THE ECONOMICS OF INFORMATION:
A SEQUENTIAL MODEL OF CAPITAL MOBILITY*

by

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1. Introduction

Capital mobility and information acquisition comprise a fundamental form of spatial arbitrage. This is true within countries and across countries and for both human capital and physical capital. One form of mobility that has been intensively studied is the labor mobility that attends job search. Even here there has been a tendency to separate the job search decision from the migration decision. In his 1975 survey of the migration literature, Greenwood does not include Stigler's 1962 search article among his 251 references. Similarly, in Lippman and McCall's 1976 survey of the job search literature, Sjaastad's 1962 seminal paper on migration is not referenced. Even though there have been several recent articles that include job search in their empirical analysis of the migration decision,[1] there is, as far as we know, no formal model linking sequential search and sequential migration. This lacuna was the initial impetus for developing the model presented here and is the first topic to be discussed. The geographic mobility of workers within large firms is also considered in this section.

While there has been considerable attention devoted to the analysis of human capital mobility, the mobility of physical capital has been studied less and virtually ignored by the information-theoretic economists.[2] These capital mobility decisions include where to locate a new plant, when and where to move an existing plant, and when to acquire another firm. The sequential model designed to study search and migration can also address these questions. A number of thorny policy issues are raised when migration of plants and people

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[1]Prime examples are: Bartel (1978), Herzog and Schlottmann (1983), Linneman and Graves (1983), and Schwartz (1976).

[2]Important exceptions include Carlton (1979, 1983), Schmenner (1975), and Stuart (1979).

are studied together. For example, a major reason for relocating a plant is to acquire an efficient and energetic labor force. But the labor force left behind may find it impossible to locate jobs without migrating. The older workers will be least likely to migrate and hence will suffer considerable capital losses when the plant leaves. Section 3 investigates the mobility of physical capital, but avoids these welfare problems.

The footnoted exceptions do consider some of the informational (search) problems that accompany intracountry labor and capital mobility. The corresponding informational analysis for international movements of labor and capital is missing.[3] This paper indicates how the Gittins sequential model can be applied to the illegal alien phenomenon. The corresponding analysis for international capital movements could also be studied along the lines of Section 3. It would seem difficult today to exaggerate the importance of information in international capital mobility decisions. No doubt a very subtle, and for us elusive, equilibrium analysis would be required to replicate Bhagwati and Srinivasan (1983) when there is search by both capital and labor. This is postponed for now. The concluding section contains some provisos and suggestions for empirical estimation.

2. Human Capital Mobility: The Migration Decision

We consider two classes of workers: the young professionals and unskilled workers. For both classes the importance of the non-pecuniary aspects of a job that are unknown when the job commences is assumed to be small relative to the non-pecuniary aspects of the region. The very nature of

[3]Bhagwati and Srinivasan (1983) and Gerking and Mutti (1983) develop models in which both capital and labor are internationally mobile, but they do not consider, explicitly, the information problems posed by these movements.

the occupation coupled with the information acquired during courtship validates this assumption for the young professional. It also seems true for the unskilled worker who faces a perfectly elastic demand curve for his services in region x both in terms of pecuniary and non-pecuniary benefits. For both classes of workers the job hunt is completed before moving. This is literally true for most professionals. Thus we assume that preliminary search estimates have identified the best wage in each of the N cities. This identification could have occured via systematic search, belated search, or systematic-belated search. In practice, both job and city characteristics may be learned together. Here for analytical convenience, we assume they are learned separately with job characteristics learned first and prior to moving.

(i) Formal Statement

The model is one in which the searcher seeks to locate in one of N different cities.[4] He possesses subjective beliefs about the wages attainable at each city location. Wage information -- a wage offer from a city -- may be obtained prior to a move decision. But here it is assumed that certain characteristics of the city are ascertained only after a move has been made -- at which point the relevant moving costs are incurred. At each decision point the optimal action among the N alternatives is the one possessing the largest Gittins index, where the index is a multi-armed bandit (MAB) generalization of the reservation wage.[5] The action associated with each index is either search, migrate and test a city, or work. Work is an absorbing state

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[4]The papers by Gittins (1979) and Whittle (1980) are basic. A lucid presentation of the Gittins methodology is contained in Chapter 7 of Ross (1983). Roberts and Weitzman (1980) independently developed the same MAB procedure. We follow their notation.

[5]Roberts and Weitzman (1980).

that commences when the searcher chooses to work a job after migration has taken place and the relevant locational characteristics have been assimilated. The ordered set of N Gittins indices are revised as new information is accumulated over time.

Subsection (ii) briefly describes MAB processes and the Gittins index which is the fundamental technique for solving these problems. In subsection (iii) a simple model of migration and belated information is posed as an MAB process. Subsection (iv) complicates the model by adding wage uncertainty. A reservation wage rule guiding migration is derived. This reservation wage depends on the various location alternatives and changes through time as more information is collected.

(ii) <u>MAB Processes and the Gittins Index</u>

A gambler is confronted with N slot machines (one armed bandits) or projects that may be played repeatedly in any order. The i^{th} machine is characterized by a success probability θ_i which is unknown to the gambler. The Bernoulli sequence of successes and failures on the i^{th} machine provides information used to obtain a Bayesian estimate of θ_i. The object is to choose the sequence of plays to maximize the total discounted expected reward.

During the past few years Gittins and his colleagues have solved this MAB problem. Simply stated the optimal policy has the following form: a policy is optimal if and only if at each decision point the selected bandit process is the one with the largest Gittins index, where this index is a variant number attached to each project state.

More concretely, suppose there are N projects indexed by $n = 1,2,\ldots,$ N. At any decision point exactly one project must be selected for further development. Suppose project n is in state i. If n is chosen a reward R_i^n is collected and project n moves from state i to state j with probability P^n_{ij}. The states of all other projects remain unchanged. The discount factor is β^n_i. Let $\psi(s)$ denote the maximal expected discounted return when the current state is $s = X^N_{n=1}\ i(n)$. Then $\psi(s)$ satisfies

$$\psi(s) = \max_{1<n<N} \{R^n_i + \beta^n_i\ \Sigma P^n_{ij}\ \psi(s - [i(n)] + [j])\}, \tag{1}$$

where $s - [i(n)] + [j]$ means state s except the n^{th} component is in state j instead of $i(n)$.

The solution to this problem is obtained by assigning each project a Gittins index and then at each decision point choosing that project with the largest index. Intuitively, the Gittins index is the value of a fallback position which would make a decisionmaker indifferent between continuing with project n in state i and rejecting the project for the fallback position. For any fallback position Z the maximum expected discounted return $V^n_i(Z)$ obtainable given the choice of either continuing with project n (in state i) or stopping and getting Z satisfies

$$V^n_i(Z) = \max \{Z;\ R^n_i + \beta^n_i\ \Sigma P_{ij} V^n_j(Z)\}. \tag{2}$$

Thus the Gittins index Z^n_i is given by

$$Z^n_i = V^n_i(Z^n_i) = R^n_i + \beta_i\ \Sigma P^n_{ij} V^n_j(Z^n_j). \tag{3}$$

Proposition 1. (Roberts and Weitzman). Let $Z^{n*}_{i(n)} = \max_n Z^n_{i(n)}$. Then the policy that chooses $n*$ when $s = X^N_{n=1}\ i(n)$ is optimal.

(iii) A Simple Bandit Model of Migration

There are N cities available for location and the wages associated with each city, w^n, $n = 1,2,\ldots,N$ are known. For each city there is a moving cost K^n, $n = 1,\ldots,N$, which is incurred once and only once the first time location at the city occurs. This assumption is somewhat unrealistic in that traveling costs — when relocation to a formerly searched city is concerned — are assumed zero. Our model stresses the costs of learning attributes of a location. Finding desirable stores, restaurants, parks, etc. could consume considerable time and expense as can the formation of a new social network. We postulate that these costs greatly outweigh moving costs, especially early in a career when the accumulation of physical capital is negligible. Another way to view the situation is that one incurs costs to learn city attributes, which in turn influence subsequent migration decisions. Finally, it is assumed that city attributes are stable over time, again implying that location costs are incurred only once for each city.[6,7]

After working one period, city attributes are learned and a decision is made whether to quit and move elsewhere or remain. For simplicity we assume that a priori the migrant views city n's attributes as a simple random variable $\alpha^n V$, $\alpha^n > 0$ with $P(V = +1) = P(V = -1) = 1/2$.[8] Since the model assumes the worker is an expected income maximizer — and so risk neutral — this assumption is not restricting. The objective is to design a testing policy that maximizes expected discounted returns where β is the discount factor.

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[6]On a more mathematical level the zero cost assumption of relocation to a formerly inhabited city is needed to ensure the Gittins solution is valid. One of the major assumptions needed for a solution is project independence. This assumption is violated if moving costs are always incurred.

[7]The number of cities being evaluated need not be fixed at N. A proof of this is contained in Whittle (1981).

[8]The belated information model is presented in Lippman and McCall (forthcoming) and Wilde (1979).

The problem can be formulated as a bandit process with $P^n_{o1} = P^n_{11} = \frac{1}{2}$, $R^n_o = w^n - K^n$, $P^n_{22} = P^n_{o2} = 1$, $R^n_1 = \frac{w^n+\alpha^n}{1-\beta}$, $R^n_2 = \frac{w^n-\alpha^n}{1-\beta}$, $\beta^n_i = 0$, $i = 1,2$, $\beta^n_o = \beta$.

The equation defining the Gittins index for the n^{th} job in state 0 is

$$Z^n_o = w^n - K^n + \tfrac{1}{2}\beta \left\{\max\left(Z^n_o, \frac{w^n+\alpha^n}{1-\beta}\right) + \max\left(Z^n_o, \frac{w^n-\alpha}{1-\beta}\right)\right\} \tag{4}$$

The optimal policy tests that city with the largest Gittins index and continues until the total renumeration of a tested city exceeds the Gittins indices of all untested cities.

Proposition 2.

a) If $K^n > \frac{\alpha^n}{1-\beta}$, then the Gittins Index is given by $Z^n_o = w^n - K^n + \frac{\beta w^n}{1-\beta}$;

b) If $K^n < \frac{\alpha^n}{1-\beta}$, then the Gittins Index is given by $Z^n_o = \{w^n - K^n + \frac{\frac{1}{2}\beta}{(1-\beta)}(w^n+\alpha^n)\}/(1 - \frac{1}{2}\beta)$. (See Figure 1.)

Proof:

a) $Z^n_o = w^n - K^n + \frac{1}{2}\beta \left\{\max\left(Z^n_o, \frac{w^n+\alpha^n}{1-\beta}\right) + \max\left(Z^n_o, \frac{w^n-\alpha^n}{1-\beta}\right)\right\}$

Suppose $Z^n_o > \frac{w^n+\alpha^n}{1-\beta}$. Then

$$Z^n_o = w^n + k^n + \tfrac{1}{2}\beta\, 2Z^n_o = w^n - K^n + \beta Z^n_o$$

$$Z^n_o = \frac{w^n-K^n}{1-\beta}, \text{ a contradiction since } \alpha^n, K^n > 0.$$

Suppose $\frac{w^n+\alpha^n}{1-\beta} > Z^n_o > \frac{w^n-\alpha^n}{1-\beta}$.

Then $Z^n_o = \{w^n - K^n + \frac{\beta}{2(1-\beta)}(w^n+\alpha^n)\}/(1 - \frac{1}{2}\beta)$

Figure 1

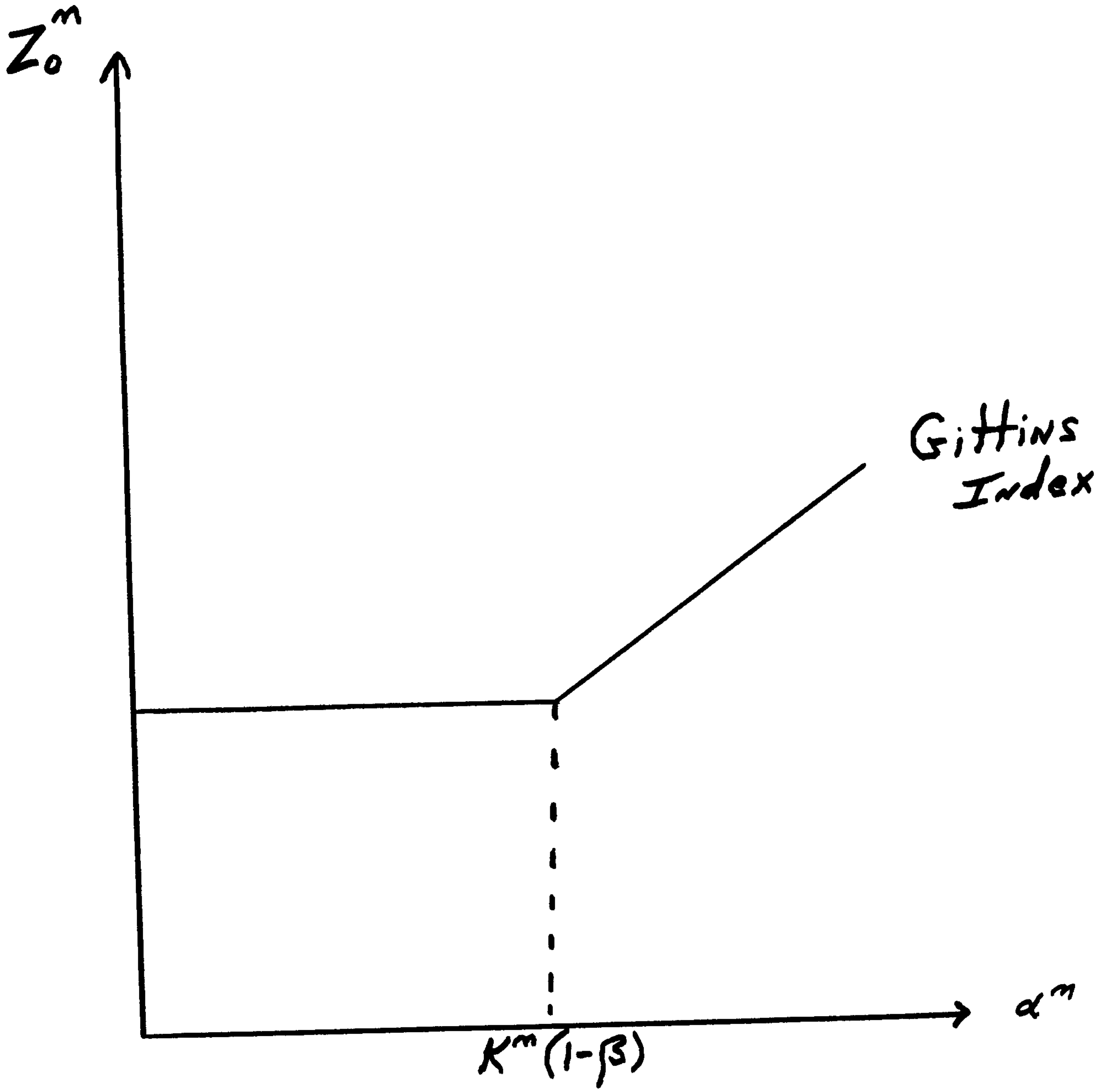

Fig 1: Graph of Proposition 2

and

$$\frac{w^n-\alpha^n}{1-\beta} < \{w^n - K^n + \beta/2(1-\beta)\ (w^n+\alpha^n)\}/(1 - \tfrac{1}{2}\beta),$$

or

$$K^n < \frac{\alpha^n}{(1-\beta)} \quad \text{a contradiction.}$$

Thus, $$Z_o^n < \frac{w^n-\alpha^n}{1-\beta} \quad \text{implies} \quad Z_o^n = w^n - K^n + \frac{\beta w^n}{1-\beta}.$$

b) From a) $Z_o^n < \frac{w^n+\alpha^n}{1-\beta}$.

Suppose $$Z_o^n < \frac{w^n-\alpha^n}{1-\beta}.$$

Now $$Z_o^n = w^n - K^n + \frac{\beta w^n}{1-\beta},$$

so $$\frac{w^n-\alpha^n}{1-\beta} > w^n - K^n + \frac{\beta w^n}{1-\beta}, \quad \text{or}$$

$$\frac{\alpha^n}{(1-\beta)} < K^n, \quad \text{a contradiction.}$$

Thus, $$\frac{w^n+\alpha^n}{1-\beta} < Z_o^n < \frac{w^n-\alpha^n}{1-\beta} \quad \text{and}$$

$$Z_o^n = \{w^n - K^n + \frac{\beta}{2(1-\beta)}\ (w^n+\alpha^n)\}/(1\ 1/2\ \beta). \qquad \text{Q.E.D.}$$

As anticipated we see that the location decision depends not only on wages and moving costs, but — when α^n is "large" relative to K^n — city attributes. In particular, for two cities with equivalent wages and costs the one with the higher uncertainty — larger α^n — will be "tested" first.

Suppose city i is the best opportunity at the outset. Then $Z_o^i = \max_{n=1,\ldots,n} \{Z_o^n\}$ and let city j be the second best opportunity $Z_o^j = \max_{n\neq i} \{Z_o^n\}$. If city i's hidden attributes turn out badly $(V = -1)$, the worker will migrate if $Z_o^j > Z_2^i$. For simplicity we will assume that $w^i = w^j$.

Now if $\alpha^j/(1-\beta) > K^j$, we have

$$Z_o^j = \{w^j - K^j + [\,½\,\beta(w^j+\alpha^j)/(1-\beta)]\}/(1 - ½\,\beta).$$

Thus a move will take place if

$$\{w^j - K^j + [\,½\,\beta(w^j+\alpha^j)]/(1-\beta)\}/(1 - ½\,\beta) > \frac{w^i-\alpha^i}{1-\beta}$$

or

$$K^j < \frac{\alpha^i + ½\,\beta(\alpha^i-\alpha^j)}{(1-\beta)}.$$

If

$$\alpha^j/(1-\beta) < K^j,$$

$$Z_o^j = w^j - K^j + \frac{\beta w^j}{1-\beta}\,.$$

So a move will take place if

$$w^j - K^j + \frac{\beta w^j}{1-\beta} > \frac{w^i-\alpha^i}{1-\beta}$$

or

$$K^j < \frac{\alpha^i}{(1-\beta)}\,.$$

A necessary condition for this to be satisfied is that $\alpha^i > \alpha^j$.

(iv) Extended MAB model of migration

The model is the same as in subsection (iii) except that the wage W_j^n at location n is a random variable with subjective probability distribution of q_j^n, $j = 1,2,\ldots J$. The individual pays a cost c — perhaps to an employment agency — to observe the true wage in city n. This wage may be considered his best wage offer obtained from some sort of search process where an amount c is allocated to the search process.[9] Here we assume that all individual job information is obtained prior to a move decision — there is no belated

[9] We envision this search process to be quite intensive — the searcher visits prospective firms within the region and ascertains the benefits associated with each. He then picks the best firm in the region. Thus, if the regional belated information renders this firm unacceptable, then all firms in the region are even less desirable.

information subsequent to a move with respect to the job. This implies there will be no subsequent intracity job search.[10] If he stays permamently at the city he will work at his initial job. This simplifying assumption is needed to satisfy the Gittins' solvability constraints.

From the above assumptions a potential migrant may search other cities before making a decision to move. For example, suppose that a migrant moves to city ℓ and finds that he dislikes the city after working there one period $(V = -1)$. He may find it in his interests to search city m to find out his true opportunities there, that is, his true w_j^m. Now if w_j^m turns out to be high given α^m and K^m he may then move there. If, on the other hand w_j^m is relatively low, then he might search the next most attractive city, or if the potential benefits of that search don't outweigh the costs, c, he may return to work in city ℓ — thus permanently residing there.

In terms of our MAB model, city n is in state 0 before it has been searched, state j after w_j^n is observed and finally state $2j$, $(+\alpha^n)$ or state $3j$ $(-\alpha^n)$ after the city has been tested. Thus

$$P_{oj}^n = q_j^n; \quad P_{j,2j} = P_{j,3j} = 1/2$$

$$R_o^n = -c; \quad R_j^n = w_j^n - K^n; \quad R_{2j}^n = \frac{w_j + \alpha^n}{1-\beta}$$

$$R_{3j}^n = \frac{w_j - \alpha^n}{1-\beta}; \quad \beta_j^n = \beta, \quad 0 < j < J$$

$$= 0 \quad j > J$$

The Gittins index for the n^{th} job in state 0 satisfies

$$Z_o^n = -c + \beta \sum_{j=1}^{J} q_j^n \max \{Z_o^n, w_j^n - K^n + \frac{1}{2} \beta$$

[10]Of course this need not be a city, but a region within a large city.

$$[\max (Z_o^n, \frac{w_j^n + \alpha^n}{1-\beta}) + \max (Z_o^n, \frac{w_j^n - \alpha^n}{1-\beta})]\} \qquad (6)$$

From (6) it is clear that Z_o^n is nondecreasing in α^n, i.e., more uncertainty is preferred to less. If city ℓ is searched, i.e., $Z_o^\ell > Z_{i(n)}^n$ for all n, then the city will be tested — migration will take place — if and only if $Z_j^\ell > Z_\ell^*$, where $Z_\ell^* = \max_{\ell \neq n} Z_{i(n)}^n$. This observation yields

<u>Proposition 3</u> If the ℓ^{th} city is searched, there is a reservation wage ξ^ℓ for the ℓ^{th} city such that the ℓ^{th} city will be migrated to it if and only if $w_j^\ell > \xi^k$ where ξ^k is defined by

a) $\xi^K = [(1 - 1/2\,\beta)(1-\beta)(Z_\ell^* + K^\ell) - 1/2\,\beta\, \alpha^\ell]/(1 + 1/2\,\beta)$ if $\frac{\alpha^\ell}{1-\beta} > K^\ell$;

b) $\xi^K = (1-\beta)\ [Z_\ell^* + K^n]$, if $\frac{\alpha^\ell}{1-\beta} < K^\ell$.

<u>Proof</u>:

a) From Proposition 2,

$$Z_j^\ell = (w_j^\ell - K^\ell + 1/2\,\beta(w_j^\ell+\alpha^\ell)/(1-\beta))/(1 - 1/2\,\beta).$$

Consequently, the job is tested — migration occurs — if and only if

$$Z_\ell^* < (w_j^\ell - K^\ell + 1/2\,\beta(w_j^\ell+\alpha^\ell)/(1-\beta))/(1 - 1/2\,\beta),$$

which implies

$$Z_\ell^* = (\xi^\ell - K^\ell + 1/2\,\beta(\xi^\ell+\alpha^\ell)/(1-\beta))/(1 - 1/2\beta). \qquad \text{Q.E.D.}$$

b) Now

$$Z_j^{\ell} = w_j^{\ell} - K^{\ell} + \frac{\beta w^{\ell}}{1-\beta}.$$

Arguing as in part (a) we obtain,

$$Z_{\ell}^{*} = \xi^{\ell} - K^{\ell} + \frac{\beta \xi^{\ell}}{1-\beta}.$$ Q.E.D.

Suppose that the individual is initially located in city m, which is now the second most attractive opportunity. That is, you have worked the city, incorporated its attributes — which are implicitly $(-\alpha^{m})$ — and decided to work the most attractive project — say ℓ. Let's suppose that project ℓ — city ℓ — has yet to be searched and $\frac{\alpha^{\ell}}{(1-\beta)} > K^{\ell}$. Then migration from city m to ℓ will take place if

$$w_j^{\ell} > w^* - w^{m} + K^{\ell} - \frac{1}{\beta(2-\beta)} (\alpha^{\ell} - K^{\ell}),$$

where w^* is the realized wage in city m. Large w_j^{ℓ}, α^{ℓ}, or α^{m} would tend to favor a move, whereas large w^* or K^{ℓ} would tend to impede it.

(v) Labor Mobility Within Firms

There is another quite important form of migration that occurs within large firms. The moves are mainly intranational, but many (especially for military personnel and international corporations) are international. The moves entail no job search and the model described here applies almost exactly, with, of course, the choice being to move, to stay where you are and risk discharge and/or a lower rate of promotion, and to quit. Military personnel may be unable to quit immediately, but when their re-enlistment and retirement decisions are made they are strongly influenced by the non-pecuniary aspects of these new assignments.[11]

3. Physical Capital Mobility

There are several forms of capital mobility that can be studied with the model presented in Section 2. The first is plant location, the second is firm acquisition, and the third is the decision by the firm to enter a new industry. These need not be mutually exclusive decisions. A firm may acquire a plant (firm) that belongs to a new industry and is located in a different region. Nevertheless, we treat them as separate decisions.

(i) Firm (Plant) Location

Consider a firm that is planning to construct a plant in one of N locations. The crucial variables entering the firm's decisions are: the availability of a trained labor force (or the ease with which one can be attracted), tax incentives provided by the local community, proximity to non-labor inputs, and so on.[12] Based on all the available information, a Gittins index is calculated for each of the N possible sites. This index for site n is a measure of the profitability of the plant at site n, given the available information. Then the firm spends c dollars and intensively searches the site with the highest index and receives a better estimate of profits. If this exceeds reservation profits, the firm begins building the plant. If not, the firm considers the location which now has the highest index. Suppose though that the reservation profits are exceeded. Then K^n dollars are spent and building commences. During this initial phase of

[11] An estimation of these effects is presented in Gotz and McCall (1984).

[12] For an empirical study of plant location see Carlton (1983). The model presented here generalizes the paper by Pascal and McCall (1980).

building, architectural plans are designed, but ground is not broken, the firm learns the precise location and composition of the labor force and has personal contacts with city officials and other local firms. If this information is positive, it locates at n. If it is negative, it may render this location inferior to that location with the previously second highest Gittins index. The firm will then move to this superior site and acquire more information there. If, after experimenting with other sites it discovers that site n is the best, it need not pay K^n dollars when it returns to n, that is, it starts where it left off.

(ii) Firm Acquisition[13]

This sequential process can also be applied to the acquisition decision. A firm wishes to acquire another firm and is considering M candidates.[14] It first calculates a Gittins index for each candidate. For the candidate with the highest index the firm pays c dollars and determines the acquisition price. If this price is less than the reservation price, the firm pays K_m dollars and begins acquisition proceedings. As these proceedings unfold it discovers more about the firm. If the discovery is good news,

[13]This application was suggested by Armen Alchian.

[14]This analysis can also be applied to animal behavior. (See Lippman and McCall (forthcoming), chapter 8. An amazing example of biological merger by amoebas is described in Prigogene and Stengers (1984).

> When the environment in which these amoebas live and multiply becomes poor in nutrients, they undergo a spectacular transformation. Starting as a population of isolated cells, they join to form a mass composed of several tens of thousands of cells. This "pseudoplasmodium" then undergoes dofferentiation, all the while changing shape. A "foot" forms consisting of about one third of the cells and containing abundant cellulose. This foot supports a round mass of spores, which will detach themselves and spread, multiplying as soon as they come in contact with a suitable nutrient medium and thus forming a new colony of amoebas.

the firm is acquired. If it is bad news, then this firm may no longer have the maximum Gittins index and the optimal policy would search, initiate acquisition, or acquire the firm possessing the maximum index.[15]

(iii) The Entry Decision[16]

The firm is contemplating entry into one of I industries. Assume further that these are all mature industries and the entrepreneur will not produce a new product, that is, create a new industry. The entrepreneur begins by assembling an experimental firm in industry i. The cost of assembly is c^i. In practice the experimental firm might be a small scale version of the final firm or simply a simulation. The experimental firm is designed to imitate the most successful firms in the industry. We refer to the assembly of an experimental firm for industry i as tentative (soft) entry into industry i. The entrepreneur operates the experimental firm for one period and receives preliminary information on π_i, the profits obtainable in industry i. Before tentative entry, the entrepreneur has a prior distribution over π_i. After the entrepreneur receives information from the experiment, he decides to remain in i if π_i exceeds reservation profits, η^i. Remaining in i will be referred to as serious or hard entry. If he remains he pays K^i and receives perfect information about profits. For simplicity we assume that there is either good news (+1) or bad news (-1). If the news is good, the firm remains in i. If it is bad, the firm may enter

[15]Once again, if the firm ever returns to firm m, it does not incur another K^m dollars, but simply acquires m.

[16]Lippman and Rumelt (1982) is the seminal paper on this topic.

tentatively, seriously or permanently enter another industry.[17]

4. International Capital Movements

Here we consider briefly the problem confronting illegal aliens moving into the United States. The analysis is essentially the same as for intra-national migration except that now the worker may be "caught" and returned to the originating country. Capture can occur during transit from country i to country n,[18] or after work begins in n. Let these events have probabilities p_n and p_n', respectively. The migrant does his search using an informal network of friends, relatives, and company recruiters before he leaves his home country. If the illegal alien arrives at the job and then is caught, he is sent back to his home country and tries again. In this circumstance the Gittins Index is defined by:

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[17]We plan to relax the competitive assumption and investigate the equilibrium that occurs when firms seek entry according to a Gittins index and each industry erects some sort of entry barrier. Strategic considerations obviously play a significant role in this equilibrium analysis. The Gittins index is now a response to the given set of entry barriers and the entry barriers are best responses to the Gittins indices of the potential entrants. In this Nash setting, natural selection involves purposeful behavior by both industry and entrant. Market forces determine which industries survive and the relative success of firms in a given industry.

As a first approximation to this problem, we have analyzed the following model. Assume that an entrant has several possible industries where entry is "profitable". For simplicty assume that each industry is monopolized. In this model the monopolist need not deter fully, but only up to the point where he becomes "second best". Of course, all monopolies will try to achieve "second best" status. There are three possible outcomes: (1) the firm enters one of the industries and (2) no entry occurs. Each of these is an equilibrium outcome. The third possibility is (3) there may be no equilibrium. Sufficient conditions have been obtained for the existence and uniqueness of both a full deterrence Nash equilibrium and a no deterrence Nash equilibrium. We are confident that this analysis can be extended to the Gittins environment. (See McCall (1982.)) It also seems to be a reasonable method for resolving the "chain store paradox."

[18]This assumes that the time till the first successful transit is a geometric random variable with parameter p_n.

$$Z_o^n = -K^n + E\beta^{\tau}w^n + \tfrac{1}{2}E\beta^{\tau+1}\left[\mathrm{Max}\left\{Z_o^n, \frac{w_o^n + \alpha^n + \beta p_n' Z_o^n}{1 - \beta(1-p_n')}\right\} + \mathrm{Max}\left\{Z_o^n, \frac{w^n - \alpha^n + \beta p_n' Z_o^n}{1 - \beta(1-p_n')}\right\}\right],$$

where τ is a geometric random variable with parameter, p_n'.[19] With this modification, everything goes through as before.

The informational problems posed by international capital movements are formally identical to those discussed in 3(i), 3(ii) and 3(iii). In practice, learning the language and customs of the host countries increases the cost of this information. No doubt, the success of the Japanese in foreign markets is partially explained by their willingness to bear these costs.

5. Conclusion

This paper has developed a rather versatile sequential model of capital mobility. It is based on the methods developed by Gittins and generalizes the familiar reservation wage search model. While its application to intra-national mobility is important, the introduction of informational considerations into international capital mobility may be its most significant contribution.

Of course, the value of this approach can only be assessed after empirical testing. The relative success of simple sequential models in

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[19] The importance of information in international migration has been emphasized by Kwok and Leland (1982, 1984) [K and L] in their analysis of the "brain drain" and Katz and Stark (1984). Their models emphasize the role of asymmetric information, with firms in the migrating country (K and L) having superior information to firms in the foreign country. This asymmetry gives rise to the standard problems of signalling. Indeed K and L show how this information asymmetry "can explain how the decision by an initially small group of graduates not to return to their home country may eventually cause almost all graduates to remain abroad."

explaining behavior is an encouraging sign.[20] One would guess that the sophisticated econometric methods developed by Flinn and Heckman (1982) and Heckman and Singer (1984) could be applied to include Gittins duration models.

[20]For example see Kiefer and Newmann (1981), Chapter 11 of Lippman and McCall (forthcoming), and Gotz and McCall (1984).

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