Real Options Approach to Inter-Sectoral Migration of U.S. Farm Labor

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The core of the literature on inter-sectoral labor migration is based on net present value models of investment in which individuals are assumed to migrate to take advantage of positive wage differentials. In this article, we argue that a real options approach, taken together with the adjustment costs associated with sectoral relocation, may provide a basis for explaining the migration of farm labor out of the agricultural sector. Given the irreversibility of migration decisions and uncertainty in the economy, potential migrants might choose to postpone migration, even in the face of positive wage differentials. Using annual U.S. employment data from between 1948 and 2009, our results indicate that large elasticities between economic incentives and out-farm migration are observed after a high threshold of wage differentials between farm and off-farm sectors is surpassed.

Key words: Occupational choice, option value of waiting, out-farm migration, real options, threshold models.

JEL codes: J62, Q12, Q18.

Since economic development depends on the existence of a competitive multi-sectoral economy, it is important to understand the factors that determine the reallocation and mobility of agricultural labor across sectors. On the other hand, off-farm income is approximately six times greater than cash farm income, and comprises nearly 80% of farmers' total household income; participation of farm labor in non-agricultural sectors can also be thought of as an investment decision that directly impacts farm households' income. One approach for explaining this tendency of farm labor to migrate into non-agricultural occupations is the concept of inter-sectoral, or occupational, migration.

In the existing labor migration literature, much attention has been given to persistent large sectoral (rural–urban or farm–nonfarm) wage differentials and the response of migration flows to such differentials (e.g., Todaro 1969, 1976; Harris and Todaro 1970; Williamson 1988; Mundlak 2000). While the core of this literature is based on the argument that individuals migrate to take advantage of positive wage differentials, the empirical evidence shows that, even in the presence of a positive wage differential, people do not always migrate (Mundlak 1979).

These findings have raised concerns about the relevance of macro-level incentives for migration. Burda (1993) suggested that the responses of migrants to wage differentials may be characterized by nonlinearities due to the existence of sunk costs and what he calls an "option value of waiting." The option value of waiting is the difference between the expected net present value of postponing migration and the expected net present value of migrating immediately, and it represents the opportunity cost of migrating in the current period. Although the applications of this argument in migration studies are relatively new, the idea of "real options value" (ROV) has been widely accepted in the investment literature since the seminal work of Dixit and Pindyck (1994). Sectoral wage differentials that are greater than the Marshallian costs of moving between two sectors, and yet do not result in a reallocation of labor, are often attributed to the option value of staying in the current sector. What makes the real

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options theory suitable for analyzing migration is that assumptions that are usually made in the context of investment—at least partially sunk costs, ongoing uncertainty in the economic environment, and the possibility of postponing investment—are equally valid in the case of migration.

In this article, we argue that threshold regression models (e.g., Hansen 2000) are a naturally good fit for empirically modeling the (potentially large) thresholds implied by adjustment costs and the real options value approach to inter-sectoral migration. These models may be more suitable than the traditional net present value models for explaining out-farm labor migration decisions. Although the existence of only the traditional Marshallian fixed costs may still imply some threshold nonlinearities in migration and persistent sectoral wage gaps, the Marshallian thresholds are expected to be smaller than those suggested by the real options theory. This is because the full-cost threshold, which includes the real options value to waiting, is significantly higher than the traditional Marshallian trigger if the latter includes only adjustment costs. If the discrepancy between wages in the farm sector and those achievable in the non-farm sector does not exceed a certain threshold that is defined by the costs of migrating (including the option value of waiting), migrants may not alter their labor allocation behavior in the same fashion that a given wage differential might imply when such costs are ignored. The implication for empirical modeling is that the functional relationships that characterize the labor migration model may be nonlinear in parameters because of such threshold wage differentials, beyond which potential migrants' moves cannot be explained by a traditional, positive linear relationship between wage differentials and migration.

This article aims to extend previous applications of U.S. out-farm migration by explicitly accounting for the implicit (sunk) costs of migration and other barriers to movement such as uncertainty and frictions that may be associated with the reallocation of farm labor. We accomplish this by accounting for the possibility of threshold nonlinearities in the underlying model of labor movements. To our knowledge, this has not been done in the context of inter-sectoral farm labor migration. Many of the existing studies that estimate some form of aggregate migration equations, including Suits (1985), Mundlak (1978, 2000), and Barkley (1990) consider only a linear specification in their regressions.

In the following section we review and compare theoretical models of internal migration—specifically the human capital approach and the real options value approach—in terms of their implications for empirical modeling. We then present an empirical investigation of U.S. off-farm migration that includes a brief review of the existing empirical literature on the subject, the model specification, the econometric methodologies, a description of the data used, and the empirical results. The final section provides concluding remarks.

Conceptual Framework: From Human Capital to the Real Options Value Theory

The concept of migration fits well in the conventional investment framework, since migration concerns the decision to incur a present cost in exchange for a stream of future income. The Neoclassical theory of investment that is purely based on the Net Present Value (NPV) rule implies that a firm undertakes an investment if its expected present value exceeds the expected cost of doing so, or if the NPV of the investment project is positive. Sjaastad (1962) introduced the human capital approach to the migration literature and modeled migration as an investment process in human capital. This model has provided a foundation for empirically examining the determinants of migration. According to the human capital approach, potential migrants evaluate expected utility, $E(U)$, less the expected discounted migration costs, C, for each location (or sector) and choose to move to the location (or sector) with the highest net outcome, or net present value. To the extent that agents are risk averse, risk differentials among sectors may also influence labor allocation decisions. Non-pecuniary attributes of various occupations may also influence migration.[1]

Consider an individual facing given returns (wages) in two mutually-exclusive occupations: the production of farm products and non-farm employment $(i, j = \{f, nf\})$. The

[1] For an excellent review of alternative migration theories, see Taylor and Martin (2001).

choice of occupation is determined by comparing the discounted expected utility derived from each job. Assuming that a person enters the labor force at age $G1$ and retires at age T, the expected utility obtained by this person over the time period of $G1 - T$ can be written as

$$(1) \qquad E\{U(R_{i,j})\} = \int_{G1}^{T} e^{-rt} U(R_{i,j}(t))dt = \frac{R_{i,j}}{r}$$

where R_{ij} represents the wage differentials between j and i sectors ($logW_{nf} - logW_f$) and r is the subjective discount rate.

The expected discounted costs can thus be written as

$$(2) \qquad E\{C_{i,j}(0)\} = \int_{G1}^{T} e^{-rt} C_{i,j}(t)dt = f.$$

These occupational migration costs include both monetary values—mainly direct and moving costs—and psychic costs. These costs may be regarded as barriers to migration and could include travel costs, changes in housing costs, the loss (or gain) of amenities, disutility created by habit persistence, and other psychological costs borne by the migrating laborer.

The net present utility (or "value") is then the difference between the expected utility and the expected discounted costs of migration:

$$(3) \qquad NPV = \frac{R_{i,j}}{r} - f.$$

Assuming certainty about the wage differentials in two sectors, migration occurs as soon as $R_{i,j}/r > f$ (or $NPV > 0$). Todaro (1969, 1976) and Harris and Todaro (1970) argue that a straightforward NPV type of analysis that is based on efficient labor markets may not be realistic for the case of the more institutionalized economies of developing countries. The continuation of migration despite high and increasing urban unemployment is the primary motivation for the Harris-Todaro "expected income" model in the presence of labor market imperfections. In Harris-Todaro models, nominal wages in the urban, non-farm sector are not completely flexible; rather they are rigid on the downside.[2]

The existence of minimum wages and labor unions in the non-farm sector influences the out-migrants' income expectations. On the other hand, the existence of wage rigidities also generates unemployment in the non-farm sector. A new migrant from the farm sector may experience a period of unemployment or underemployment before earning higher non-farm wages. According to Harris and Todaro (1970), a rural migrant who is assumed to be perfectly informed and rational weighs the probabilities associated with various outcomes against the alternative of staying in agriculture.

The novelty in Harris-Todaro models is the assumption that migrants consider not only wage differentials in their migration decisions, but also *the probability of being employed* in the city. With this assumption, Harris and Todaro (1970) are able to explain historical observations of increased labor pull into the urban sector in spite of existing high unemployment rates. Todaro states that migration follows as a response to urban-rural differences in *expected* rather than actual earnings. Here, expected earnings are a function of wage differentials and the probability of obtaining a job. This probability is approximated by using unemployment rates in the non-farm sector, u_j:

$$(4) \qquad E\{U(R_{i,j}, \pi)\} = \int_{G1}^{T} e^{-rt} \pi(t) U(R_{i,j}(t))dt = \frac{\pi R_{i,j}}{r} = \frac{(1-u_j)R_{i,j}}{r}.$$

Accordingly, the net present value implied by the Harris-Todaro model can be written as

$$(5) \qquad NPV = \frac{R_{i,j}(1-u_j)}{r} - f.$$

In the Harris-Todaro version of the human capital model, migration occurs when $R_{ij}(1-u_j)/r > f$.[3] The key implication of the

[2] The Harris and Todaro (1970) model is a slight modification of the original Todaro (1969) model, which adds a two-sector neoclassical trade model to the analysis. However, it is the migration equation that represents the innovative feature of the Harris-Todaro models.

[3] After accounting for uncertainty by adding non-farm unemployment rates into the model, equation 5 can be treated the same as a model under certainty. In this sense, $(1-u_j)R_{ij}$ is often called Todaro–adjusted returns (wages).

human capital view of migration is that the types of workers who select into migration are those for whom the discounted income (or expected income) differentials between migration and non-migration are greatest and/or migration costs are lowest. In addition, human capital theory implies that income (or, in the Harris-Todaro case, expected income) differentials between rural and urban areas are eliminated over time through the migration process.

The Harris-Todaro model was a first step towards accounting for the uncertainty associated with migration. In this model, however, it is assumed that the probability of obtaining a job is known and can be measured using the off-farm sector's unemployment rate as $(1 - u_j)$. A fundamental change to conventional NPV models has involved incorporating (stochastic) uncertainty in theoretical investment models. The theory of real options value aims to explain why agents often delay decisions in situations where expected NPV would predict immediate action. For example, Dixit and Pindyck (1994) indicate that the main shortcoming of the net present value approach is that either one of the following is implicitly assumed: *a*) investment is completely reversible (or there are no sunk costs to making the investment); *b*) if investment is irreversible, the opportunity to invest presents itself as a now or never proposition.

While some investment decisions may meet the above criteria, migration usually does not because it is not completely reversible, even with the possibility of return migration. This is because the costs associated with migration are usually sunk.[4] Furthermore, while a job offer in the non-farm sector may present itself as a "now or never" proposition, it may be too restrictive to assume that the migration opportunity is lost if not taken in the current period. Since (at least partial) irreversibility and the choice of delaying migration are faced by most migrants, accounting for the (option) value of waiting to make the investment may provide valuable insights.[5]

Modeling migration in a real options value framework was first suggested by Burda (1993), and later by O'Connell (1997). Potential migrants do not have perfect insight into future levels of wage and unemployment differentials; therefore, they may not always be able to maximize their utility from migration. Under these conditions, potential migrants have the option of postponing their decision to move. Waiting for a certain amount of time enables them to reduce the risks associated with uncertainty.[6] As a result, the conventional decision criteria on migration—"whether to move" and "where to move"—may be expanded to include another decision criterion, that is, "when to move," with the possible presence of an option value to waiting.

Given the irreversibility of the migration decision and uncertainty in the economy, waiting has positive value since it reduces risks over time. Waiting for a certain amount of time may not only help the migrants avoid the downside risk in wages over that interval, but may also allow them to realize potential increases in wage differentials. In such an environment, migration occurs only when the wage differential exceeds the "Marshallian trigger" by a positive margin.[7] In other words, due to the "option to wait," a potential migrant chooses to move only after a threshold of wage differentials between the region or sector of the destination and that of the origin is reached, rather than moving as soon as the NPV of migration becomes positive. The value of waiting, taken together with the adjustment costs associated with relocating, suggests that a nonlinear relationship between migration and wage differentials may be observed in aggregate-level migration models.

[4] "The costs of migration and income flows have different time paths. The cost of migration is incurred largely in the first period of migration, whereas the benefits last as long as the individual maintains the new occupation. The problem should therefore be considered within a multiperiod framework" Mundlak (2000).

[5] The analogy comes from a financial call option, where the bearer of the option has the right but not the obligation to buy an asset in the future. If the firm decides to exercise the option to buy (invest now), it kills the option to wait (expected value of the "wait and see" alternative), which is the opportunity cost of investing. As a result, the firm invests if the discounted sum of expected future rewards exceeds the "full cost" of investing today, which is the direct cost of investment plus the opportunity cost of exercising the option.

[6] Mundlak (1970) acknowledges that migration might be zero even in the case of positive wage differentials due to risks associated with changing occupations. Within the Harris-Todaro framework, he discusses the possibility of "threshold" levels of wage differentials that might occur because of risk and other factors.

[7] The Marshallian trigger is where the decision in favor of migration is based only on the expected positive net value. This criterion only accounts for acting instantaneously to obtain the utility of migrating versus not migrating at all. It does not take into consideration that waiting and reassessing the decision is also possible.

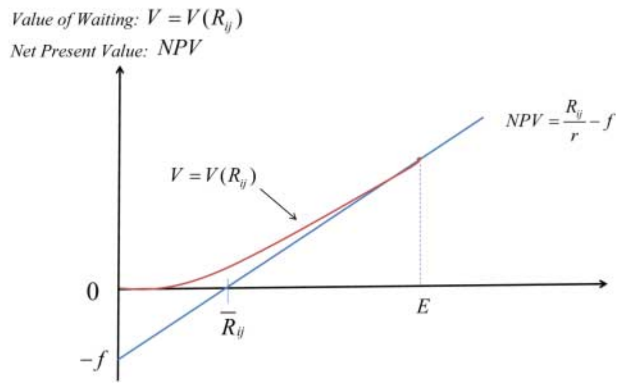

Figure 1. Net present value approach versus the real options theory

Following Basile and Lim (2006), figure 1 is used to illustrate the implications of the traditional human capital model and the more recent real option theory of migration. In figure 1, NPV represents the net present value of the migration at different current wage differentials (given on the horizontal axis). Assuming that workers are "certain" about the wages (or Todaro-adjusted wages) in the two sectors, migration occurs as soon as $R_{ij}/r > f$ (or in the Harris-Todaro model, $(1 - u_j)R_{ij}/r > f$). An increase in the fixed costs associated with relocation, f, raises the Marshallian trigger $\bar{R}_{i,j}$.

When uncertainty is introduced, however, this may no longer be true. Suppose that the future wage gaps in two sectors are only imperfectly predictable. The probability distribution of future wage differentials is determined in the present, but the actual realized path remains uncertain. Assume that in each period, R_{ij} can either increase or decrease, and assume that the Marshallian trigger is currently where the potential migrant is. Waiting for a certain period of time might still be profitable for two reasons. First, in the case of increasing wage differentials, a migrant would be able to realize potential wage gains in the future. Second, in the case of decreasing wage gaps, a migrant would be able to avoid potential wage losses by waiting. Consequently, even if $R_{ij} > \bar{R}_{ij}$ (the Marshallian trigger), waiting may still be more valuable for a potential migrant than migrating.

On the other hand, the cost of postponing migration is the foregone wage differentials over the period of delay. Therefore, when the current wage gap between farm and non-farm sectors, R_{ij}, becomes sufficiently larger than the Marshallian trigger, $\bar{R}_{ij}$, it is not beneficial for the migrant to wait, and migration occurs. In figure 1, point E represents this "threshold" level of wage gaps (which is larger than the Marshallian trigger), beyond which migration is always optimal. The value of waiting in figure 1 is the difference between curve V and the value of migration under certainty (NPV). At all points beyond E, the decision to migrate is stronger than waiting, as it brings higher utility to the migrant.

The implication of adopting real options theory in aggregate migration models is that potential migrants may move out of agriculture only when the wage gaps between farm and non-farm sectors exceed a certain threshold point. If this hypothesis is plausible, the relationship between inter-sectoral migration and wage differentials may be nonlinear around a relatively "large" threshold. On the other hand, if migration plays a perfect role in equalizing factor prices (wage rates) across the two sectors, then the relationship between wage differentials and migration rates is expected to be linear in parameters.

In the migration literature, threshold effects or other forms of nonlinearity have rarely been tested empirically. Basile and Lim (2006) consider such possible nonlinearities in modeling inter-regional migration, and obtain a nonlinear representation of the relationship between wages and inter-regional migration among the U.S. Metropolitan Statistical Areas by using a semi-parametric model that allows for additive components. These authors find a range of "inertia" determined by threshold wage differentials within which potential migrants' moves cannot be explained by the traditional Todaro-type positive linear relationship between wage differentials and inter-regional migrations.

Application of U.S. Out-farm Labor Migration

In this section, we focus on the case of U.S. out-farm labor migration. The following subsections include a brief review of the existing empirical literature, the specification of the empirical model and econometric methods, a description of the aggregate data used, and the empirical results.

Literature Review

Different approaches to labor allocation decisions have been studied extensively. One strand of the literature has focused on off-farm work and farm labor holding multiple jobs as a channel that moves labor out of agriculture (e.g., Huffman 1980; Sumner 1982; Kimhi 2000; Goodwin and Holt 2002; Goodwin and Mishra 2004; Kimhi and Rapaport 2004; Ahearn, El-Osta, and Dewbre 2006). A related area for this topic has been permanent exits from agricultural work (e.g., Goetz and Debertin 2001). Another strand of literature mainly utilized investment and human capital theories to suggest models of industry choice and the migration of farm labor to other sectors.

Empirical studies on labor migration have been conducted at different levels of aggregation, ranging from households to countries, covering different occupational choices, as well as international and inter-regional migration. In a household-level study, Perloff (1991) used cross-section data from the Bureau of Labor Statistics's (BLS) 1988 Current Population Survey (CPS) to examine the likelihood that nonagricultural workers would join the agricultural work force in response to an increase in the agricultural wage. Perloff found that a 1% increase in the relative agricultural wage increased the probability of a nonurban male with no more than a ninth-grade education working in agriculture by almost 3.5% at the sample mean. Furthermore, a 10% increase in wages increased the proportion of those males who chose to work in agriculture by nearly one-quarter.

Perloff, Lynch, and Gabbard (1998) and Emerson (1989) examined the migration of seasonal agricultural workers. Using a longitudinal data set provided by the U.S. Department of Labor's National Agricultural Workers Study (NAWS), Perloff, Lynch, and Gabbard (1998) found that a 10% earnings differential raised the probability of migrating by slightly more than 1%, indicating substantial costs to migrating for seasonal agricultural jobs. Emerson (1989) explained the behavior of domestic seasonal farm workers with the principle of comparative advantage, which suggests that individuals with the greatest potential advantage in (non)migratory work choose (not) to migrate. Tran and Perloff (2002) used NAWS data set to estimate a Markov model of employment turnover between agriculture, nonagricultural work, and unemployment for different legal status groups. Job mobility patterns differed by legal status such that the steady state probability of working in agriculture was higher for someone with amnesty than for an undocumented worker.

However, relatively few studies have focused on farm labor participation in nonagricultural jobs from a macroeconomic perspective. In this article, we aim to contribute to the literature by evaluating the U.S. out-farm migration at an aggregate level. Suits (1985) conducted an earlier study on U.S. occupational migration using aggregate data, and applied the Harris-Todaro migration model to the case of U.S. out-farm migration using time-series data between 1900 and 1976. This author found that the U.S. experience within this period was consistent with the implications of the Harris-Todaro hypothesis. In a similar study, Hatton and Williamson (1992) concluded that wage differentials explained long-run migration trends, while non-farm unemployment rates determined the timing of, and annual fluctuations in, migration.

Perhaps one of the most frequently cited, macro-level papers on U.S. agricultural out-migration was written by Barkley (1990). This seminal paper examined the determinants of off-farm labor migration between 1940 and 1985 using a linear (semi-logarithmic) regression equation. Barkley (1990) considered two alternatives to measuring relative labor returns in the non-farm sector—the non-farm to farm ratio of average value-added, and alternatively, the ratio of per-capita incomes in the two sectors. Barkley concluded that agricultural out-migration increases as non-farm income and employment rise relative to their agricultural counterparts. The elasticity of the migration rate with respect to the inter-sectoral income differential obtained from regressions was 4.5 for total agricultural labor and 3.34 for farm operators. Barkley (1990) further argued that an increase in the real value of land decreases off-farm migration. On the other hand, non-farm unemployment rates and direct government payments to farmers had no statistically significant effects on agricultural out-migration.

More recently, D'Antoni, Mishra, and Barkley (2012) presented estimates of the Harris-Todaro migration models using more up-to-date time-series data on U.S. farm employment. Using Barkley's (1990) specification, the authors particularly focused on the effect of direct government payments to farmers on off-farm migration between 1939 and 2007. Although government payments were found to significantly affect out-farm migration, there was no statistically significant effect of relative returns on migration, which conflicts with the Harris-Todaro hypothesis.

In a multi-country comparison between 72 countries using aggregate data from 1960 to 1970, Mundlak (1978) found that the annual rate of out-migration from agriculture is determined by the sectoral income differentials, the composition of the labor force, the growth rate of the labor force, and some other related variables. Mundlak also discussed how the income differentials should be measured, and argued that using the average labor productivity rather than wage rates performs better in empirical models. Larson and Mundlak (1997) expanded on Mundlak's (1978) study and fit the same regression equation to 98 countries over five decades from 1950 to 1990; they obtained similar results to those of Mundlak's original study. In particular, the rate of off-farm migration increased, on average, by roughly 0.36% when the income differential (approximated by the ratio of average products between agriculture and nonagriculture) increases by 1%.

The abovementioned studies follow the traditional human capital approach to migration by applying Harris-Todaro type models in their analyses. The paper by Dennis and Iscan (2007) is an exception, because they considered the real options value of migration and the existence of potentially large relative wage thresholds in their out-farm labor migration model. However, their analysis of these thresholds did not include a statistical analysis; they assumed that workers have to incur sunk costs when they move between sectors, and argued that this creates a degree of inertia in the sectoral allocation of labor. Dennis and Iscan assumed that migration decisions follow (S, s) rules, whereby relocation is triggered only when sectoral wage gaps exceed S (or s) percentage points.[8] Finally, Dennis and Iscan (2007) characterized these relocation (between farm and off-farm) thresholds analytically using calibration methods and the parameters of the theoretical model. These authors used 1920–1970 U.S. data to estimate the parameters used in calibrations. In the following empirical analysis, we aim to fill this gap by suggesting an econometric model that is consistent with the real options approach to migration.

Model Specification and Econometric Procedures

Barkley's (1990) specification, which is derived from Todaro's version of a human capital migration model, is used as a basis for our empirical analysis. However, to allow for the alternative approach of Dixit and Pindyck's (1994) real options theory, the empirical model is modified to allow for a threshold in the relative returns of the non-farm sector. The first step of model specification is to define the occupational migration from the farm to the non-farm sector. This is a difficult task since data on the number of migrants are rarely available. Following Barkley (1990), occupational migration rates are approximated using percentage changes in agricultural employment (L_f), from one year to the next:[9]

$$M_t = \frac{(L_{f,t-1} - L_{f,t})}{L_{f,t}}. \tag{6}$$

This definition does not distinguish between retirements or actual movements to non-farm

[8] Dixit and Rob (1994) introduced (S,s) rules to the investment literature.

[9] Following Mundlak, it is assumed that without migration, agricultural labor will grow at the same rate as the total labor force. Deviations from this rate are attributed to migration. Therefore, migration can be written as $m = n - n_f$ where n is the growth rate of total labor force, and n_f is the growth rate of farm labor force. As a result, $m_t = (L_t - L_{t-1})/L_{t-1} - (L_{f,t} - L_{f,t-1})/L_{f,t-1} = (L_{f,t-1}(1 + n_t) - L_{f,t})/L_{f,t-1}$. Barkley assumed that n_t is negligible from one year to another.

positions; rather, it is an approximation defined by changes in the number of jobs in the farm sector. The second important step is to choose the variable that represents the economic incentives that stimulate migration between the two sectors, that is, the relative returns to labor. Although this choice is quite important for the final estimation results, and the original Harris-Todaro models suggest using wages as a measure of labor returns, other proxies have been used in applied work, often without justification. Mundlak (1978, 2000) is an exception who argued that for a long-run decision involving expectations such as migration out of agriculture, income is thought to be a more informative measure of future prospects than wages, since wages are not the only component of a farmer's income. He also noted that measurement problems with wage data provide another reason to use relative income rather than relative wages. Barkley (1990) also avoided using wage rates as a measure of the relative returns to labor, whereas Hatton and Williamson (1992) used relative wages in their empirical application. In this article we use the relative wage rate to explain migration of hired farm workers. For the case of total farm workers, which includes farm operators, we use both wage rates and a measure of relative value-added per worker.

The simplest form of the Harris-Todaro type migration equation has only relative wages and unemployment rates in the non-farm sector on the right-hand side.[10] A more comprehensive Harris-Todaro type model can be written as

$$M = a_0 + a_1 log(R) + a_2 log(U) + a_3 log(G) + a_4 log(EX) + e \tag{7}$$

where R is the ratio of returns to labor in non-farm to those in the farm sector; U is the unemployment rate in the non-farm sector; G is the ratio of relative labor force, non-farm to farm; and e is a random disturbance term. Other exogenous variables that might help explain migration, such as direct government payments to farmers and real farmland values, are represented by variable EX. The rate of unemployment in the non-agricultural sector (U) is a measure of the probability of obtaining employment in that sector and is a direct implication of the Harris-Todaro migration equation.

We assume that the migration rate depends on the composition of the labor force (the ratio of labor in non-agricultural sectors to that in agriculture, G), and not on the absolute size of the total labor force. The relative returns ratio (R) and labor force ratio (G) are isolated in the model from other variables for the following reasons. While the relative returns ratio constitutes a major incentive for an individual migrant, at the aggregate level the size of the labor force in the two sectors needs to be considered in addition to relative returns. The sign on a_3 can be either positive or negative. The number of out-farm migrants depends on the size of the labor force in agriculture (the origin); the larger the labor force in agriculture relative to the non-agricultural sector, the more off-farm migration can be expected. The labor force ratio G may also reflect the likelihood of finding work in the non-farm sector.

Two definitions of farm labor are considered for analyzing off-farm migration: all farm labor (including family and unpaid workers, some of whom are farm operators) and hired farm workers. The main difference between the empirical models for these two groups of migrants is the way in which relative labor returns are measured. For hired farm workers, wage differentials are considered as best representing the economic incentive for migration since wages constitute the main source of income for hired farm employees. In the case of total farm labor migration, an approximate measure of the relative average productivity, as well as relative wage rates, are considered to measure returns to labor in each sector. An additional variable used to explain migration of total farm workers is the value of farmland (LV). If well-functioning land markets exist, the value of land should reflect the expected stream of all future returns to resources in agriculture (Barkley 1990). Land values are not considered as an explanatory variable for the migration of hired farm workers since farmland is usually not owned by wage and salaried employees, and is therefore not likely to affect the expected future income of this group.

Endogeneity is a problem in Harris-Todaro type (structural, reduced-form) regression

[10] The standard Todaro migration model allows for unemployment only in the urban sector. The choice of using non-farm unemployment rates rather than a relative unemployment measure is also dictated by the lack of reliable data on the unemployment rate in the agricultural sector.

models. First, a causal relationship between labor movements and relative wages is likely to occur. Another potentially endogenous variable is the non-farm (urban) unemployment rate. If the possibility of obtaining a job off-farm increases (i.e., if the off-farm unemployment rate decreases), higher levels of out-farm migration eventually cause a higher supply of workers in the off-farm sector, potentially raising the unemployment rate. In previous studies, endogeneity and possible simultaneity problems were addressed by taking lags of all explanatory variables in the regression model. The same approach is followed here. After denoting natural logarithms as lowercase letters, and taking lags of all right-hand side variables, the resulting Harris-Todaro type empirical migration models of total farm workers can be written as

$$(8)\qquad M_{all,t} = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 u_{t-1} + \alpha_3 g_{t-1} + \alpha_4 lv_{t-1} + \varepsilon_t$$

and

$$(9)\qquad M_{all,t} = \beta_0 + \beta_1 w_{t-1} + \beta_2 u_{t-1} + \beta_3 g_{t-1} + \beta_4 lv_{t-1} + \varepsilon_t.$$

The hired farm workers' migration model is

$$(10)\qquad M_{hired,t} = \theta_0 + \theta_1 w_{t-1} + \theta_2 u_{t-1} + \theta_3 g_{t-1} + \varepsilon_t$$

where r is the gap in average productivity (or value-added) of labor between the farm and off-farm sectors $(log(R_{nf}) - log(R_f))$, w is the wage gap $(log(W_{nf}) - log(W_f))$, g is the log of the ratio of labor in the non-agriculture sector to that in agriculture, u is the log of the off-farm sector's unemployment rate, and lv is the log of real farmland values. Equations 8 through 10 are estimated using standard OLS.

As discussed previously, Harris-Todaro type models imply that migration occurs "instantaneously" when Todaro-adjusted return differentials exceed the Marshallian migration costs (i.e., when $R_{ij}(1-u_j)/r > f$). However, if the existence of sunk costs and the option value of delaying migration decisions are recognized, migration may not occur even after the Marshallian trigger point is reached (figure 1). In such a case, labor allocation costs and real options theory predict a nonlinear relationship between relative wages and migration rates. Despite its theoretical attractiveness, empirical tests of the real options theory of investment are scarce in the literature. One difficulty with such tests concerns the construction of the "trigger points" that reflect the real options effect. In this article, we propose a simple, purely empirical way of approximating the effects of real options in a piece-wise linear regression framework using Hansen's (1996, 2000) threshold estimation procedures. Threshold regression models of the following form are estimated:

$$(11)\qquad M_t = \mathbf{X}_{t-1}\Theta^{(1)} I(z_{t-1} > \lambda) + \mathbf{X}_{t-1}\Theta^{(2)} I(z_{t-1} \le \lambda) + v_t$$

where $\mathbf{X_t}$ represents the explanatory variables given in equations 8–10. The superscripts (1) and (2) denote regime 1 and regime 2, respectively. The variable z is the observable variable that forces differences in migration between regimes, resulting in different sets of parameters in each regime ($\Theta^{(1)}$ and $\Theta^{(2)}$). Within the context of sectoral migration, z, is the gap in returns to labor between the non-farm and farm sectors (i.e., $(log(W_{nf}) - log(W_f))$, or $(log(R_{nf}) - log(R_f))$).

Parameter λ is the unknown threshold parameter to be estimated endogenously from the model, and reflects the trigger point E in figure 1. This is where this paper departs from other applied studies estimating threshold percentage points based on real options theory. Specifying the thresholds in a purely empirical context imposes none of the parametric restrictions implied by the theory of real options. This allows one to test the real options value approach against other competing migration models such as the Harris-Todaro model. In equation 11, I is the indicator function, which equals one if the argument in parentheses is true, and is zero otherwise. Based on the predictions of the real options theory, we expect that when wage differentials between two sectors are below the estimated threshold λ, the real options effect leads migrants to delay migration. This might cause a weaker (or no) relationship between migration and wage gaps in regime 2 than what the standard Todaro models suggest. However, if wage differentials exceed the threshold λ, there is no reason to delay migration. This suggests that the estimated coefficients in regime 1 may exhibit a stronger positive relationship between wage gaps and migration rates than the neoclassical migration theory predicts, and which existing empirical models typically find. Therefore, the out-farm migration elasticity with respect to the wage differentials is expected to be larger in regime 1, where $z > \lambda$.

The empirical model is estimated using conditional least squares. The observations are sorted on the threshold variable and the sums of squared residuals are computed for all possible values of the threshold variable.[11] The optimal value of the threshold variable, λ, is the value that minimizes the sum of squared residuals. Once the threshold parameter λ is inserted in equation 11, the remaining model parameters are obtained.

An important question is whether the estimated threshold parameter is statistically significant, or in other words, whether the threshold model is statistically different from its linear counterpart. The answer to this question is equivalent to testing for the null hypothesis of $H_0 : \Theta^{(1)} = \Theta^{(2)}$. A likelihood ratio type statistic to test for the linearity hypothesis was suggested by Hansen (2000):

$$(12) \quad LR = T\frac{SSE - SSE(\lambda)}{SSE(\lambda)}$$

where SSE and $SSE(\lambda)$ are the sum of squared residuals from the linear model and the threshold model, respectively, and T is the number of observations. The threshold parameter λ is not defined under the null hypothesis, causing a nuisance parameter problem. Hansen (1996) shows that asymptotically valid p-values can still be constructed using bootstrap methods. Under this approach, simulation methods are used to approximate the asymptotic distribution of the test statistic in equation 12 under the null hypothesis. Hansen (1996) recommended running a number of simulations whereby the dependent variable is replaced by standard normal random draws. For each simulated sample, the regime–switching model is estimated and the likelihood ratio test statistics in equation 12 are computed. From this simulated sample of test statistics, the asymptotic p-value is approximated by the percentage of replications for which the actual test statistic exceeds the simulated LR statistics.

Data

We compiled annual time series data between 1948 and 2009 from various sources.[12] The empirical analyses are carried out for two categories of agricultural labor: *hired* farm workers and *all* farm workers. All farm workers include all persons involved in farm work and is measured as the sum of self-employed and unpaid family workers and hired farm workers. Agricultural employment data are obtained from the Economic Report of the President (ERP), table B-100. In this table, data on hired farm workers comes from the National Income and Product Accounts (NIPA) of the Department of Commerce, Bureau of Economic Analysis (BEA). The source of self-employed and unpaid family workers data, on the other hand, is the Current Population Survey (CPS) conducted by the Department of Commerce, Census Bureau, for the Department of Labor, Bureau of Labor Statistics (BLS). Finally, total farm workers reported in the ERP is defined as the sum of these two variables.

One potential problem with the measure of total farm workers is that it may contain outliers during the sample period that may be caused by the definitional changes in the Current Population Survey.[13] In previous studies, researchers, including Barkley (1990), address this problem by adding annual dummy variables to their regression models. After a general-to-specific modeling approach that involved removing insignificant dummy variables one at a time, a dummy variable for 1973 ($dum73 = 1$ *if* $year > 1973$, *and* $dum73 = 0$ *if* $year \leq 1973$) was used in the empirical models for total farm workers.[14] The CPS sample was revised

[11] The top and bottom 20% of T observations are "trimmed" away to ensure a minimum of $0.20.T$ observations in each of the two regimes.

[12] The pre-World War II period is excluded from the analysis since the dynamics of agricultural labor markets, including migration to non-agricultural sectors, were very different in this period.

[13] Some of the important changes include the following: revisions based on new census data and new occupational and industrial classification systems; revisions made by BLS reflecting changes in the concepts of the labor force, employment and unemployment; revisions incorporating events that might affect survey sample and population estimates, such as recent international migration trends and Hurricane Katrina. Details and the complete list of changes to CPS are reported by BLS, and can be found at https://www.census.gov/prod/2002pubs/tp63rv.pdf.

[14] Once the significant year dummies are determined based on the linear model, they are kept in the threshold specifications.

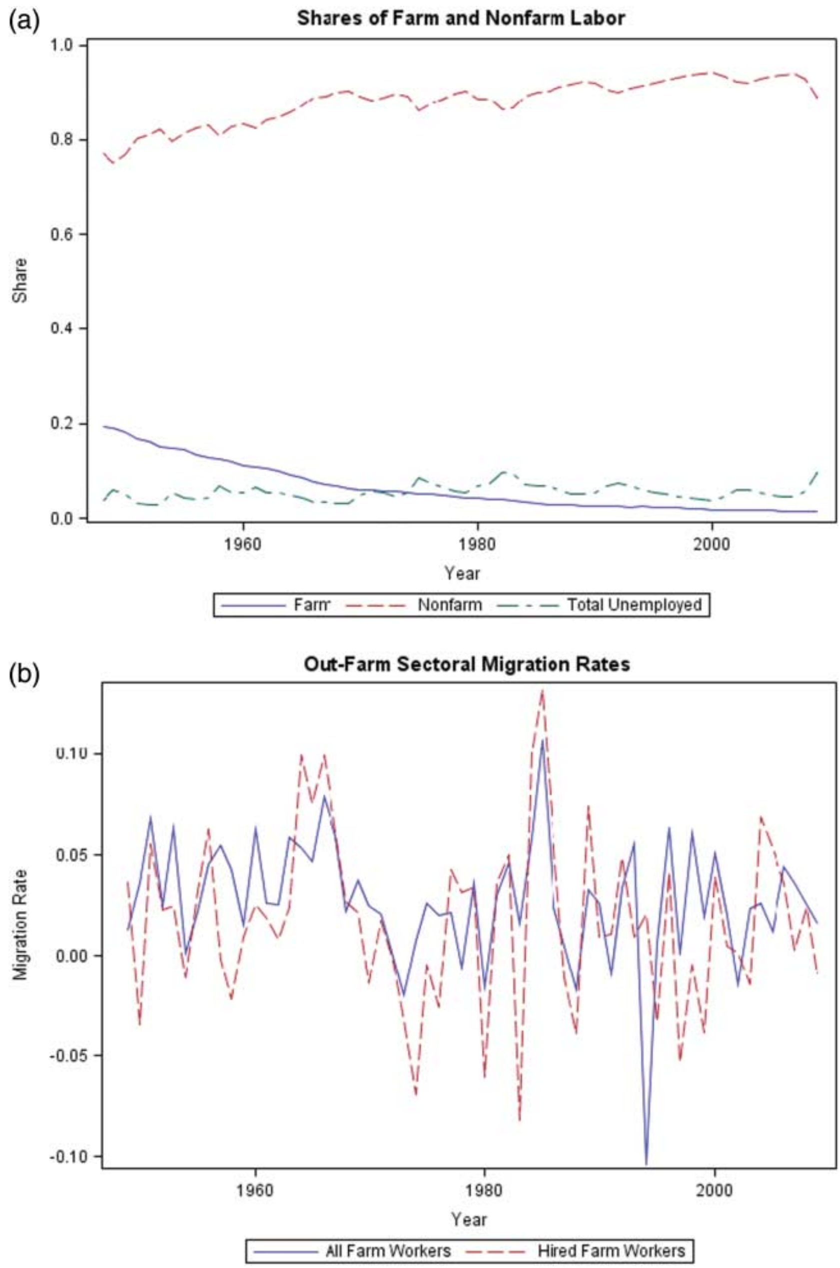

Figure 2. Shares of farm and non-farm labor and out-farm migration rates

Note: (a) Shares of Farm and Non-farm Labor, 1948–2009 (b) Out-farm migration rates of All and Hired Farm Workers, 1949–2009

gradually between 1971 and 1974 to reflect the changes in population size and distribution, and occupational classifications described by the 1970 census. The dummy variable coincides with these definitional changes that occurred around 1973, and it reflects the mean shift observed in migration rates of total farm workers around the same year (figure 2b). On the other hand, none of these definitional changes is found to be significant for the migration of hired farm workers. This is not surprising since the data for hired farm workers come from the NIPA database and are not subject to the same definitional changes that are observed in the CPS data set.

The data source for non-farm sector employment is the Current Employment Situation (CES) database from the BLS.[15] Non-farm employment is measured as total private non-farm wage and salaried workers. Therefore, it is assumed that the off-farm migrants may take jobs only in private sectors; government sector jobs are excluded from non-agriculture employment.

Two measures of the returns to labor are used in this paper: (*a*) a measure of value-added per worker, and (*b*) data on hourly wage rates. The first measure is the gross domestic product divided by the number of workers, which reflects the average productivity of labor. Value added by agricultural and non-agricultural sectors are obtained from the GDP by Industry database of the BEA. As in Barkley's paper (1990), value-added data for both farm and private non-farm sectors are used in nominal terms to capture the effects of relative price changes (the terms of trade) between agricultural and non-agricultural products. The value-added data used in this paper consist of all returns, including government payments. Therefore, direct government payments to farmers are not included separately in the model as an additional explanatory variable. Hourly wage rates of hired farm workers are published in Farm Labor Surveys conducted by the United States Department of Agriculture (USDA), National Agricultural Statistical Service (NASS). Hourly wage rates of private non-farm goods-producing workers are used as non-farm wage rates; they are published by the BLS.

Figure 3 illustrates plots of both productivity measures and wage rates in the farm and non-farm sectors. The average productivity measure for the farm sector shows more variability compared to that of the non-farm sector, which reflects relatively larger realized productivity shocks and random output shocks in agriculture. Figure 3 also shows that throughout the sample period, returns to labor have always been larger for non-agricultural workers than agricultural workers, regardless of how they were measured. Unemployment rates of non-agricultural private wage workers are used to measure non-farm unemployment rates. The measure of real farmland prices used is the USDA series of farm real estate values (U.S. dollars per acre), deflated by the producer price index (PPI) for farm products. The PPI data are taken from the BLS. Table 1 shows how the variables used in equations 8 to 10 are constructed, and presents relevant descriptive statistics.

Empirical Results

Harris-Todaro type models predict a positive relationship between relative returns to labor (originally measured by wages) and migration rates. As a first step, before estimating formal models, simple plots of return differentials (non-farm to farm) and out–farm migration rates are used to visualize their relationship. Figure 4 shows the scatter plot for total farm workers, while figure 5 displays the scatter plot for hired farm workers. A Panelized B-spline curve (Eilers and Marx 1996) is fitted and added to each scatter plot to visually capture the potentially nonlinear relationships between relative returns to labor and migration rates. As previously emphasized, two plausible measures of returns to total farm employees include a measure of productivity and wage rates. Figure 4a presents productivity (or value-added per worker) gaps between non-farm and farm sectors, whereas figure 3 presents wage differentials on the horizontal axis. A striking difference between figures 4a and 4b is that the functional relationship seems to be almost perfectly linear when relative productivity differences are used as a measure of returns to labor. However, the same relationship seems highly nonlinear when wage differentials are considered to be incentives for total farm employees to migrate. This difference is interesting considering the fact that most influential work on U.S. out-farm migration uses relative productivity (or value-added) differences to measure relative labor returns, and not the relative wage rates. Using wages to explain returns to all farm workers, which include family and self-paid workers and operators, may not be appropriate because wages tend to represent only a fraction of total income. However, it is reasonable to assume that

[15] Both the Current Population Survey (CPS) and the Current Employment Statistics (CES) surveys are conducted by BLS, and both are monthly surveys. However, the CPS is based on household surveys, and the CES is based on establishment surveys. One main difference between the two surveys is that the CPS collects data on the self-employed, as well as agriculture and other types of employment that are not included in the CES, whereas CES collects data only on private non-farm employment. According to BLS, CPS employment data are subject to larger sampling errors, about four times that of the CES on a monthly basis. For a more detailed comparison, see http://www.bls.gov/opub/mlr/2006/02/art2full.pdf.

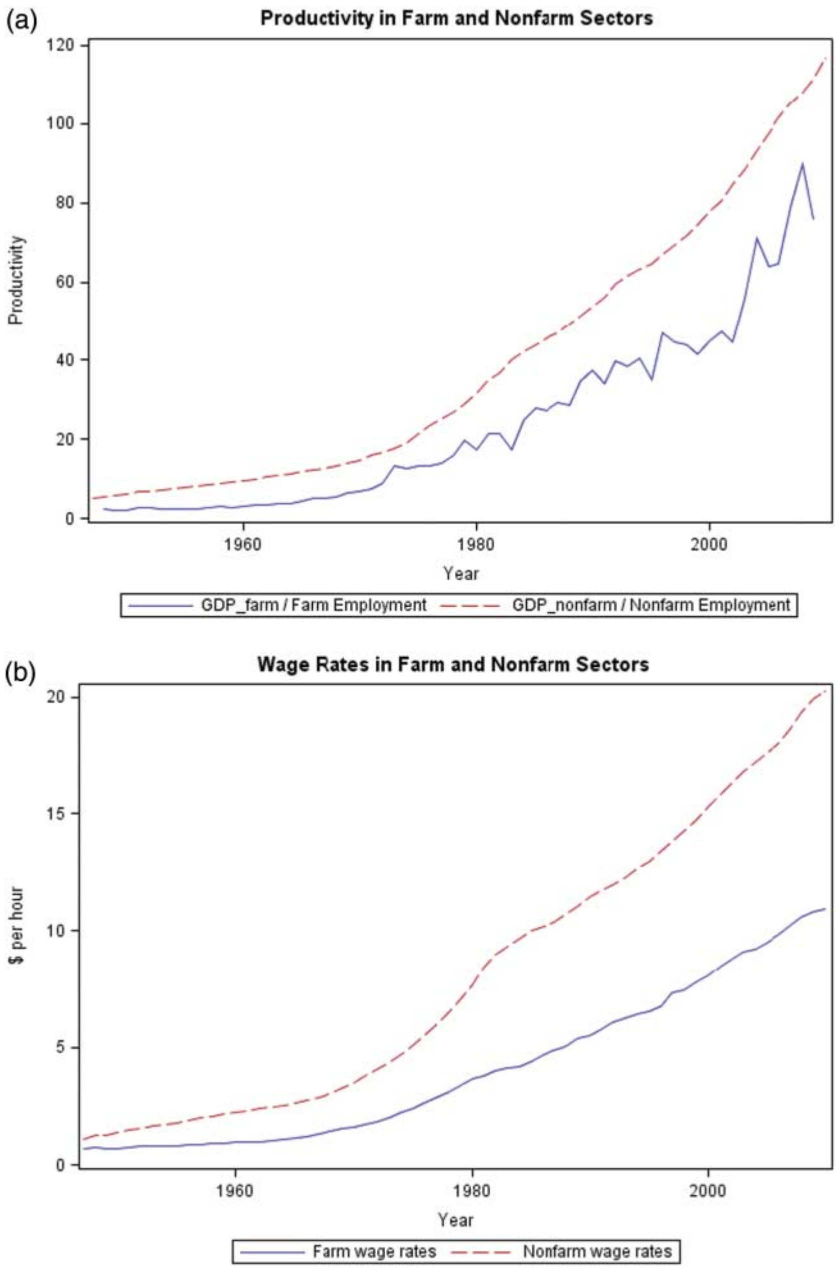

Figure 3. Two alternative measures of returns-to-labor: productivity and wage rates

Note: (a) Labor Productivity in Farm and Non-farm Sectors, 1948–2009 (b) Wage Rates in Farm and Non-farm Sectors, 1948–2009

hired farm employees obtain the primary share of their income from wages. Similar to figure 4b, figure 5 also reveals a nonlinear relationship between migration rates of hired farm workers and wage differentials. Overall, this initial visual inspection is encouraging to proceed with the formal threshold models.

The estimation results from linear, standard Todaro-type regressions that are given by equations 8–10 and those from threshold models that are specified as in equation 11 are presented together. Table 2 reports the estimation results for out-farm migration of total farm employees using value-added

Table 1. Summary Statistics and Description of Data

Variable	Description	Mean	Std. Dev.	Min.	Max.
L_{nf}	Number of Employees in (Private) Non-farm Sector	73,310.50	25,758.12	37,893.00	115,380.00
L_f	Number of All Farm Workers	4,197.61	2,230.40	1,757.00	9,759.00
L_{hired}	Number of Hired Farm Workers	1,312.92	481.86	732.00	2,326.00
y_{nf}	Value Added by (Private) Non-farm Sector	3,734,055.23	3,891,210.75	193,778.00	12,542,492.00
y_f	Value Added by Farm Sector	63,650.56	41,721.97	18,401.00	160,131.00
APL_{nf}	Labor Productivity in Non-farm Sector: y_{nf}/L_{nf}	39.84	33.28	5.04	116.85
APL_f	Labor Productivity in Farm Sector: y_f/L_f	24.03	22.81	1.92	89.65
w_{nf}	Wage Rate in Non-farm Sector (Dollars/hour)	8.11	6.00	1.12	20.27
w_f	Wage Rate in Farm Sector (Dollars/hour)	4.09	3.26	0.68	10.95
u_{nf}	Non-farm Unemployment Rate	6.01	1.62	3.40	10.10
$nominal\_lv$	Nominal Farmland Values (Dollar/acre)	617.42	574.14	60.00	2,170.00
PPI_f	Producers' Price Index for All Farm Goods	80.59	34.41	39.00	161.30
$real\_lv$	Real Farmland Values: $nominal\_lv/PPI_f$	6.24	3.86	1.31	15.67
M_{all}	Out-farm Migration Rates of All Farm Workers: $(L_{f,t-1} - L_{f,t})/L_{f,t-1}$	0.02	0.03	−0.10	0.10
M_{hired}	Out-farm Migration Rates of Hired Farm Workers: $(L_{hired,t-1} - L_{hired,t})/L_{hired,t-1}$	0.01	0.04	−0.08	0.13
r	$log(APL_{nf}/APL_f)$	0.67	0.28	0.18	1.17
w	$log(w_{nf}/w_f)$	0.72	0.08	0.48	0.86
u	$log(u_{nf})$	1.75	0.26	1.22	2.31
g	$log(L_{nf}/L_f)$	2.92	0.84	1.36	4.15
lv	$log(real\_lv)$	1.62	0.67	0.27	2.75

per worker to represent differences in labor returns. Results from both the linear model and the threshold model in table 2 confirm the expected positive relationship between labor productivity gaps and the out-farm migration rates. As the relative value-added per worker in the non-agricultural sector increases, off-farm migration also increases. The elasticity of migration with respect to this sectoral gap in labor returns can be computed at the mean values using $\epsilon = \beta_1(1/\bar{M}_{all})$. The estimated elasticity for 1948–2009 is 3.25; Barkley (1990) estimated this number as 4.5 for 1940–1985. Despite the different samples used, the elasticity results are quite similar to those reported by Barkley (1990).

The non-farm unemployment rate is found to have no significant effect on migration in the linear Harris-Todaro model; although β_2 bears the expected sign, it is statistically insignificant. Further, β_3 was reported to be a large *positive* number in Barkley's (1990) paper. However, table 2 shows that the ratio of the non-farm labor force to the farm labor force has a significant *negative* impact on migration rates. As the size of non-farm employment relative to that of farm employment increases, the probability of getting a job in the off-farm sector for potential off-farm migrants may decrease, which explains the negative sign on β_3. Real farmland values are also found to be statistically significant. However, Barkley's (1990) results indicated a large, negative response of labor migration to the price of farmland (−0.11) as opposed to the smaller, positive relationship reported in table 2 (0.055). Land values are a proxy for the returns to all assets used in agriculture and they reflect expected future earnings

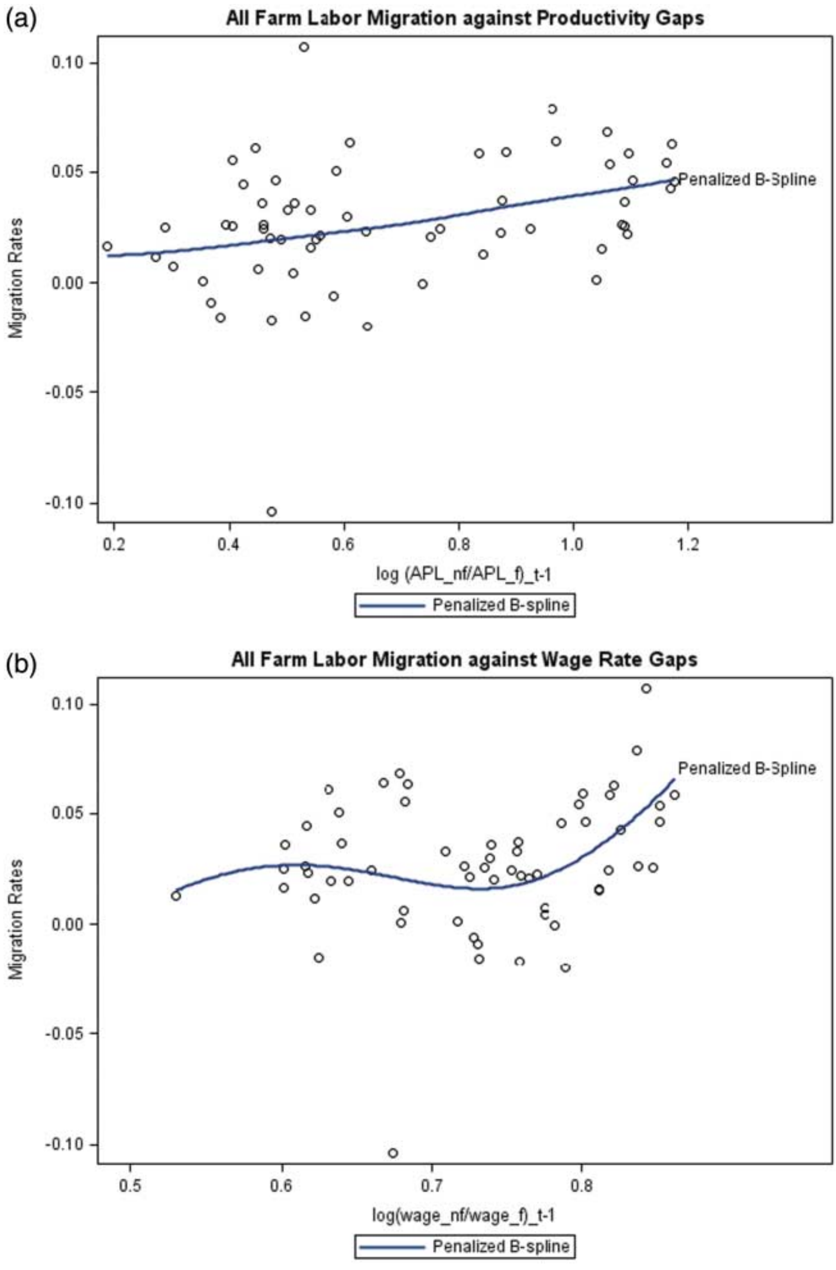

Figure 4. Plot of migration rates of all farm workers against relative returns-to-labor

Note: (a) Returns-to-Labor is Measured by Productivity (b) Returns-to-Labor is Measured by Wage Rates

in agriculture. On the one hand, high land values provide benefits to land owners by increasing their capital gains and developing positive expectations about future profits in agriculture. On the other hand, higher land values raise input costs for tenant farmers, thus causing subsequent input substitution and off-farm migration of labor associated with this group of farmers. Barkley's estimate of β_4 indicates that the first effect outweighs the second effect of higher farmland prices. However, the estimated coefficient of 0.055 in table 2 suggests the opposite.

The threshold counterpart of the same migration model is reported in the bottom part of table 2. The estimated threshold parameter is 0.48, but it is statistically insignificant: the linearity hypothesis cannot

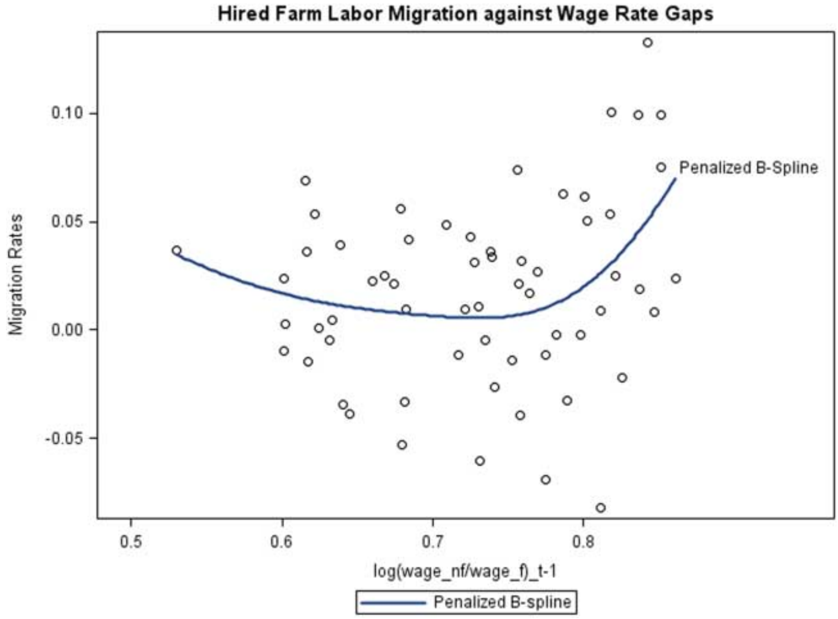

Figure 5. Plot of migration rates of hired farm workers against relative wage rates

be rejected. This suggests that, in a Harris-Todaro type regression model where returns to labor are approximated by value-added (or productivity), a linear specification fits the data, and a threshold specification is not warranted. Furthermore, although regime 1 coefficients are highly significant, their magnitudes are generally not very different than those estimated from the linear model. This result is consistent with figure 4a.

When wage differentials are used to represent relative gains in the two sectors (as originally suggested in Todaro models), the results differ considerably from those obtained using productivity differences. The signs and magnitudes of the standard regression coefficients reported in table 3 are similar to those reported in table 2. However, with the exception of β_3 and β_4, coefficients are statistically insignificant. In other words, when wage differentials are used to express relative gains in each sector, the linear model fails to provide support for the Harris-Todaro hypothesis. This picture dramatically changes when a threshold is allowed; the threshold is estimated via a grid search that involves searching for the minimum sum of squared residuals. The plot of sequential SSR values is given in figure 6a. The candidate values of threshold parameter (after trimming) are on the horizontal axis, and the corresponding SSR values are on the vertical axis. Estimated threshold is 0.72, and it is significant (the *p*-value for testing the null of linearity is 0.10). This threshold parameter is also consistent with the turning point of the fitted penalized B-spline curve in figure 4b.

Parameter estimates in regime 1, in which sectoral wage gaps $(log(W_{nf} - log(W_f))$ exceed 0.72, are greater than both their linear counterparts and the parameters of regime 2 (corresponding to smaller wage gaps). The threshold version of the migration model predicts the estimated elasticity of out-farm migration with respect to wage differentials to be 15.67 in regime 1, and 10.67 in regime 2. All parameters, except for the parameter on land values, are statistically significant and have the expected signs in regime 1. In regime 2, only the unemployment rate lacks a significant effect on migration. The coefficients of log of the labor force ratio and real farmland values are much larger in regime 2 than in regime 1. This indicates that expectations about the prospects of jobs in off-farm sectors and the expectation about future returns in agriculture have greater impacts on out-farm migration when the relative non-farm wages are below the estimated threshold level. Once this threshold is exceeded, economic incentives play a greater role in inter-sectoral migration decisions. This result is consistent with the predictions of real options theory of migration. First, the

Table 2. Estimation Results for Out-farm Migration of All Farm Workers: Returns-to-labor Measured by Productivity

Parameter	Estimate	Std. Error	t-value
Linear Model: $M_{all} = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 u_{t-1} + \alpha_3 g_{t-1} + \alpha_4 lv_{t-1} + \gamma dum73$			
α_0	0.057	0.065	0.89
α_1	0.065	0.033	2.00**
α_2	−0.028	0.018	−1.58
α_3	−0.046	0.025	−1.87*
α_4	0.055	0.026	2.11**
γ	0.033	0.020	1.67*
Threshold Model: $M_{all} = \delta[\alpha_0^1 + \alpha_1^1 r_{t-1} + \alpha_2^1 u_{t-1} + \alpha_3^1 g_{t-1} + \alpha_4^1 lv_{t-1}]$ $M_{all} = (1-\delta)[\alpha_0^2 + \alpha_1^2 r_{t-1} + \alpha_2^2 u_{t-1} + \alpha_3^2 g_{t-1} + \alpha_4^2 lv_{t-1}] + \gamma dum73$			
α_0^1	0.105	0.077	1.37
α_1^1	0.077	0.040	1.97**
α_2^1	−0.043	0.020	−2.18**
α_3^1	−0.081	0.029	−2.78***
α_4^1	0.092	0.032	2.85***
α_0^2	−0.143	0.128	−1.12
α_1^2	0.113	0.093	1.22
α_2^2	0.002	0.042	0.04
α_3^2	0.025	0.044	0.57
α_4^2	0.008	0.045	−0.19
γ	0.045	0.021	2.08**
Estimated Threshold:	0.47		
Observations in Regime 1:	44		
Observations in Regime 2:	17		
Hansen's (2000) Linearity Test:			
Test Statistics	9.17		
Bootstrapped p-value	0.79		

Note: Three asterisks *** indicate significance at the 1% level, ** indicate significance at the 5% level, and * indicates significance at the 10% level.

estimated threshold is large relative to what one might expect for a standard "Marshallian trigger" (figure 1). Second, expectations matter more when wage differentials are below the trigger level, which indicates that some potential migrants may be postponing their decisions to migrate during those periods. After the threshold is reached, a majority of migrants, including those who might be waiting to migrate, respond more to larger economic incentives offered in the off-farm sector.

Estimation results for hired farm workers' migration are presented in table 4. None of the coefficients from the linear model are statistically significant. This finding is discouraging in terms of the traditional Harris-Todaro models. However, as soon as the possibility of a threshold in the model is allowed, the results change dramatically. The estimated threshold is 0.80, and corresponds to the point where the slope of penalized B-spline curve in figure 5 changes direction. Accordingly, in regime 2, where wage differentials are smaller than the estimated threshold of 0.80, the coefficient on wage gaps has the wrong sign. However, it is not statistically significant. In fact, regime 2 parameters are all insignificant. On the other hand, regime 1 parameters are all significant and have the correct signs. The elasticity of out-farm migration with respect to wage differentials is quite large for hired farm workers (30.50) compared to that for total farm workers (15.67). This large difference suggests that hired farm employees are relatively more mobile, and respond to economic incentives more than the general group of all farm employees, which includes operators. Another difference between the groups

Table 3. Estimation Results for Out-farm Migration of All Farm Workers: Returns-to-labor is Measured by Wage Rates

Parameter	Estimate	Std. Error	*t*-value
Linear Model: $M_{all} = \beta_0 + \beta_1 w_{t-1} + \beta_2 u_{t-1} + \beta_3 g_{t-1} + \beta_4 lv_{t-1} + \gamma dum73$			
β_0	0.114	0.062	1.83
β_1	0.045	0.058	0.78
β_2	−0.030	0.019	−1.55
β_3	−0.064	0.023	−2.74***
β_4	0.068	0.026	2.65***
γ	0.014	0.017	0.41
Threshold Model: $M_{all} = \delta[\beta_0^1 + \beta_1^1 w_{t-1} + \beta_2^1 u_{t-1} + \beta_3^1 g_{t-1} + \beta_4^1 lv_{t-1}]$ $M_{all} = (1-\delta)[\beta_0^2 + \beta_1^2 w_{t-1} + \beta_2^2 u_{t-1} + \beta_3^2 g_{t-1} + \beta_4^2 lv_{t-1}] + \gamma dum73$			
β_0^1	−0.189	0.110	1.73*
β_1^1	0.467	0.135	3.46***
β_2^1	−0.054	0.024	−2.26**
β_3^1	−0.051	0.027	−1.93***
β_4^1	0.044	0.032	1.36
β_0^2	0.058	0.097	0.61
β_1^2	0.324	0.173	1.87*
β_2^2	−0.038	0.028	−1.36
β_3^2	−0.154	0.046	−3.37***
β_4^2	0.162	0.054	2.99***
γ	0.040	0.020	2.05**
Estimated Threshold:	0.72		
Observations in Regime 1:	38		
Observations in Regime 2:	23		
Hansen's (2000) Linearity Test:			
Test Statistics	20.41		
Bootstrapped p-value	0.10		

Note: Three asterisks *** indicate significance at the 1% level, ** indicate significance at the 5% level, and * indicates significance at the 10% level.

of hired farm workers and all farm workers is that the effect of relative size of the non-farm labor force is positive on the hired farm workers' migration. This is consistent with Barkley's (1990) results. The positive sign of θ_3^1 indicates that hired farm workers may perceive this as a signal of off-farm job opportunities and the non-agricultural sector's absorption capacity regarding new out-farm migrants.

Concluding Remarks

The migration of labor away from the agricultural sector has long been considered an important element characterizing the development of an economy. Although the vast majority of the migration literature is based on the argument that individuals migrate to take advantage of positive wage differentials, the existing empirical literature seems to ignore some other important characteristics of migration as an investment in human capital.

Migration decisions are usually characterized by the following features: *a*) sunk costs; *b*) uninsurable uncertainty; *c*) the possibility of waiting and postponing the decision, and therefore postponing the payment of sunk costs. As a result, potential migrants might choose to flow to off-farm sectors only beyond some threshold level of the wage differences between farm and non-farm sectors, rather than moving immediately when this difference turns out to be positive. The implication of this argument for aggregate-level migration studies is that a

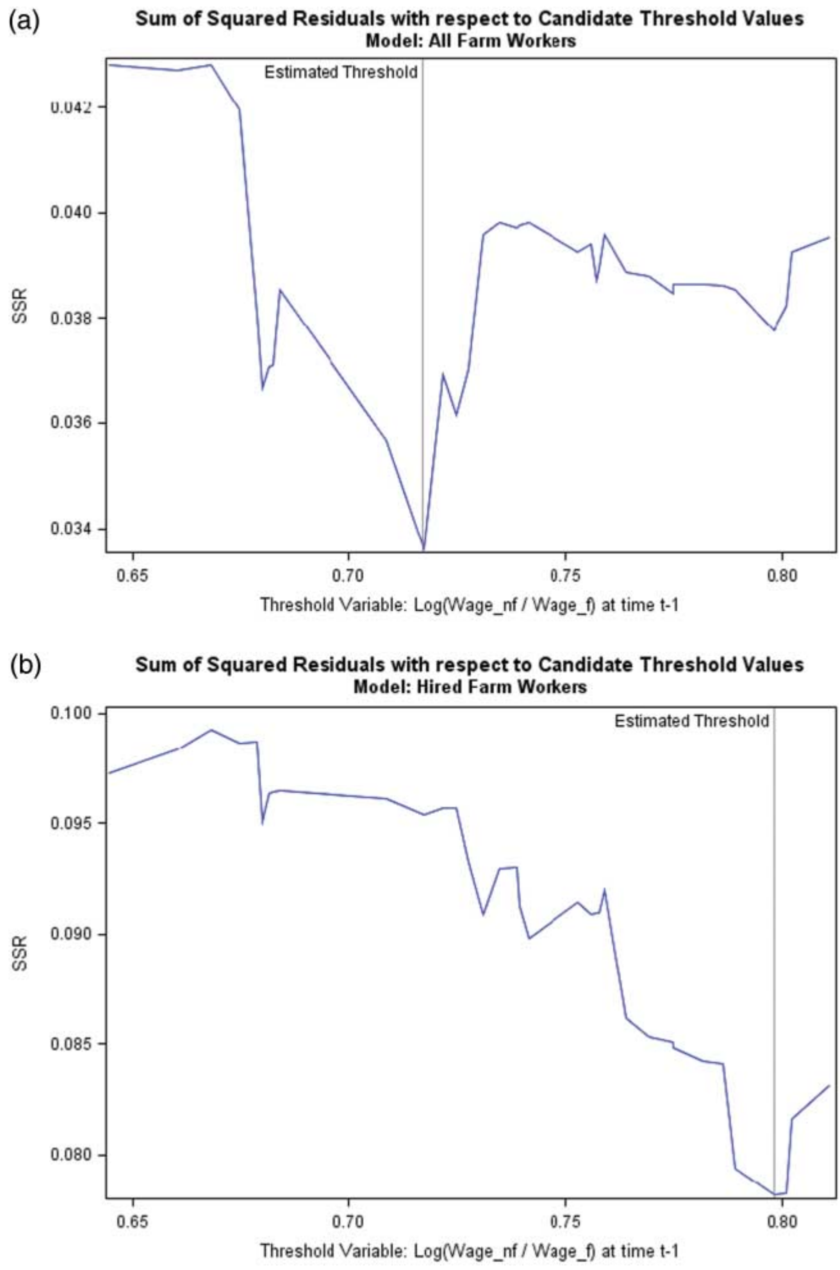

Figure 6. Squential Sum of Squared Residuals and the Estimated Thresholds

Note: (a) All Farm Workers (b) Hired Farm Workers

nonlinear relationship between migration and wage differentials may be present. Surprisingly, researchers generally assume linear (in parameters) relationships between migration rates and the differences in economic conditions of farm and off-farm sectors. The objective of this paper is to extend the empirical literature on out-farm migration by re-examining Harris-Todaro type off-farm migration models, considering the possibility of nonlinear threshold effects on the relationships among off-farm migration and its macroeconomic determinants.

Hansen's (1996, 2000) threshold specifications are used to estimate empirical migration models. These models are applied to annual time series data on the U.S. farm employment between 1948 and 2009. In

Table 4. Estimation Results for Out-farm Migration of Hired Farm Workers: Returns-to-labor is Measured by Wage Rates

Parameter	Estimate	Std. Error	t-value
	Linear Model: $M_{hired} = \theta_0 + \theta_1 w_{t-1} + \theta_2 u_{t-1} + \theta_3 g_{t-1}$		
θ_0	−0.056	0.069	−0.81
θ_1	0.106	0.082	1.30
θ_2	−0.001	0.023	−0.08
θ_3	−0.000	0.007	−0.01
	Threshold Model: $M_{hired} = \delta[\theta_0^1 + \theta_1^1 w_{t-1} + \theta_2^1 u_{t-1} + \theta_3^1 g_{t-1}]$ $M_{hired} = (1-\delta)[\theta_0^2 + \theta_1^2 w_{t-1} + \theta_2^2 u_{t-1} + \theta_3^2 g_{t-1}]$		
θ_0^1	−0.947	0.430	−2.20**
θ_1^1	1.224	0.509	2.40***
θ_2^1	−0.097	0.043	−2.24**
θ_3^1	0.064	0.022	2.96***
θ_0^2	0.079	0.080	0.99
θ_1^2	−0.096	0.097	−1.00
θ_2^2	0.009	0.025	0.34
θ_3^2	−0.006	0.007	−0.76
Estimated Threshold:	0.80		
Observations in Regime 1:	16		
Observations in Regime 2:	45		
Hansen's (2000) Linearity Test:			
Test Statistics	21.27		
Bootstrapped p-value	0.03		

Note: Three asterisks *** indicate significance at the 1% level, ** indicate significance at the 5% level, and * indicates significance at the 10% level.

general, evidence suggests that farm labor responds to economic incentives when making their migration decisions. Results also indicate considerable evidence in favor of threshold effects when *wage differentials* are considered as the relevant relative non-farm returns to labor. On the other hand, when *value-added per worker* (a proxy for labor productivity) is chosen to represent returns to all farm workers, the nonlinear model is not supported and the estimated elasticity of agricultural out-migration with respect to inter-sectoral returns is 3.25. This is consistent with existing literature. If wage differentials are used to represent relative returns to labor, the linear specification is rejected in favor of the threshold model and the responsiveness of off-farm migration of all farm workers to wage differentials is found to be much larger than what is suggested by the linear model with relative productivity gaps. This elasticity is even larger when only hired farm workers are considered, which indicates that this group of farm labor has a relatively higher level of inter-sectoral mobility.

Overall, the empirical results suggest that estimating the determinants of inter-sectoral migration in a linear fashion may overlook potential nonlinearities in the relationship among model variables, potentially resulting in erroneous conclusions regarding the responsiveness of farm employment to economic policy variables. Land value appreciation seems to increase the rate of labor migration out of production agriculture, regardless of the chosen returns measure and model specification. The effect seems much larger during the periods of "waiting" (i.e., below the threshold). The impact of relative labor market size is also stronger when a threshold level of wage gaps is yet to be reached, suggesting that risk and expectations play a larger role when relative non-farm wages are below some threshold level. Therefore, off-farm migration may not be solely explained by wage differentials, especially when wage gaps are not large enough to pass the wage thresholds that arise from adjustment costs and the option value of waiting. Once the inter-sectoral difference in labor returns is sufficiently large, the major economic determinant of out-farm migration is the relative returns to labor.

These results have important policy implications. First, hired farm labor is very migratory and responds to relative wages between sectors. However, the wage gap needs to be very large to induce intersectoral migration. Expectations matter, especially during the periods in which workers evaluate the relative option value of deferring the out-farm migration. Another important policy implication of the results is that, in general, farm subsidies and other government payment programs are unlikely to provide the desired result of slowing down the out-farm migration when the economy is characterized by large sectoral productivity gaps and income growth in the nonfarm sector. On the contrary, government programs that result in increased land values may indirectly encourage the out-farm migration of a group of farmers, including farm operators, and self-employed and unpaid family workers.

A possible avenue for future research on the issue of inter-sectoral migration involves taking advantage of disaggregated data to shed more light on the attributes of migrants that are relevant to the migration decision, such as age and heterogeneity among individual migrants. Another aspect of inter-sectoral migration that is important and that might be possible to explore with micro-level data is the impact of foreign agricultural workers on the U.S. farm labor supply. Foreign workers have been an important part of U.S. labor-intensive segments of agriculture such as production of crops; according to the National Agricultural Worker Survey, 72% of the U.S. farm workforce from 2007–2009 were foreign-born, and more than half lacked proper authorization to work in the United States (Taylor 1992; Taylor, Charlton, and Yúnez-Naude 2012). The issue has important policy implications, particularly with the recent changes in U.S. immigration laws.

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