \( \bar{\alpha} < \alpha_M \equiv F^{-1}(\frac{T}{2} - T) \).

Worker productivity now rises linearly with ability up to \( \alpha_M \). The flat segment of \( Q(\cdot) \) to the right of \( \alpha_M \) insures that all persons with \( \alpha \geq \alpha_M \) become managers.

The efficient allocation now involves a \((2T+1)\)-way partition of the ability distribution for old people. The first \( T \) intervals contain \((N-1)\) workers each. The remaining intervals correspond to managers. One of these remaining intervals contains \( T/2 \) persons who manage young workers, and each of the others contains a unit mass of persons who manage old people. For large \( T \), almost everyone engages in mobility between teams as they age. As in case 2, no teams survive more than two periods, and a few survive only one period. Teams are completely ordered by (expected) worker productivity and by managerial ability, and no two teams are identical.

The equilibrium wage structure is more complicated in this case, and I limit myself to a few remarks. First, the heterogeneity among teams means that markets are “thin,” and there is some indeterminacy in the equilibrium wage structure. When \( T \) is large, the scope for indeterminacy is small, so there would seem to be little cost in ignoring it. (See Sattinger (1993) and McLoughlin (1994) for discussions related to this issue.) Second, it may be that further parameter restrictions are required to insure existence of a decentralized equilibrium of the sort I considered in cases 1 and 2. I have not thought through this matter. Third, subject to the caveat about existence, wages now rise monotonically with ability. More interesting, the sensitivity of
wages to ability rises with ability because of complementarity between workers and managers and because of complementarity among workers ($\gamma > 1$). Thus, the mean and dispersion of wages tend to rise with age, occupational progression, and (conditional on age and occupation) advancement to higher-quality organizations.

Case 4: High sensitivity to worker ability
If worker productivity is sufficiently sensitive to ability throughout the distribution, then the efficient allocation may no longer exhibit a two-way partition of old persons into managers and workers. Instead, some old persons with $\alpha > \alpha_M$ may become workers on teams with very-high-ability managers.

There are two opposing forces at work in the determination of efficient sorting patterns. First, the asymmetry between workers and managers in the team production function ($N > 2$) favors the assignment of the most able old people to the managerial occupation. Second, the complementarity between managers and workers in the production function favors the formation of teams that combine highly-able workers and highly-able managers. The first effect always dominates in determining the partition between managers and workers in cases 1-3, although the second effect operates in cases 2 and 3 to generate an ordering of teams by both worker and managerial ability. When worker productivity is sufficiently sensitive to ability throughout the ability distribution, then the second effect may be strong enough so that some persons with $\alpha > \alpha_M$ become workers in the efficient allocation. The two-way partition of old persons into managers and workers no longer holds. Greater complementarity among workers (larger $\gamma$) reinforces the second effect, increasing the scope for efficient allocations in which some high-ability persons become workers while some lesser-ability persons become managers. I refer the reader to Kremer and Maskin (1996) for examples of this type of outcome in a related model.

Concluding remarks
Occupational mobility in the Team Production model reflects acquired information about the workers' innate abilities and suitability for particular jobs. In this respect, the Team Production model is like the Bandit model and unlike the Stepping Stone model. But experimentation has no value in the Team Production model, so there is no motive for young workers to try risky occupations. Quite the opposite, workers tend to progress from safer to riskier, higher-variance occupations, as in the Stepping Stone model. The mean and dispersion of wages rise with age and with occupational progression in the Team Production model.

In light of these observations, I do not think the "Evidence Favoring
the Stepping Stone Model" in Jovanovic and Nyarko's Section 5.1 can be interpreted as favoring models that emphasize acquired skills. That evidence is also consistent with models that emphasize acquired information about innate abilities, even if it is not supportive of the Bandit model. Indeed, while I have not read some of the primary studies cited by Jovanovic and Nyarko, it appears that all of the evidence that they discuss in Section 5 and elsewhere in the paper fits comfortably with the Team Production model or a closely related model.

The Team Production model with learning also delivers implications about sorting and mobility among organizations and about the connection of organizational sorting and mobility to wages and occupational mobility. Endogenizing team size in the Team Production model, perhaps in the manner of Lucas (1978), would deliver additional predictions on these dimensions.

I conclude that there is much room for useful research that fleshes out and evaluates the implications of learning about ability when jobs have scarcity value. I suspect that this class of models has more to teach us about occupational sorting and mobility behavior than the Bandit model, and that it is an important complement to models of sorting and mobility that emphasize the consequences of acquired skill.
References


