Hysteresis and the Shortage of Agricultural Labor

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Abstract:

The GAO disputes growers' claims of a labor shortage, using unreliable farm employment data rather than relative wages. A shortage, implying a failure of intersectoral arbitrage, may arise due to hysteresis in labor movement. Estimates find the probability of a farm labor shortage (30%) three times that of a surplus.

Introduction

As growers throughout the U.S. complain of a shortage of harvest workers, a recently released General Accounting Office (GAO) report finds that no such nationwide shortage exists and, in fact, cites Labor Department sources claiming that many of the nation's most important agricultural areas have a surplus of labor. However, their conclusions rely on unemployment data -- data that Martin shows to be notoriously unreliable and the USDA criticizes as non-representative of local rural labor market conditions. Even if these data are reliable, there is some question if unemployment among all workers truly represents a surplus of agricultural labor (Barkley). To economists, growers' notion of a shortage implies an excess demand at the prevailing wage -- a situation which would normally cause agricultural wages to be bid up, thereby inducing an increase in the quantity of agricultural labor supplied until the shortage disappears. However, this equilibration process does not appear to be occurring as static, neo-classical economic theory would suggest.

Many empirical studies question the ability of labor markets to clear between the agricultural and non-agricultural sectors. Although Barkley shows that migration from agriculture does respond to relative returns between the sectors, he argues that "...the flow of labor to higher wages does not take place instantaneously..." because there is some chance that the migrant will not obtain a job in the other sector. Hatton and Williamson (1991a) find that 9% to 13% of the urban-farm wage gap remains after correcting for differences in personal characteristics, perks in agricultural jobs, urban unemployment, and the cost of living and cite this as evidence that the Michigan labor markets of the 1890s were not integrated. However, defining integration in terms of wage equality is unsatisfactory as two markets can be integrated if wages tend toward an equilibrium differential or relationship with another set of variables, or are cointegrated. Alston and Hatton conduct formal cointegration tests that support earlier findings of non-integration. Using more recent (1988) survey data, Perloff provides empirical evidence that the elasticity of labor supply between the non-agricultural and agricultural sectors is very high -- above 3.3 for non-skilled workers, suggesting that worker migration responds readily to price signals.

In the macroeconomics literature, the apparent unwillingness of labor to move between sectors is attributed to sector-specific demand shocks (Lucas and Prescott), worker-employer mismatches (Jovanovic and Moffitt), insider-outsider models of wage determination (Blanchard and Fischer), and, more recently, to hysteresis in worker's sectoral employment choices (Dixit and Rob). The hysteresis argument is particularly compelling in the case of farm-labor adjustment.

In general terms, hysteresis refers to the failure of a phenomenon to reverse itself once its initial cause is removed (Dixit 1989, Cross). In this example, hysteresis means that agricultural workers, once induced to move to the non-agricultural sector are hesitant to return even though the relative returns to doing so may make such a move rational under traditional static optimization rules. The reason for this hesitation lies in the fact that workers make an irreversible investment in human capital specific to the non-agricultural sector to make the initial move, or simply invest time and financial capital in making a physical move to the source of the non-agricultural job. When this investment is made under conditions of ongoing uncertainty in returns to both agricultural and non-agricultural employment, a real option value arises to remaining in the non-agricultural sector. Therefore, the relative returns to farm employment must rise above the level that traditional analysis would suggest by this option value. Hysteresis is thus reflected in both perceived shortages of one type of labor or the other and a gap between wages in the two sectors that may appear to be abnormally large (relative surplus of agricultural labor) or abnormally small (relative shortage of agricultural labor).

The objective of this paper is to determine if agricultural labor is indeed in shortage and, if so, if hysteresis forms a plausible explanation for the disequilibrium. To accomplish this objective, the next section describes an empirical test of hysteresis based on Dixit's real option-value framework. This empirical test involves applying a variation of Spiller and Huang's parity bounds model to monthly agricultural and non-agricultural wage data from Washington state. After a discussion of estimates obtained with this model, the concluding section offers some implications for labor market conduct and potential policy reforms.

Economic Model of Hysteresis in Labor Markets

For simplicity, assume that workers have a choice between employment in one of two sectors. The non-agricultural sector, *n*, consists of low or semi-skilled jobs which pay a wage w_n, while jobs in the agricultural sector, *a*, pay a wage w_a. To simplify model description, the wage relevant to a worker considering a move from one sector to the other is the relative wage, $w_n - w_a = w$. Assume that moving from one sector to the other causes the worker to incur search costs, costs due to a temporary loss of income, and, if the worker moves from *a* to *n*, the costs of a minimal amount of training. Call this irreversible entry cost *k*, and the cost of moving back to the farm sector *q*. Given these costs, the neo-classical, or Marshallian optimality condition to move out of agriculture requires the relative wage to rise above the annualized cost of entry, or $w = \rho k$, where ρ is the interest rate. A symmetric argument holds for leaving the non-farm sector. The objective of this section is to show that the full-cost trigger, which includes the real option value, is significantly higher than this Marshallian trigger.

To begin, assume further that returns to employment in either sector is inherently uncertain, where uncertainty is defined in terms of a stochastic wage series. Specifically, the relative wage follows a geometric Brownian motion with drift:[1]

$$dw/w = \mu dt + \sigma dz, \qquad (1)$$

where μ is the mean growth rate, σ is the standard deviation of the process, and *dz* defines the Wiener increment with properties: $E(dz) = 0$ and $E(dz^2) = dt$. Given this structure, the derivation of the full-cost trigger level of wages that induces a worker to move from the agricultural sector to the non-agricultural sector closely follows Dixit (1989, 1992) and is given by w^H.

Assume that a representative worker decides which sector in which to work on the basis of

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[1] The assumption of a positive drift term is valid given the rising nominal gap between agricultural and non-agricultural wages over time. Assuming the alternative, that relative wages follow a mean reverting process, reduces the option value as this implies a lower probability of large upside movements in the wage differential (Dixit and Pindyck).

the present value of lifetime earnings and, as such, is risk neutral. A worker will willingly remain in his or her current state (a = agriculture, n = non-agriculture) only if the expected total return to doing so, including the periodic capital gain to the value of lifetime earnings and the per-period inflow, is equal to the annual "normal return" on the capitalized value of lifetime earnings. The periodic inflow is equal to the relevant wage less the opportunity cost, or the wage in the other sector (Dixit, 1989). Applying Ito's Lemma to value of lifetime earnings in the farm sector, $V_a(w)$, gives:

$$dV_a = V_a^{/}(w)\,dw + (1/2)\,V_a^{//}(w)\,\sigma^2 w^2 dt. \tag{2}$$

Taking expectations of (2), and dividing by dt provides an expression for the expected capital gain to remaining in agricultural employment, which, when set equal to the normal return on earnings provides the arbitrage condition:

$$E[dV_a(w)/dt] = (1/2)\,\sigma^2 w^2 V_a^{//}(w)\,\sigma^2 w^2 + \mu w V_a^{/} - \rho V_a(w) = w, \tag{3}$$

while the equilibrium condition for remaining in the non-agricultural sector is symmetric.

Solving these partial differential equations for the relative wage that is low enough to induce entry to agricultural sector (w_L) or high enough to induce exit (w_H) is simplified considerably by considering the polar cases where w_n and w_a are either sufficiently close or far apart to rule out either entry or exit (Dixit 1989). For the entry trigger wage, solving for w_L gives the relationship between the full cost trigger to enter the farm sector and the Marshallian trigger, $m_L = q\rho$:

$$w_L = -(1/2)\left(\frac{\alpha}{\alpha - 1}\right)(m_L - q\mu). \tag{4}$$

Clearly, the size of this gap depends upon α, the magnitude of exit costs, q, and the growth rate of w, the wage differential. The difference between the full cost and Marshallian wages is, therefore, a nonlinear function of α. The parameter α, in turn, depends upon the level of uncertainty in the wage gap as the general solution to (3) includes (Dixit):

$$-\alpha = \frac{(1 - 2\mu/\sigma^2) - [(1 - 2\mu/\sigma^2)^2 + 8\rho/\sigma^2]^{1/2}}{2}. \qquad (5)$$

In the empirical model below, this difference is approximated by the function $O_L(\mu,\sigma)$, or the option value to remaining in the non-agricultural sector. Symmetrical notation applies to the entry trigger.

From (5), it is clear that the more variable the difference in wages, the greater is the option value. Further, the higher the option value, the greater is the difference between the Marshallian and full-cost exit wages. Shortages in farm labor will disappear only if the difference between farm and non-farm wages drops below a certain level, w_L, so the probability that this will not happen is the probability of observing a shortage of agricultural labor despite small relative increases in the farm wage. Other researchers, however, conduct tests for hysteresis that do not consider the elements of this option value approach, or do not attempt econometric estimation.

Empirical Test of Hysteresis in Labor Markets

Empirical models of the "hysteresis gap" caused by a real option value arising an uncertain investment environment rely on simulation models calibrated with typical parameter values (Purvis, et al.; Dixit). Others define hysteresis simply as the path dependence of an economic phenomenon and, therefore, test for its presence with relatively simple single equation time-series models (Parker; Song and Wu), more complex structural vector autoregression methods (Dolado and Jimeno), or with unobserved components models (Jaeger and Parkinson). Greater interest, however, lies in estimating either the option value that drives a wedge between the non-farm wage that induces entry to that sector and the agricultural wage high enough to induce workers back, or the actual amount of frictional unemployment caused by labor market hysteresis.

Given the data problems inherent in defining and measuring the quantity of agricultural labor in a given market (Martin), studies of labor market adjustment must focus on the former problem, namely, using relatively accurate relative earnings data to estimate option values. Consequently, this study uses data on agricultural and non-agricultural wages in order to test for departures from efficient arbitrage between the two sectors. Violations of these arbitrage conditions have been attributed to imperfect competition, imperfection information, or other sources of friction in commodity markets (Spiller and Huang; Sexton, Kling, and Carman; Baulch), but can equivalently be attributed to unobserved real option values in dual labor markets. Differences between wage series that are greater than the Marshallian cost of moving between the two sectors and yet do not result in arbitrage are attributed to the option value of remaining in the existing sector. This option value, in turn, gives rise to relative shortages or surpluses of labor and are attributed to hysteresis.

Formally, the empirical model follows the parity bounds model of Spiller and Huang as extended by Sexton, Kling, and Carman and Baulch. Wage differentials are assumed to result from both adjustment costs between sectors and the option value of remaining in the chosen sector. Using the expression for the option value in (5) and the symmetrical expression for the entry-wage (w_H) and the exit-wage (w_L) three possible market conditions can be written as:

$$w_n^i - w_a^i = \begin{pmatrix} w_L^i & = m_L(q^i) - O_L(\mu,^i\sigma^i) \\ w^i & = m^i \\ w_H^i & = m_H(k^i) + O_H(\mu,^i\sigma^i) \end{pmatrix} \tag{6}$$

where w_n is the non-agricultural wage in period t, w_a^i is the agricultural wage in period t and region i, m_j^i is the cost of entering (H) or leaving (L) the non-farm sector in region i, σ^i is the variance of w^j, and the difference between the full-cost and Marshallian wage triggers is the real option value of remaining in the current sector, or O_j. Although both moving costs and option values are unobservable, in this model moving costs represent the minimum or "frontier" wage difference that exists when the option value is zero.[2] This value is determined by the fixed costs of entry (k) or exit

[2] Sexton, Kling, and Carman suggest that this model is similar to a stochastic production frontier. By using both positive and negative values of the error term u, all observations on the frontier represent efficient arbitrage,

(q). Entry and exit option values, therefore, are apparent only when wages differ by more than this minimum amount and are functions of the mean growth rate and the variance of the relative wage. Writing these arbitrage conditions in terms of relative wages and moving costs, the three regimes become:

$$\begin{aligned} w_{n,t} - w_{a,t}^{i} &= m^{i} + v_t \ \textit{with prob} \ 1 - \lambda_1 - \lambda_2, \\ w_{n,t} - w_{a,t}^{i} &= m_H^{i} + O_H(\sigma^{i}) + v_t + u_t \ \textit{with prob} \ \lambda_1, \\ w_{n,t} - w_{a,t}^{i} &= m_L^{i} + O_L(\sigma^{i}) + v_t - u_t \ \textit{with prob} \ \lambda_2. \end{aligned} \tag{7}$$

v is a normally distributed iid random variable, and u is a half-normal random variable, distributed independent of v and truncated at zero from below (Sexton, Kling, and Carman).

With this specification, the first equation represents efficient arbitrage where agricultural and non-agricultural wages differ only by the costs of moving between sectors and a random error, whereas in the second wages differ by more than moving costs by the value of the real option of remaining employed in the agricultural sector. Similarly, the third equation represents a state of relative surplus (shortage) of non-agricultural (agricultural) labor where the wage gap falls short of moving costs by the real option value.[3] Hypothesis tests of the probabilities λ_j, therefore constitute tests of whether farm sector labor markets are in equilibrium, in surplus, or in shortage. To estimate the probabilities in (7), the parameters are chosen in order to maximize the log of the likelihood function:

$$L = \prod_{1}^{n} [\lambda_1 f_t^1 + \lambda_2 f_t^2 + (1 - \lambda_1 - \lambda_2) f_t^3)], \tag{8}$$

where the specific form of the densities f_t^i are given by Sexton, Kling, and Carman and are

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while those lying off of the frontier may represent either a glut or surplus.

[3] Note that a negative value for O provides evidence of a shortage of agricultural labor, while a positive value suggests a relative surplus.

functions of relative wage variability, and the endogenous moving costs and option values. This parsimony is one advantage of studying sectoral labor migration with an arbitrage model as compared to a structural model, such as that employed by Barkley. Another is that it places far fewer demands on the data.

The data consist entirely of wage rates over the period of January 1994 to August 1997. Hourly agricultural wages for five regions in Washington state are provided by the Washington Employment Security Department's Employment Training Agency (ETA) 223 surveys compiled for the Bureau of Labor Statistics. These surveys report monthly wages for a wide variety of agricultural occupations, so an average wage is constructed by weighting each hourly wage by the proportion of workers in each occupation. Given that the five regions span nearly the entire state of Washington, it is likely that labor market conditions differ between each. Therefore, estimates of the arbitrage model are obtained using a state-wide average agricultural wage, as well as five region-specific wages. Similarly, there is some question as to which non-agricultural market is the dominant alternative for agricultural workers.

Non-agricultural workers are assumed to earn the average hourly wage prevailing in either semi-skilled industrial jobs (manufacturing or construction sectors) or in low-skilled service jobs (retail and wholesale sector). These sectors are chosen both because they represent the most likely alternative employment for low- and semi-skilled laborers and because they are the only ones for which wage data are available. Hourly wages for workers in each of these sectors are from the Bureau of Labor Statistics' *State and Area Employment, Hours, and Earnings* database.

Given the uncertainty over which occupation represents the dominant alternative, estimates of the arbitrage model consider a pooled average industrial (construction and manufacturing) wage in addition to each of the three non-agricultural wages separately. Estimating models for each of these industry-alternatives over five regions and a state average agricultural wage provides thirty market scenarios. Comparisons between these scenarios may provide evidence as to whether labor market conditions are consistent throughout the state, or are entirely local, as the GAO suggests.

To identify region-specific option values and, therefore, arbitrage conditions, the model assumes that each option value parameter is a function of both the mean rate of drift and the regional variance of relative wages. In order to account for the implementation of a higher minimum wage in October of 1996, the estimated model also includes a binary variable taking on a value of 1.0 beginning in this month. Given these considerations, estimates of each model are found using the maximum likelihood procedure in LIMDEP version 7.0.

Results and Discussion

Estimates of the arbitrage model indicate whether the farm labor market, the non-farm labor market, or neither is likely in shortage over this sample period. In the interest of brevity, only the results from aggregating the construction and manufacturing sectors are presented here, although results for each of the other scenarios support the pattern that emerges. These sectors represent occupations with distinctly higher salary structures than either agriculture or the retail and wholesale trade alternative, but also entail the greatest investment to enter. Table 1 shows the arbitrage-model estimates for both a state-wide average wage and the regional markets.

[table 1 in here]

Tests for labor market hysteresis concern the probability parameters, λ_j. The results in table 1 do not provide for a direct test of agricultural labor shortage over the sample period, but rather whether the probability of observing either a shortage or surplus is significantly different from zero. Conceptually, this approach is preferable to estimating a single kink in the labor demand curve because the theoretical model suggests that labor markets will be in a continual state of flux. Over the sample period, it is likely that the labor market moves through many periods of relative shortage, glut or stability, and that these cycles differ by region and by industry. Abstracting from any regional differences for now, estimates of the state-wide average wage model support the existence of a shortage of agricultural labor, but the probability of this shortage is significant only at a 10% level with a one-tailed test. Nonetheless, this result implies that there is a statewide shortage of farm labor almost 3% of the time, whereas the probability of a surplus is not significantly different from zero. An option value of -$6.50 implies that the full-cost trigger to exit the non-agricultural sector is far below the Marshallian level, estimated here to be $11.41.[4] In other words, the difference in wage rates would have to fall below $5.00 in order to induce labor to flow back to the agricultural sector. Given the relative size of employment in the non-agricultural sector, it is not likely that such a difference will be created by falling non-farm wages, but will require significant increases in farm wages. Relaxing the assumption that option values are constant from region to region permits an indirect test of the GAO's contention that agricultural labor problems are primarily local. Indeed, it may be the case that there is a greater probability of shortages in specific regions.

Table 1 bears this out. In every region, the probability of observing a farm-labor shortage (λ_2) is greater than observing a surplus. In fact, the probability of a shortage varies from 30.7% in Region 3 to 82.1% in Region 2 and is statistically significant in all cases at a 10% level or lower. This hysteresis is caused by the option value to remaining in the non-farm sector. In each case, the "negative" option value means that the full-cost trigger (w_L) is lower than the Marshallian trigger, meaning that the existence of an option value requires the agricultural wage to move much closer to the industrial wage before workers will exit the non-farm sector and work on farms. This option value varies from $6.50 per hour (or 57% of the moving cost) for the state-wide average wage, to $2.24 per hour (or 19.9%) in Region 2. The option value for Region 5 is not significant. Despite popular arguments linking conditions in farm labor markets to overall unskilled wage deterioration, it is interesting to note that these results suggest these markets are rarely integrated so may, in fact, be treated separately by policy makers.

Following the logic of this option value approach, worker migration may be aided by policies that reduce the option value to remaining out of agriculture. Because the option value increases in the variance of relative wages, reducing wage variability may speed labor market adjustment, or make labor markets more flexible. One means of reducing relative-wage variability

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[4] Note that option values are reported with their signs indicating they are either additional to (+) the estimated Marshallian trigger, or subtracted from (-) m_j .

may be to impose a wage floor. To test this hypothesis, the empirical model includes a binary variable (D) to segment the sample into periods before and after implementation of the higher minium wage in October, 1996. Table 1 shows that, for the average non-farm wage case, the wage gap $(w_n - w_a)$ widens during the minimum-wage period. This result suggests that the agricultural wage need not rise as high as would otherwise be the case in order to induce workers back to the farm. While minimum wages may have other deleterious side effects that are not considered in this paper, one unintended result may indeed benefit growers by increasing the flexibility of the labor market through reducing the option value to remaining out of the agricultural labor pool.

Conclusions

This paper develops an empirical test of hysteresis as an explanation for observed shortages in agricultural labor markets, despite the existence of significant unemployment in many agricultural counties. Hysteresis is likely to arise in workers' decisions to move between sectors because moving to another job requires fixed costs in training or relocating, and the relative wage between the two sectors is likely to be highly variable over time. These conditions create an option value to maintaining current employment. Because of this option value, wages that induce entry to the non-agricultural sector must rise far above their Marshallian values, or fall below the level that would cause exit from the sector.

Empirical tests of the hysteresis model rely only upon relative wage data. If agricultural and non-agricultural labor markets are integrated, then the relative wage should follow arbitrage conditions where the difference in wages is the Marshallian, or static costs of moving between sectors. Violations of these arbitrage conditions are attributed to hysteresis. Such violations can find the agricultural wage too low to be in a Marshallian equilibrium (a surplus of agricultural labor) or too high (a shortage). Estimates of a maximum likelihood parity-bounds model find the probability of observing a shortage of agricultural labor to be consistently far higher than the probability of observing a surplus. These results contradict the general conclusions of the GAO research report, but support their contention that agricultural labor shortages may exist on a regional basis.

The primary implication of this result is that policy makers can help alleviate the apparent shortage of agricultural labor by creating conditions that reduce the relative variability of agricultural wages, or by reducing the sunk costs of moving between sectors. If relaxing immigrant labor restrictions is politically infeasible, long-term employment contracts may be one way of achieving the former result. However, such institutional changes are not likely to emanate from Congress and must come from the private sector. Policies designed to lower the cost of training, however, are moving through Congress and have a broad base of bipartisan support. Although not an intended purpose of these programs, they may help to improve labor market flexibility and alleviate the shortage of agricultural labor.

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Table 1. Non-agricultural / Agricultural Wage Arbitrage Model: Washington State and Five Regions, 1994-97

Region	m[1]	D	O	λ_1	λ_2	σ_v^2	σ_u^2	LLF
Average	11.406	0.397	-6.500	0.009	0.029	0.025	0.469	-35.014
	(247.111)	(5.990)	(-5.528)	(1.112)	(1.522)	(0.811)	(1.009)	
Region 1	11.695	0.181	-2.856	0.137	0.749	0.003	0.060	-30.020
	(358.808)	(2.963)	(-3.033)	(3.773)	(5.768)	(0.843)	(3.547)	
Region 2	11.247	0.193	-2.237	0.043	0.821	0.006	0.104	-18.573
	(163.429)	(1.912)	(-23.807)	(1.635)	(12.056)	(0.959)	(3.093)	
Region 3	11.415	0.239	-3.713	0.004	0.307	0.033	0.134	-32.318
	(121.506)	(2.968)	(-1.417)	(1.759)	(1.855)	(1.184)	(0.863)	
Region 4	11.352	0.272	-2.525	0.139	0.420	0.098	0.176	-32.230
	(181.756)	(4.072)	(-7.858)	(1.652)	(2.428)	(1.185)	(2.290)	
Region 5	11.675	0.344	-0.988	0.001	0.649	0.019	0.161	-32.911
	(84.358)	(3.137)	(-1.033)	(1.023)	(1.749)	(0.711)	(2.431)	

[1] The parameters are defined as follows: m = Marshallian moving costs, D = minimum wage dummy, O = option value of moving either from farm to non-farm or vice versa, λ_1 = probability of a surplus of farm labor, λ_2 = probability of a shortage of farm labor, σ_u^2 = variance of u error term component, σ_v^2 = variance of v error term component. A single asterisk indicates significance in a two-sided hypothesis test at a 5% level.