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VALUE OF WAITING**

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ABSTRACT

Migration and the Option Value of Waiting*

Migration is an investment: it involves fixed, unrecoverable costs and uncertain future returns. If migration can be postponed, the option value of doing so may have positive value. Migration may not occur for a range of individuals who would otherwise migrate on a net present value basis. This paper models the migration decision using ideas developed by Pindyck (1991) and Dixit (1992). The option value of waiting is related to the interest rate, fixed costs, and especially uncertainty governing the evolution of income at home and abroad. The 'bad news principle' predicts that only unfavourable states of the world will affect the value of the migration option. In a rational intertemporal equilibrium of two regional labour markets, low migration rates may coexist with large or even increasing current wage differentials.

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NON-TECHNICAL SUMMARY

Migration continues to be a central issue in public policy discussions, especially in Europe and North America. Declining transportation costs, growing foreign 'attractor' populations around the world, and more liberal social policies in receiving countries have increased the international supply of migrants. The real puzzle, however, is that so *little* international migration actually occurs, given the very large and – according to some observers of economic growth, non-converging – wage and income differentials that exist across countries. Two striking examples of this phenomena are that despite large wage differentials and the absence of institutional barriers, one observes relatively low migration rates between Puerto Rico and the United States, and between East and West Germany. Such low levels of migration can be attributed to several factors, including migration costs, incomplete information, and risk aversion of migrants.

This paper examines an alternative, complementary explanation of observed immobility. It rests on the insight that the migration decision is an investment, involving fixed, to some extent unrecoverable costs and uncertain future returns. Because uncertainty is resolved only with the passage of time, the timing of the migration decision may be of central importance to economic agents. If migration can be postponed, the value of doing so may be positive in that it brings additional and perhaps fundamentally new information to bear on the decision. As a result of this value of waiting, migration may not occur for a range of individuals who would otherwise migrate on the basis of net present values of wages or utility.

This 'real option' framework for investment decisions, first proposed by MacDonald and Siegel (1986) and developed by Pindyck (1991) and Dixit (1992), underlies the analysis of migration in this paper. First, the option value of waiting is derived under simple conditions in a two-period set-up. Next, I propose a more complicated model of migration by economic agents with very long time horizons. The option value of waiting derived under these conditions is related in complex ways to the interest rates, fixed costs, and especially uncertainty governing the evolution of income at home and abroad.

The 'bad news principle' predicts that only unfavorable states of the world will affect the value of the investment option, since by assumption postponement does not rule out taking the decision later in good states. This idea also applies to the migration case; it also has interesting implications for equilibrium across labour markets. In a rational intertemporal equilibrium in a simple

model of two regional labour markets, low migration rates today may coexist with large and increasing current wage differentials. This puzzling outcome can explain why efforts expected to close regional wage inequality in the future may paradoxically lead to larger wage differentials and less migration today.

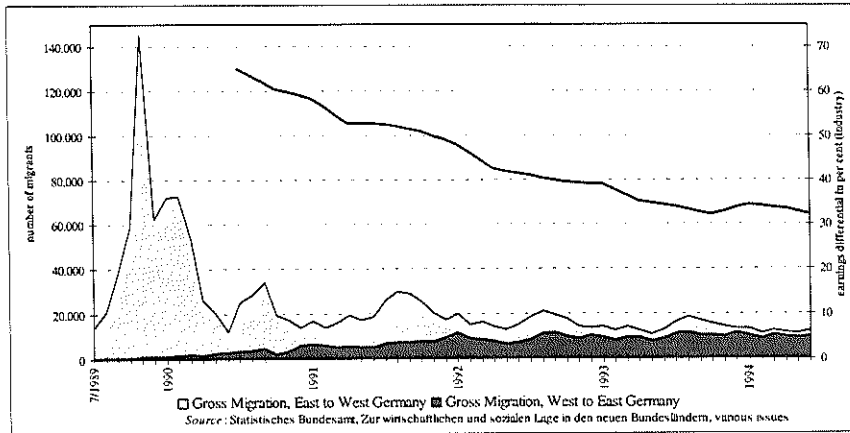
1. Introduction and Survey of Issues

The spatial mobility of labor is central to trade theory, development, and the economics of the workplace. As labor is the most important factor of production, it is only natural that migration should occupy a large role in these fields. Assumptions concerning the degree of labor mobility often determine the existence and properties of equilibria in theoretical models. Migration is a key factor in economic development and integration. The developmental path of the ex-communist economies of Central and Eastern Europe will depend in a fundamental fashion on the evolution of migration, as will the economic integration of eastern and western Germany, and of Europe on a larger scale. International mobility may affect the degree of wage inequality in a population, if migrants possess significantly different skill levels than natives (which they often do). Migration can therefore determine the average quality of the labor force and its productivity.

At the aggregate level, one key stylized fact which seems to cry for an answer is the "slow bleed" nature of regional and international migration. Figure 1 illustrates the situation for East-West German migration since 1989, a context with which I am pretty familiar for various reasons. Yet the same holds, whether the context is Irish migration to North America in the 19th century or to England in the 20th, eastern German migration to Berlin or the richer west, Polish migration to Germany, Ukrainian and Russian migration to Poland, or third-world migration to Russia, or even Latin American population movements to the United States (see Freeman 1993): despite large, sometimes very large income differentials, migration is a drawn-out process in the aggregate. In the case of Germany, in 1989 wages in the eastern half were one-tenth of western levels; in 1991 they were just under one half; now they are roughly 70%. Gross East-West German migration on the other hand has stabilized since late 1993 at 12,000 per month, and are not too different from West-West migration patterns. Surveys indicate that eastern Germans are ambivalent to migrating: in my work on the German Socioeconomic Panel in the ex-GDR (Burda 1993), I found that while roughly 35% of the adults surveyed considered migration a feasible economic option, less than 4% were totally enthusiastic about it.¹

¹Similar findings are reported by Akerlof et al. (1991).

Figure 1. East-West German Migration Flows and Earnings Gap



One interpretation of sluggish migration is that it reflects the imperfect availability of information about the host country (Pickles and Rogerson (1984), McCall and McCall (1987)). The decision to migrate can be thought of as a sequential search process in which individuals maximize expected net wages and face a time invariant wage distribution: migration occurs when an offer is drawn which exceeds some reservation level. Because migrants tend to be employed before they migrate, this type of search has important on-the-job aspects to it. Similarly, aggregate migration can be seen as the outcome of a matching process which reflects the availability of vacancies and the number of job seekers in both sender and receiver regions (Pissarides and Wadsworth (1989)). The probability of migrating to another location after having obtained a job offer is a function of local labor market conditions, i.e. competition from other individuals seeking within the particular region. Jackman and Savouri (1992) model net migration across regions based on these ideas as a function of regional unemployment and vacancy shares, as well as the distance between the respective regions. This approach uses the results of extended gravity models, originally applied in the theory of international trade, where distance between regions or countries serves as a proxy for migration costs (see Foot and Milne (1984), Burridge and Gordon (1981)).

In the search interpretation, the underlying distribution of uncertainty is unchanging: economic agents are simply fishing for better draws. An alternative interpretation, which I develop in this paper, is that the "slow-bleed" may reflect a rational choice of procrastination on the part of individual migrants. Deferring the migration decision may reflect economically rational choice, to the extent that it allows the migrant to profit from a favorable turn of events. Central to this interpretation is the insight, which was articulated in print by Larry Sjaastad in the early 1960s, that migration is an *investment*. It represents the incurring of an immediate up-front fixed cost for future and possibly uncertain gains.² As a human capital investment, its net return will depend on the discount rate, the relevant time horizon, the magnitude of fixed outlays, and the expected flow wage or utility differential relative to that available at home. It will also depend on the value of waiting in the sense of Pindyck (1991), Dixit (1991, 1992) and Dixit and Pindyck (1994). I would therefore like to propose this "real option" framework, which is already well-established in investment, industrial organization, and exchange rate theory, as an alternative framework for studying migration.

My discussion today will focus exclusively on a relatively narrow aspect of the migration decision itself.³ I will not deal with issues such as the effect of migration on wages in the home and receiving countries, nor will I discuss the issues of assimilation, or how rapidly earnings of migrants converge to those of natives for given quality. I will not have much to say about the multifarious nature of the mobility decision --- households typically face a much richer choice set than we economists are accustomed to dealing with. To some extent these choices can be parametrized by distance, which has always been an important nonlinear determinant of migration (Schwartz (1973)). At my own peril, I will ignore other important aspects of migration -- for example, insurance motives or those deeply rooted in household structure (Stark (1991)). I ignore unemployment, although those who migrate tend to have jobs already; in any case the model can be adapted in terms of *expected* wages (Harris and Todaro (1970)). I will also neglect issues of selection (Roy (1951), Borjas (1987, 1994)); evidence seems to indicate that individuals with below-average productivity are attracted to

²Sjaastad (1962) defines migration as "... an investment in increasing the productivity of human resources, an investment which has costs and renders also returns" (p. 83).

³For reviews of the migration literature, see Molho (1986), Greenwood (1990) and Greenwood et al. (1993).

environments in which the dispersion of remuneration is relatively low, while those with high skill endowments gravitate toward countries with large income spreads. Finally, migration is also to some extent reversible. Reverse migration is a well-recognized, if not always well-understood phenomenon (see Djajic and Milbourne (1988), Stark (1991), Dustmann (1994)). The possibility of return migration is an important one, and vitiates some of my results, as one of my key assumptions is that some part of the initial outlay for the migrant is unrecoverable; returning home may undo some of these costs.

II. General Remarks on the Option Value of Investment Approach

The migration decision has three key aspects which make it amenable to the analysis in Pindyck/Dixit (1994). First, the act of migration involves up-front *fixed costs* which are to some extent irreversible and nonrecoverable. These include moving expenses and the disruption and discomfort of moving, the permanent loss of friends, social infrastructure, and professional contacts; giving up an apartment or house, loss of job-match capital, etc. Second, the migration decision is taken in an uncertain environment. Future rewards to migration, in terms of additional income, improved standard of living, and social livelihood are uncertain. An essential aspect of uncertainty in this problem is that new information can be acquired by waiting. Finally, we assume that the migration decision is postponable; procrastination is a viable option.⁴

Inasmuch as the possibility of migration creates an option, many of the obvious analogies with financial options theory arise. This was recognized in the context of investment projects by McDonald and Siegel (1986) and picked up later by Pindyck and Dixit. In this line of analysis, taking the action (here: migrating) amounts to "killing" or exercising the *option* to do so. The option -- the right, but not the obligation to take some action -- has value as long as the future can evolve differently from the present. Thus, in order to justify the action, expected future benefits must exceed not only the up-front costs, but also the value of the option itself.⁵

⁴An exception might be the case of totalitarian regimes which are expected to close the door on emigration in the future at some point in the future. For a discussion of this aspect of East-West German migration, see Akerlof et al. (1991).

⁵It is important to stress that the theory of investment under uncertainty does not require risk aversion; all of the following are derived under risk neutrality. Risk aversion can be incorporated into the model in a fairly straightforward way; see Dixit and Pindyck (1994).

Applied to migration, the theory is relatively straightforward. I plan to illustrate it in this section in a series of simple two-period examples, then propose a more formal model. Consider a hypothetical decision faced by an eastern German migrant considering two time intervals. In the first period, she faces a wage gap of DM 30,001 with the West; by migrating, she can increase her salary by DM 30,001 with probability 1. In period 2, the wage differential is uncertain, given information available in period 1; it could worsen, increasing to 60,000 DM with probability 0.5, or fall to zero with probability 0.5. The expected value of the wage gap in the second period is therefore DM 30,000. The migration decision, which may be taken either in period 1, postponed until period 2, or never taken, involves a one-off cost of 60,000 in the period migration occurs. The migrant is assumed able to work in the period she migrates, and return migration is ruled out for the moment. The discount rate is set to zero for simplicity. The following table summarizes the key aspects of the problem.

Table 1: The Returns from Migration, I

	Period 1	Period 2	Net Present Value
Migrate	$-60,000 + 30,001$	$(0.5)(60,000) + (0.5)(0) = 30,000$	1
Wait	0	$-60,000 + 60,000 = 0$	0

A risk-neutral agent comparing net present values (NPVs) would be just tempted to migrate in the first period ($-60,000 + 30,001 + 0.5(60,000) + 0.5(0) = 1 > 0$). Alternatively, the decision could be postponed to the second period; in this case she would migrate only if the gap were to widen to 60,000. Yet Table 1 is *constructed* so that procrastination is not a profitable strategy, with an NPV of $-60,000 + 60,000 = 0$. The contingency with migration in the second period leaves the worker just as well off as he would have been had he not migrated. To use Dixit's (1992) terminology, the "Marshallian criterion", which compares expected NPV with zero, gives the correct answer in this case. Waiting has no value. Furthermore decreasing the period 1 wage from 30,001 to 29,999 would induce the agent to cancel the migration decision.

This case is, of course, designed to make a point. Now consider an alternative scenario, in which costs and payoffs in the first period are as before, but the income gap in period 2 can now increase to 70,000 or fall to -10,000 with equal probability. The latter outcome is the "bad state" with respect to the migration decision, implying that wages are *higher* at home than abroad. If one is willing to take a broader view of income, this negative payoff could also reflect regret or homesickness in the receiving region. The payoffs are shown in Table 2.

On the basis of the Marshallian criterion, our would-be risk-neutral migrant should leave in period 1, since an expected net gain of 1 DM is possible. Yet this would be overly hasty: postponement of the migration decision to period 2 can make the agent even better off! Waiting until the second period means forsaking an immediate 30,001 of extra earnings in the first, but as a result the agent is able to observe the wage gap in the second period and migrate selectively (i.e., only if the income gap increases to 70,000), with a net gain of 10,000. Otherwise she stays home, avoids the losses, and saves the fixed costs. The expected value of this strategy (or option, please pardon the pun) is 5,000, which is considerably greater than DM 1 the agent gets otherwise. Furthermore, increasing the current wage from 30,001 as high as 34,999 induces no change in this relative outcome. Because procrastination has value, it induces a greater "region of inaction" or non-response of potential migrants to changes in current wages.⁶

Table 2: The Returns from Migration, II

	Period 1	Period 2	Net Present Value
Migrate	$-60,000 + 30,001$	$(0.5)(70,000) + (0.5)(-10,000)$	1
Wait	0	$(0.5)(-60,000 + 70,000)$	5,000

⁶Discounting can affect, but need not overturn these results. In the second scenario, only a negative discount rate could overturn a "wait and see" strategy. This issue is considered more fully below.

More generally, the problem can be formulated algebraically in the two-period, two state setup. I shall do this as a means of introducing notation necessary for the more difficult model in the following section. Let F be the fixed one-off cost of migration, r be the discount rate, W_1 denotes wage income in period 1 that could be earned in the West relative to the opportunity costs in the East. Denote with W^G_2 and W^B_2 respectively the two values relative wages can take in period 2 (in "good" and "bad" states), with probabilities p^G and p^B , with $p^G+p^B=1$. Both W_1 and W^B_2 are assumed less than F . The costs and payoffs associated with the two choices are summarized in Table 3.

The decision rule for the migrant from the perspective of period 1 is: migrate if the NPV in the first row exceeds that of the second, or

$$-F + W_1 + (p^G W^G_2 + p^B W^B_2)/(1+r) > p^G(W^G_2 - F)/(1+r). \quad (1)$$

In contrast, the discussion above suggests that waiting has value if

$$-F + W_1 + (p^G W^G_2 + p^B W^B_2)/(1+r) < p^G(W^G_2 - F)/(1+r) \quad (2)$$

or, since $p^G+p^B=1$, as long as

$$V^W(W_1) \equiv F(r+p^B)/(1+r) - W_1 - p^B W^B_2/(1+r) > 0 \quad (3)$$

where the function V^W is defined as the excess of the value of the waiting strategy over the classical expected net present discounted value when migration is undertaken immediately. V^W is (perhaps misleadingly) called the *option value of waiting*. When the value of the option goes to zero, the option is exercised, and the investment is undertaken. If V^W is positive, the option has value and it is optimal to wait. The "investment project" therefore has total value $V=V^I + V^W$, where the former is the value of the project if implemented immediately, and V^W

denotes the value of the project postponed (not adopted immediately but implementable at some future date).

Table 3: The Returns from Migration, III (algebraically)

	Period 1	Period 2	Net Present Value
Migrate	$-F + W_1$	$p^G W^G_2 + p^B W^B_2$	$-F + W_1 + (p^G W^G_2 + p^B W^B_2)/(1+r)$
Wait	0	$p^G(W^G_2 - F)$	$p^G(W^G_2 - F)/(1+r)$

The formula (3) contains several insights which are often lost in more complex models of real options. The value of the migration option is:

- 1) decreasing in W_1 (the current wage gap)
- 2) increasing in F (fixed costs)
- 3) increasing in r as $(1 - p^B)F > -p^B W^B_2$; decreasing in r as $(1 - p^B)F < -p^B W^B_2$
- 4) decreasing in W^B_2 (the bad news wage gap)
- 5) increasing in p^B (the probability of the bad state)
- 6) independent of W^G_2 (the good news wage gap).

First, the value of the option depends negatively on the wage differential, all things equal. This is intuitive, as higher current wages paid in the West render immediate migration more attractive relative to waiting. Second, the value of the option is positively related to the fixed cost F , since in the absence of fixed costs there are no gains to procrastination. Third, the effect of the interest rate on the option value is not unambiguous: an increase in r reduces V only if the expected fixed costs in the second period are small relative to the expected regret in the bad state. Clearly $W^B_2 < 0$ (regret) is a necessary condition for $\partial V / \partial r < 0$.⁷

⁷ There is a discount rate that will make the option valueless, but it need not be positive:

Finally, note that the option value of migration does not depend on values taken by wages in the good state (a high wage gap) in the second period. This is an illustration of the "bad news principle" (Bernanke (1983), Dixit (1992)). Waiting does not foreclose migration in the second period, so the prospective migrant can always profit from good states. The option value only depends on the bad realization of the future wage gap (recall that bad news is quick wage convergence or regret) as well as the probability of that event. An increase in W^B_2 reduces unambiguously the option value. In contrast, an increase in p^B will increase the option's value as long as $W^B_2 < F$, which we assumed ($W^B_2 < 0$ is sufficient).

One can exploit the formula for the option value to see how the "trigger wage" H , all other things given, is higher than the break-even point associated with zero net present value. For the former, the decision rule is to migrate whenever

$$W_1 > H \equiv F - (p^G F + p^B W^B_2)/(1+r) > 0, \quad (4)$$

as contrasted with the Marshallian NPV criterion

$$W_1 > M \equiv F - [W^G_2 + p^B(W^B_2 - W^G_2)]/(1+r) > 0 \quad (5)$$

The difference between the two trigger points H and M is given by $p^G(W^G_2 - F)/(1+r)$; as long as the agent is tempted to procrastinate ($W^G_2 > F$) the migration trigger point will be higher than that predicted by normal mobility models.⁸

In contrast to Dixit and Pindyck, this simple formulation does not require persistence of the underlying statistical processes as a necessary condition for the migration option to have value. This is because I have reduced the horizon to two periods, so persistence is not really well-defined. Moreover, W^B_2 is taken as exogenous and does not depend on W_1 . If on

$$V(W_1) = 0 \Leftrightarrow r = ((1-p^B)F + p^B W^B_2)/(F - W_1) - 1.$$

⁸See, for example, Ehrenberg and Smith (1991) and Hamermesh and Rees (1993).

the other hand, current wages predict future W^B_2 then the option value will be influenced by the predictive value (or persistence) of the wage.⁹

III. A Formal Model with an Infinite Time Horizon

I will now sketch a model of the migration decision with an infinite horizon. At the outset I should say that this is a rough characterization and not completely satisfactory, but reveals aspects of migration which are not evident from the two-period model. Sometimes I feel a bit like the inebriated man who was asked why he was looking for his key under the lamppost when he actually dropped it across the street, who replied, "because I can see over here." The cost of doing this is that my setup has a few undesirable side properties, which will be evident shortly. Nevertheless, the model delivers the intuition in the end, which helps us better understand the nature of the economics, and that is always our primary objective.

Keeping the notation of the previous section, let us now assume that time is continuous and that the migrant is infinitely-lived, or chooses vicariously for his or her descendants who will remain in the receiving country forever. The instantaneous wage gain from working in the West is given by W_t , which is modeled as a simple Brownian motion process with drift:

$$dW_t = \mu dt + \sigma dz_t \quad (6)$$

where dz is an increment to a Wiener process (a continuous-time Markov process with independent and normally distributed increments): $dz_t = \varepsilon_t \sqrt{dt}$, with $\varepsilon_t \sim N(0,1)$. Here the drift $\mu < 0$ is the rate at which the absolute wage differential shrinks; σ is the standard deviation of the Brownian motion per unit time.¹⁰ It follows then that

$$E(dW) = \mu dt \quad (7)$$

$$Var(dW) = \sigma^2 dt \quad (8)$$

⁹Suppose $W^B_2 = (1-\theta)W_1$; then $V(W_1) = F(r+p^B)/(1+r) - W_1[1+(1-\theta)p^B/(1+r)]$.

¹⁰I chose this particular setup, because, unlike the geometric Brownian motion setup preferred by Dixit, Pindyck and others, it allows the wage differential to be flipped in favor of the sending country. In the cleaner geometric Brownian motion setup, the solution is not defined for negative values of W , which one needs for "regret."

and

$$E[(dW)^2] = \mathcal{V}_m(dW) + [E(dW)]^2 = \sigma^2 dt + [\mu dt]^2. \quad (9)$$

For any initial condition W_0 , the wage gap will inexorably shrink to zero in finite time; moreover the wage gap can be forecast in the long run to become arbitrarily negative -- the ultimate case of homesickness. Despite this, discounting makes migration attractive all the same from the perspective of period 0. Perhaps now you understand better the reason for my remark about the drunk looking for his key. Maybe a more appropriate analogy is the Irishman in Boston contemplating spending Saturday night in Rose's in Faneuil Hall. I hope you would agree that this kind of discussion makes it imperative for us all to go have a pint of Guinness after my talk.

Note that this stochastic process has an extreme form of persistence: past W are not only useful in forecasting future W , but combined with the drift μ constitutes the *best* forecast of future relative wages. I continue to use the symbol F to denote the fixed, one-off costs of migration, so in a Marshallian world of risk-neutral migrants without regrets or procrastination, migration would occur when¹¹

$$W_t > \underline{W} \equiv rF - \mu/r. \quad (10)$$

As in the previous section, the agent can procrastinate, especially since he knows that the ultimate homesickness attack will set upon him with near certainty in the foreign country. Nevertheless, migration can still be tempting from the perspective of $t=0$. In the event of a deterioration of the home wage, migration is still possible, but now procrastination reveals information about the distribution of wages in subsequent periods. More so than before, in the

¹¹The present discounted value of expected future wages is $\int_0^\infty e^{-rt} E(W_t) dt$. But $E(W_t) = \int_0^t E(dW_s) ds = W_0 + \mu t$, so $\int_0^\infty e^{-rt} E(W_t) dt = [W_0 + \mu/r]/r$.

event of a good turn of events, migration and the associated fixed costs can be avoided. You now see why we began with the two-period case.

The solution to the migrant's decision problem is to find the trigger wage gap H which reflects the value of procrastination, given the structure of uncertainty, costs and benefits. As long as waiting has some value, H will be greater than the break-even point \underline{W} in expression (10). In doing so, I will value the option of waiting, defined as before as the difference between the value of the investment project with all procrastination possibilities built in, less the value of migration *if undertaken at this instant*. (As before, migration occurs immediately if the option value of waiting is negative). Define $V(W)$ as the value of the migration project when the agent behaves optimally. It consists of the sum of $V^I(W)$, the expected value of undertaking the project immediately, and $V^W(W)$, the value of postponing the investment to the future without further commitment. We will now value V when V^W is positive using an arbitrage argument.¹² By Ito's Lemma, the expected capital gain from holding the "asset" $V(W)$ can be expressed as

$$dV = V'(W)dW + 0.5V''(W)(dW)^2; \quad (11)$$

and taking expectations of both sides yields

$$\begin{aligned} E(dV) &= V'(W)E(dW) + 0.5V''(W)E[(dW)^2] \\ &= V' \mu dt + 0.5V'' [\sigma^2 dt + \mu^2 dt^2]. \end{aligned} \quad (12)$$

¹²See Pindyck and Dixit (1994) for a more complete discussion. A more rigorous approach is to apply Ito's Lemma to Bellman's functional equation equating the value of the option to the current realization of the wage plus the expected discounted value of the maximized value function in the next instant. See Dixit (1991).

If the agent is behaving optimally and assuming risk neutrality, this "asset" -- which yields only a capital gain -- should earn an expected return equal to the normal return over the period dt , say $rVdt$. Arbitrage implies then

$$rVdt = E(dV) = V' \mu dt + 0.5V'' [\sigma^2 dt + \mu^2 dt^2]. \quad (13)$$

Dividing (13) by dt and ignoring second order and higher terms results in a second order differential equation

$$(\sigma^2/2)V'' + \mu V' - rV = 0 \quad (14)$$

The solution of equation (14) will consist of linear combinations of the form $e^{\beta W}$, i.e. has solution

$$V(W) = Ae^{\beta_1 W} + Be^{\beta_2 W} \quad (15)$$

where A and B are constants to be determined and β_1 and β_2 are the solutions to the quadratic equation $(\sigma^2/2)\beta^2 + \mu\beta - r = 0$:

$$\beta_1 = [-\mu + (\mu^2 + 2\sigma^2 r)^{0.5}]/\sigma^2 > 0 \quad (16)$$

$$\beta_2 = [-\mu - (\mu^2 + 2\sigma^2 r)^{0.5}]/\sigma^2 < 0.$$

Three boundary conditions yield the particular solutions we are looking for. First, I impose the condition that the value of the migration option $V(W)$ goes to zero as W goes to negative infinity (infinite homesickness or negative wage gap).¹³ This implies immediately that $B=0$. We can then write the valuation of the migration option in the waiting region ($W < H$) as

¹³I am grateful to Michael Maluytov for pointing out the correct boundary condition for this problem.

$$V(W) = Ae^{\beta_1 W} = Ae^{[(1-\mu + (\mu^2 + 2\sigma^2)^{1/2})/\sigma^2]W} \quad (17)$$

which is unambiguously positive as long as $A > 0$. (To repeat, this is the valuation of the entire migration investment, meaning the value of migrating today *plus* the option value of waiting). To determine the two unknown constants, A and H , two additional boundary conditions are necessary. The "smooth-pasting" condition sets the derivative of V with respect to W equal to that of the NPV valuation, when W equals H :

$$\begin{aligned} V'(H) &= A\beta_1 e^{\beta_1 H} = 1/r. \\ \Rightarrow A &= (r\beta_1)^{-1} e^{-\beta_1 H}. \end{aligned} \quad (18)$$

The "value-matching" condition equates the value function with the present discounted valuation of the investment project at $W=H$:

$$\begin{aligned} V(H) &= (r\beta_1)^{-1} e^{-\beta_1 H} e^{\beta_1 H} = (r\beta_1)^{-1} = (H + \mu/r)/r - F. \\ \Rightarrow H &= \beta_1^{-1} - \mu/r + rF. \end{aligned} \quad (19)$$

The value function can be written, for $W < H$, as

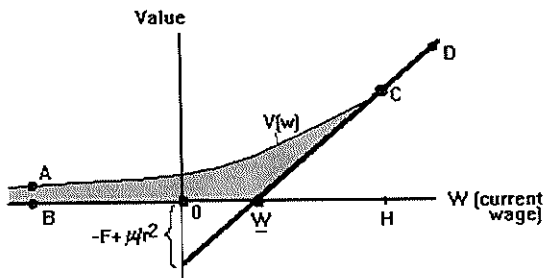
$$\begin{aligned} V(W) &= (r\beta_1)^{-1} e^{\beta_1(W - rF + \mu/r) - 1} && \text{for } W \leq H \\ &= (W + \mu/r)/r - F && \text{for } W > H. \end{aligned} \quad (20)$$

Straightforward comparative statics reveals that $dH/d\sigma > 0$ and $dH/dF > 0$. In words, the optimal migration trigger value depends positively on the variance of innovations to relative wages and the level of unrecoverable costs. It can also be shown that $dH/d\mu$ and dH/dr have ambiguous sign. An increase in the interest rate or a slowdown in the convergence process has

conflicting effects on the value of waiting, in a fashion similar to the two-period model of the previous section.

Diagrammatically, the model can be conveniently summarized in Figure 2. The valuation of the investment without waiting is given by $B\underline{W}D$ --- the traditional present value calculation. The value of the investment is zero for $W < \underline{W}$ because it is not undertaken. The value of the migration option in total is given by ACD . The value of waiting is the difference, which is shaded. It should be evident that the high degree of persistence of the stochastic process -- here in the case of Brownian motion -- is central to the valuation of this option. Were the current realization of the wage gap orthogonal to expected future wage gaps, the height of the shaded function would be constant and independent of current W . In the present case, in contrast, value of waiting rises from zero at $-\infty$ until $W = \underline{W}$, after which it declines, reaching zero at $W = H$.

Figure 2. The Option Value of the Migration Decision



What do we learn from the model? One central and perhaps surprising conclusion is that an increase in uncertainty can actually *suppress* migration: higher variance of the return to migrating increases the option value and thereby the effective cost of migration; in the

diagram the trigger migration wage H rises, as does the vertical distance between OBC and OWC for any wage gap less than H . It follows that sudden changes in migration behavior are possible due to unobservable changes in subjective assessments of risk, or the perceived fixed costs. For example, immobility increases in response to an increase in risk. In contrast, wars, natural catastrophes or political repression can kill the option to wait, leading to surges of migration.

IV. General Equilibrium Considerations

This section addresses some questions which arise for the real option model of migration when one departs from a partial equilibrium analysis. Most importantly, how does the theory play out in the aggregate? We know that waiting in principle can be useful and valuable, but what if perfect competition governs the market for mobile labor? Is a gap between Marshallian and Dixit/Pindyck trigger wages differentials possible and sustainable? Besides this, under which conditions will the option value be consistent with the determinants of the wage gap in the West (receiving region)?¹⁴ These questions are especially relevant for regional migration, where general equilibrium considerations loom large.

To look at these issues I now return to the two-period framework of Section 2, but now add neoclassical wage determination in both East and West.¹⁵ In addition, I allow for individual heterogeneity in the East among those considering the migration option. First, recall from equation (3) that the option value of waiting -- the valuation V minus the value of migrating, were it undertaken immediately, is given by

$$V^W = (r+p^B)F/(1+r) - W_1 - p^B W^B/(1+r). \quad (21)$$

¹⁴Dixit and Rob (1994) have shown in a general equilibrium model of sectoral mobility, for example, that waiting behavior will lead to more price volatility in the aggregate.

¹⁵This means, of course, that the model assumes full employment. This can be modified with few complications.

Now suppose that individuals differ, but only with respect to their fixed costs of migration, F . Specifically, assume that fixed migration costs faced by the i th individual F_i lies on the continuous interval $[0, F^{\text{MAX}}]$, and that the cumulative density function $G(x)$ gives the number of individuals in the East with fixed costs equal to or less than x for $x \in [0, F^{\text{MAX}}]$. All individuals earn the same wage in a particular period.

Using the G function, one can now derive migration flows. Individual i migrates when V_1^W is negative, or when

$$W_1 > (r+p^B)F_i/(1+r) - p^B W^B/(1+r)$$

or

$$F_i < [(1+r)W_1 + p^B W^B]/(r+p^B) \quad (22)$$

The total amount of migration in the first period is given by those for whom (22) holds, or by $G([(1+r)W_1 + p^B W^B]/(r+p^B))$.

Labor demand in the two regions is given by $L^{D,E} = \alpha^E - \beta\omega^E$ and $L^{D,W} = \alpha^W - \beta\omega^W$, where ω^E and ω^W are the current wage levels in East or West respectively. Besides migration, labor supply is assumed exogenous in both regions at $L^{S,E}$ and $L^{S,W}$. The equilibrium condition for the two labor markets in East and West respectively, are

$$L^{S,E} - G([(1+r)W_1 + p^B W^B]/(r+p^B)) = \alpha^E - \beta\omega^E \quad (23)$$

$$L^{S,W} + G([(1+r)W_1 + p^B W^B]/(r+p^B)) = \alpha^W - \beta\omega^W \quad (24)$$

Migration occurs on the basis of the gap $W_1 = \omega^W - \omega^E$. Subtracting (23) from (24) gives one condition determining W_1 :

$$LS^W - LS^E + 2G([(1+r)W_1 + p^B W_2^B]/(r+p^B)) = \alpha_1^W - \alpha_1^E - \beta W_1 \quad (25)$$

Note that on the basis of labor market equilibrium today, the current wage is a function of current relative labor demand and supply factors, as one would expect. The "bad news principle" implies, however, that only the worst case wage tomorrow enters the option valuation calculation. Therefore only the worst case in the future can affect the current wage! Comparative statics on (25) shows that

$$dW_1/dW_2^B = -2gp^B/[(r+p^B)\beta + 2(1+r)g] \quad (26)$$

where g is the "density" corresponding to G . The expression is unambiguously negative, which makes sense: the more favorable the worse case scenario is, the more migration that can be expected today and the lower the wage gap today that results.

Presumably, the worst case scenario is determined by factors in the second period, but also by those in the first (i.e., migration). In order to obtain a full "intertemporal equilibrium", we need to solve for the worst case scenario in the future.¹⁶ How is W_2^B determined? If the migration decision is irreversible, labor supply in the second period is equal to what it was in the first (no new migration). Let us ignore uncertainty in α^W , so that it is invariant across both states: all action in Eastern wages and in the wage gap comes from movements in α_2^E ; we impose $\alpha_2^{E,B} > \alpha_2^{E,G}$. It follows that W_2^B must satisfy

$$LS^W - LS^E + 2G([(1+r)W_1 + p^B W_2^B]/(r+p^B)) = \alpha_2^W - \alpha_2^{E,B} - \beta W_2^B. \quad (27)$$

¹⁶I leave it to the reader to solve for W_2^G , the wage in the good state, not because it is uninteresting, but because it is irrelevant for wage determination and migration in the current model.

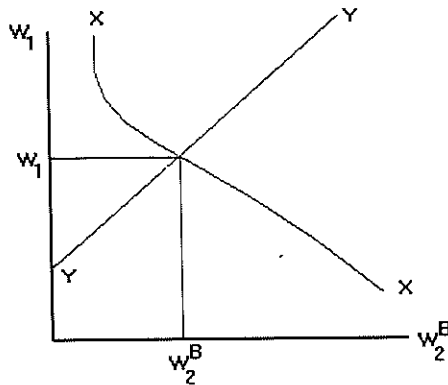
The intertemporal migration equilibrium is therefore a pair of wage differentials W_1 and W_2^B which solve (25) and (27).

It is useful to use a diagrammatic apparatus to study the solution to the problem. Figure 3 provides details. The YY locus is the 45° line, which reflects the fact that both (25) and (27) have the same left-hand side. This schedule is given by

$$W_1 = W_2^B + [(\alpha_2^{E,B} - \alpha_1^E) - (\alpha_2^W - \alpha_1^W)]/\beta. \quad (28)$$

The other relationship that matters is the current period equilibrium (25). Since the form of G is unspecified except for $G'=g \geq 0$, the curve will have a negative slope as (26) shows, but will depend crucially on the distribution of fixed migration costs in the population. If a flat portion of the distribution is reached with then g close to 0, the XX locus will be flat. A hypothetical case is drawn in Figure 3.

Figure 3. General Equilibrium with Migration



The diagram separates factors determining the current wage differential W_1 into those affecting the current labor market (25) and those related to the future relative to the present (28). Consider briefly the effect of an exogenous decrease in labor force in the East (due to early retirement or restricted access to child care for women). The YY curve is unchanged, while the XX curve shifts inwards, leading to lower wage differentials both today and in tomorrow's worst case. A more complicated case is the system's response to an increase in α_1^E (or a decrease in α_1^W). The XX curve shifts down, but the YY curve shifts down as well. Unambiguously the current wage differential narrows, but the effect on the future wage gap in the bad state of the world cannot be signed.

The final and perhaps most interesting case I would like to consider is a change in expectations about the future position of the Eastern labor demand curve. Suppose $\alpha_2^{E,B}$ were to increase, meaning that the labor demand curve shifts outwards in the bad state, leading to more wage convergence, all other things equal. The YY curves shifts up and to the left, while the XX curve remains unchanged. This implies a smaller wage gap in the second period (an increase in the worse case scenario). As a consequence, there is less migration in the first period, and the current wage gap *worsens!* Almost paradoxically, the model implies that policies which promote wage equality in the future may actually lead to more *current* wage inequality in general equilibrium!

V. Concluding Remarks

Migration is clearly one of the hottest topics in policy circles, although one wouldn't get that impression from reading the journals. Increases in information, reductions in transport costs and growth in "seed" populations around the world of all ethnic, national and religious backgrounds has made migration an attractive option for more and more people. In addition, many of the irreversibilities associated with the migration decision which deterred migrants in

the past are less relevant today. My objective, as that of many others, is to show that wage and GDP differentials are only one facet of migration. The investment nature of the decision is so important that details about the costs of migration are equally crucial. The option value approach suggests that the extent of uncertainty over future wages may inhibit migration.

Many extensions of the theory presented here today can be anticipated. The option to *return migrate* can be dealt with in a straightforward fashion. The migration decision, when taken, results in V^1 plus an option to return which can be valued in the same fashion as the option to migrate. Especially the setup in section 3 is amenable to such an extension. I have ignored unemployment at my own peril, but modifications are easy to imagine along the lines of Harris and Todaro. Other modifications, such as the introduction of credit restrictions, would reduce migration for poorer individuals and further reduce migration at any given wage gap.

Empirical implementation and testing of the model is difficult for a number of reasons. The most important problem is the availability of large data sets on migrants. Despite these difficulties, there is evidence that the option value may have an effect on aggregate migration movements.¹⁷ The changing nature of uncertainty for example, could explain Freeman's (1993) puzzle that despite massive differences in present values between the US and Latin America in the 1950s and 1960s, Mexican immigration at the time barely exceeded Canadian levels and total immigration from South and Central America was one-sixth that from Europe. Now the situation is dramatically different. Freeman appeals to the lack of attractor communities in the US in the earlier period. An alternative explanation is that -- among other things, of course -- the development prospects in Latin America were more variable than in the 1980s. It would thus be instructive to study current migration trends given recent improvements in the economic outlook of these countries.

¹⁷In ongoing joint work with Wolfgang Härdle. I am investigating the possibility of estimating, either non- or semiparametrically, the shape of the option value for migrants and would-be migrants on individual data.

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