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Logit Analysis in a Rotating Panel Context and an Application to Self-Employment Decisions

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Does the timing of the transition into informal self-employment follow a life-cycle pattern where credit-constrained workers first accumulate capital in the formal sector? Or does self-employment correspond better to a traditional "safety-net" for the unemployed?

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Summary findings

González and Maloney derive a methodology for analyzing logit models in a rotating panel context. They then apply the technique to test two theories of why and when salaried workers enter the informal self-employed sector.

In the traditional view, workers fired from formal jobs queue in the informal sector to reenter the formal sector. González and Maloney argue that for many, self-employment is a desirable goal, but that credit constraints often dictate that they work in the formal sector until enough start-up capital is accumulated.

They model the decision to move as a stopped Markov process in which, in each period, the worker compares accumulated savings with the target level for switching sectors dictated by the forecasted stream of discounted utility arising from employing labor and capital in each sector.

They test and find support for the model using the new logit methodology and rotating panel data from Mexico.

This paper — a product of the Poverty Reduction and Economic Management Sector Unit, Latin America and Caribbean Region — is part of a larger effort in the region to understand the functioning of developing country labor markets. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Tania Gomez, room I8-102, telephone 202-473-2127, fax 202-522-2119, Internet address tgomez@worldbank.org. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/html/dec/Publications/Workpapers/home.html. The authors may be contacted at wmaloney@worldbank.org or paroca@socompa.cecun.uncn.cl. February 1999 (19 pages).

Logit Analysis in a Rotating Panel Context and an Application to Self-Employment Decisions*

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I. Introduction

A substantial literature exists on limited dependent models in a panel context (see or Maddala 1983 or Baltagi, 1996 for overviews) and continuous dependent variables in an incomplete or rotating panel context (Bjorn and Jansen 1983, Nijman, Hsiao 1986, Verbeek and van Soest 1991). This paper derives a methodology for estimating logit models in a rotating panel. It then uses the technique to examine an unresolved problem in development economics: the role of self-employed workers unprotected by labor legislation in the LDC labor force. In particular, we are interested in the determinants of the decision to leave protected (formal) work to enter self-employment. An alternative theoretical model to the dualistic view generally accepted is offered. Both views are tested using rotating panel data set from Mexico and the alternate view supported.

II. An Alternate View of Informal Self-employment

Much of the literature on the informal self-employed sector in LDCs beginning with Harris and Todaro(1970) has seen self-employed workers unprotected by labor legislation as those rationed out of protected or "formal" salaried jobs sector jobs by above market clearing remuneration in the protected sector. Transitions should be largely unidirectional, from the informal and presumably very low capitalized micro-enterprises, to the formal sector except in the event of downturns in which case laid off workers will be thrown back on the informal safety net.

However, there is little reason to suppose that the expanding literature on self-employment in the industrialized world that views self-employment as a desirable and more flexible alternative to wage work may not also be relevant in LDCs. In particular, the debate over the dynamics underlying patterns of worker transitions into self-employment is likely to be relevant. Johnson (1978), Jovanovic (1979) and Miller(1984) argue that younger individuals are better able to bear the risk involved and hence should be heavily represented among entrants into self-employment. However, as Evans and Jovanovic note, this is inconsistent with Evans and Leighton's (1989) finding of the hazard into self-employment being constant in age which they attribute to liquidity constraints that dictate that workers require time to build up the capital needed to start a business.

We argue that this phenomenon may be exacerbated in the developing world where credit markets are poorly developed. The problem can be seen as a Stopped Markovian Decision Process (SMDP)[1] where workers, faced with uncertainty about future streams of income as salaried and self-employed workers must decide the optimal savings and switching strategies. Their behavior can be seen as similar to that of workers who, perhaps with the idea of opening a business upon their return, migrate to a country that offers the possibility of accumulating wealth more quickly, and return home only when they reach their target level of savings (See Piore 1979). This problem has been analyzed in detail by Berninghaus and Seifert-Vogt (1993) and we adapt their work to our problem as a way of generating predictions to be tested in the empirical work.

We assume the worker will open his own business at time τ and plans on operate it for T-τ years where T is the end of his planning horizon. He has subjective

[1] See Eckstein and Wolpin(1989) for a review of the specification and estimation of dynamic stochastic discrete choice models.

expectations π on the return to his invested accumulated real wealth x_τ in the business. Upon starting his business, the worker will choose a sequence of consumption bundles, c_t such as to maximize

$$\sum_{t=\tau}^{T} u(c_\tau)$$

s.t. $0<c_t<x_t$, $x_{t+1=}\ \pi(x_t - c_t)$, $t = \tau,\ldots,T$, where u(.) represent the continuous per period utility function. We abstract from the discount factor since it will be the same in both sectors and we assume it unchanged. This reduces to a standard dynamic programming problem where $V_\tau(x)$ is the value function at switch time τ, the maximal value of the sum of per period utility from being an entrepreneur from τ to T.

While in the salaried sector from $t = 1, \ldots, (\tau-1)$ the worker earns y_t where $\{Y_t\}_t$ is a stochastic process whose probability law is known to the worker. In each period, the worker chooses a consumption bundle c_t subject to the condition $c_t \leq (x_t + y_t)$. Any surplus can be saved at a real interest rate, i_{t+1}, which is the realized value of a stochastic process $\{I_t\}_t$ of real interest rates. In each period, the worker must decide whether to work in the salaried sector for another period, or start his business and receive $V_t(x_t)$.

The optimal policy for this problem is a sequence of consumption strategies (c(.) and the stopping (switching) time τ such that the total expected reward E

$$E_{(x_0, i_0, y_0)}\left(\sum_{t=0}^{\tau-1} u(c_t(.)) + V_\tau(x_\tau)\right)$$

is maximized given the initial state(x_0, i_0, y_0). The optimal stopping time is associated with each "state history" (x_t, i_t, y_t) and because these are realizations of a stochastic process, τ too, is a random variable.

From the framework, several predictions emerge. First, there exists a critical level of target savings below which the worker will prefer to continue to stay salaried. For the case of a two period model with logarithmic utility, Berninghaus and Seifert-Vogt show that the target level of savings falls with a rise in the subjective return to self-employment, π, rises with an increase in the opportunity cost of savings, i, and rises if a higher wage in the salaried sector raises the required comparable stream of income resulting from self-employment, and hence the start up capital required. The first two also have a predictable effect on the switch time, τ. In the last case, however, the overall impact of current income on τ is ambiguous since higher incomes both increase the level of target savings as well as increase the possible rate of savings accumulation. Given two workers with identical savings, the one with higher income may find himself below the target rate of income and stay one more period to earn another period wage.[2]

In sum, the probability of a move into self-employment at a particular moment:

$$\Pr(\text{move}) = P(\pi, i, y)$$

$$\frac{\partial P}{\partial \pi} \geq 0, \quad \frac{\partial P}{\partial i} \leq 0, \quad \frac{\partial P}{\partial y} = ?$$

It is worth comparing these predictions to those from the standard dualistic view where an above market clearing formal sector remuneration, y, rations workers into the informal sector where the returns fall to absorb those in the queue. A fall in relative

[2] By the same token, a worker who suddenly loses his job, y goes to 0, will suddenly see the target level of saving decline and is more likely to move. In this way, the common vision of the informal sector as the reserve army of the unemployed can be seen in somewhat different light.

returns of self-employment for salaried work occurs in the context of economic downturns where the informal return must fall to absorb displaced workers. Similarly, to the degree that increased interest rates are associated with recession and the loss of salaried jobs, again, we may expect more movement of the displaced into the informal sector: movement into self-employment would be counter-cyclical. In both cases, the predicted signs would be the opposite of those postulated by the model above.[3]

The next section offers a method for using logit methods in a rotating panel context to estimate the determinants of the worker's decision to move, and hence to test between these two views.

III. Logit Analysis in a Rotating Panel Context

Selection of Individuals

In the relatively common case that we address, individuals are selected according to a "rotating" scheme in the following manner. In period 1 of a total of T periods, the first sample is selected of N individuals who will remain in the sample for z periods : y_{11}, y_{21},…., y_{N1}. In the second period, the first m = N/z individuals are retired and the first place until the Nth place are occupied by the individuals who follow individual m: y_{12}, y_{22} ,….,y_{N2}. The process of retiring and replacing continues for each period t with a new sample: y_{1t}, y_{2t} ,….,y_{Nt}.

The combination of data obtained by this process is called a Rotating Panel and we

can considered it ordered as:

[3] See Maloney (1997) for a discussion of the relative merits of formal vs informal work and the procyclicality of the latter in Mexico.

$$
\begin{array}{llll}
y_{11}, y_{21}, .., y_{m1}, y_{(m+1)1}, \cdots & & \cdots y_{N1} & \\
& y_{12}, y_{22}, \cdots, y_{m2}, y_{(m+1)2}, \cdots & & \cdots, y_{N2} \\
& & y_{13}, \cdots\cdots, y_{m3}, \cdots & \cdots, y_{N3}
\end{array}
$$

In this manner, $H = (T\text{-}1)m + N$ individuals are partially observed across T periods. In our example, y represents whether the worker moves in that period (y=1) or stays in salaried employment (y=0).

It is useful to reframe the problem as a T X H fixed panel:

$$
\begin{array}{cccc}
\bar{y}_{11} & \bar{y}_{21} & \cdots\cdots & \bar{y}_{H1} \\
\bar{y}_{12} & \bar{y}_{22} & \cdots\cdots & \bar{y}_{H2} \\
\vdots & \vdots & & \vdots \\
\bar{y}_{1T} & \bar{y}_{2T} & \cdots\cdots & \bar{y}_{HT}
\end{array}
$$

where $\bar{y}_{jt}$ denotes the position of individual j in time t, whether there is an entry or not. For example: $\bar{y}_{12}\ \bar{y}_{22} \ldots\ \bar{y}_{m2}$ are positions that do not have entries.

<u>Observation:</u> Each position in the fixed panel corresponds to one in the rotating sample:

$$\bar{y}_{jt} = y_{j-(t-1)m\ t} \qquad (1)$$

However, an individual is included in the rotating sample, and has an entry in the fixed panel in time t only if:

$$1 \le j - (t-1)m \le N$$

In the analysis, we will only be concerned with individuals in the sample for a full z periods which can be shown to be the case for individuals entering the panel in **t** $\in$ **{1,2,…,T-z+1 }**. Several results pertaining to this group are described in appendix I.

Definition: For $\mathbf{t} \in \{\mathbf{1,2,\ldots,T\text{-}z+1}\}$, if individual j enters the sample of size N in period t, we define $\bar{Y}_{jt}'$ as a vector representing the sequence of the z consecutive entries.

$$\bar{Y}_{jt}' = (\bar{y}_{jt}, \bar{y}_{j(t+1)}, \ldots \bar{y}_{j(t+z-1)})$$

In the present application, this is the sequence of moves that individual j is observed to make across the z periods in the sample. In theory, there could be multiple moves or none.

<u>Probability Function</u>

We are interested in understanding what determines the timing of the individual's decision to change state. To be consistent with the theory above, we assume the individual moves only once into self-employment, and that the decision to move in each period is independent of the previous decisions. The vector

$$e'_k = (0, \ldots 1, 0 \ldots . 0) \in \mathbb{R}^z$$

position k

permits us to identify the period in which the individual changes state.

We define the probability that an individual j that has been k periods in the sample, changes its state in period t, and that it changes only once as:

$$p_{jt}(k) = p\left(\bar{Y}_{jt} = e_k \,\middle|\, \sum_{k=1}^{z} \bar{y}_{j(t+k-1)} = 1 \right) \quad k=1,2,3,\ldots,z$$

To calculate $p_{jt}(k)$, we first find an expression for :

$$p\left(\overline{Y}_{jt} = e_k\right) \qquad k = 1,2,...z$$

For example:

$$p(\overline{Y}_{jt} = e_1) = p(\overline{y}_{jt} = 1)p(\overline{y}_{jt+1} = 0)...p(\overline{y}_{jt+z-1} = 0)$$

We assume that the probability that an individual changes state follows a logit distribution, and this probability is a function of a set of the environment and individual's characteristics (X). This can be shown equal to:

$$= \frac{\exp[\beta X_{j-(t-1)m,t}]}{(1+\exp[\beta X_{j-(t-1)m,t}])} \frac{1}{(1+\exp[\beta X_{j-tm,t+1}])} \cdots \frac{1}{(1+\exp[\beta X_{j-(t+z-2)m,t+z-1}])}$$

$$= \frac{\exp[\beta X_{j-(t-1)m,t}]}{M_{jt}(\beta)}$$

where $M_{jt}(\beta)$ is the product of the denominators above. Generalizing, we obtain that the probability of changing states exactly once in the kth period of observation is:

$$P\left(\overline{Y}_{jt} = e_k\right) = \frac{\exp[\beta X_{j-(t+k-2)m,t+k-1}]}{M_{jt}(\beta)}$$

The probability of moving in the kth period of observation, given that the individual will move exactly once in one of the k periods is:

$$P_{jt}(k) = \frac{p\left(\overline{Y}_{jt} = e_k\right)}{p\left(\overline{Y}_{jt} = e_1\right) + p\left(\overline{Y}_{jt} = e_2\right) + ...+ p\left(\overline{Y}_{jt} = e_z\right)}$$

$$= \frac{\exp[\beta X_{j-(t+k-2)m,t+k-1}]}{\exp[\beta X_{j-(t-1)m,t}] + \exp[\beta X_{j-tm,t+1}]....+\exp[\beta X_{j-(t+z-2)m,t+z-1}]}$$

And finally, the conditional probability that individual j who enters in the sample of size N in period t and remains z periods counting from t and who changes state in exactly one of the z periods is:

$$p_{jt} = P_{jt}(1)^{\bar{y}_{jt}} P_{jt}(2)^{\bar{y}_{jt+1}} \ldots P_{jt}(z)^{\bar{y}_{jt+z-1}}$$

As $\bar{y}_{jt}$ takes a value of 0 or 1, and in our example there is uniquely one non-zero entry, this expression effectively selects which P_{jt} determines p_{jt}.

Likelihood Function

Before writing the likelihood function we establish some definitions to simplify the presentation.

Definition: Let M(K*J) be the set of the matrix of rank (K*J). If $1 \le u \le K$, we can define:

$$\pi_u : M(K*J) \to R^J$$
$$\pi_u(A) = \pi_u(\alpha_{kj})_{\substack{1\le k\le K \\ 1\le j\le J}} = (\alpha_{u1}, \alpha_{u2}, \ldots, \alpha_{uJ})$$

which states that π_u projects the row u of the matrix A. This ensures the condition that each individual moves only once or:

$$\pi_1 \bar{Y}_{jt} + \pi_2 \bar{Y}_{jt} + \ldots + \pi_z \bar{Y}_{jt} = 1$$

Definition: Let B_t = {j such that $\pi_1 \bar{Y}_{jt} + \pi_2 \bar{Y}_{jt} + \ldots + \pi_z \bar{Y}_{jt} = 1$}, that is the set of j where the individual moves only once.

Definition: Let B = {B_t such that $1 \le t \le T - z + 1$}, that is, the set of B_t such that the individual is in the sample for exactly five periods.

Definition: Let $\bar{X}_{jt}$ be the z*p matrix of independent explanatory variables for each individual (See appendix for more detail).

With these definitions, we can rewrite $P_{jt}(k)$ as:

$$P_{jt}(k) = \frac{1}{\sum_{l=1}^{z} \exp[(\pi_l - \pi_k)\overline{X}_{jt}\beta']} \qquad \forall \quad 1 \le k \le z$$

and finally :

$$p_{jt} = \prod_{k=1}^{z} P_{jt}(k)^{\pi_k \overline{Y}_{jt}}$$

Therefore the log of the likelihood function for all individuals in the panel through all periods will be:

$$\lambda = \sum_{t \in B} \sum_{j \in B_t} \ln p_{jt} = -\sum_{t \in B} \sum_{j \in B_t} \sum_{k=1}^{z} \pi_k \overline{Y}_{jt} \ln\left(\sum_{l=1}^{z} \exp([\pi_l - \pi_k]\overline{X}_{jt}\beta') \right)$$

Employing the Newton-Raphson algorithm, the first and second derivative of the likelihood function with respect to the parameters are calculated as:

$$\nabla\lambda(\beta) = -\sum_{t \in B} \sum_{j \in B_t} \sum_{k=1}^{z} \pi_k \overline{Y}_{jt} p_{jt} \left(\sum_{l=1}^{z} \{\exp([\pi_l - \pi_k]\overline{X}_{jt}\beta')\}[\pi_l - \pi_k]\overline{X}_{jt} \right)$$

$$\nabla^2\lambda(\beta) = -\sum_{t \in B} \sum_{j \in B_t} \sum_{k=1}^{z} \sum_{l=1}^{z} \sum_{r>l} \pi_k \overline{Y}_{jt} p_{jt}^2 \exp([\pi_r + \pi_l - 2\pi_k]\overline{X}_{jt}\beta') * [[\pi_l - \pi_r]\overline{X}_{jt}]'[[\pi_l - \pi_r]\overline{X}_{jt}]$$

which permits us to estimate β, and $V(\hat{\beta})$.

IV. Data:

The National Urban Employment Survey (NUES) conducts extensive quarterly household interviews in the major metropolitan areas and is available from 1987 to 1993. It is structured as a rotating panel where in each quarter, a fifth of the sample is dropped and replaced by individuals who will be interviewed for each of the next five quarters. In 24 overlapping panels spanning 1987-1993, individual workers can be followed as the move among sectors of work. Individuals are matched by position in an identified household, sex, level of education, and age to ensure against generating spurious transitions. The analysis restricts itself to men aged 16-65 with a high school education or less. It also focuses on formal salaried workers and the "informal" self-employed, including owners of firms under 16 employees who do not have social security or medical benefits and are therefore not protected.[4] Only those who begin in formal salaried employment and move only once over five quarters into self-employment are retained, yielding a sample of 1087 workers. In the estimations, we employ predicted earnings in each sector as a measure of the "own" and "alternate" earnings, given the standard human capital variables, experience, experience squared, education, education squared. The return to accumulated capital (the opportunity cost of using savings to open a business) is the real 30-60 day deposit rate as calculated from the International Financial Statistics of the IMF deflated by growth of the consumer price index. We also test state dependence through introducing the lag of the independent variables in the regressions.

V. Results:

Table 1 presents the results of the estimation of the model set out in section II.

Table 1: Results from Rotating Panel Logit Regression

	COEF.	S.E	COEF	S.E.
Wage (Salaried)	-.347	1.34	-.357	1.28
Wage (-1)	.132	1.41		
Earnings (Self)	4.02	.249	4.03	.235
Earnings (-1)	-.115	.354		
Interest Rate	-3.39 e-3	2.45 e-5	-2.71 e-3	1.92 e-5
Interest Rate(-1)	-2.68 e-3	1.93 e-5	-3.83 e-3	1.65 e-5

Nobs=1078, Sample includes 24 complete panels of 5 quarters each spanning 1987-1993

[4] It is often the case that the informal sector is defined as firms with five or less workers. As we are ocusing on informality defined as being unprotected by social security or other legislation, we loosen the size limit to the next category tabulated. In practice, the vast majority of firms are under 3 workers.

The results are supportive of the model. The first and second columns present the complete specification and show that for only the interest rate are lagged values significant. This suggests the absence of state dependence. The second specification presents only the significant coefficients. Here, self-employed earnings appear very strongly and of the correct sign reflecting that as opportunities improve in the informal sector, workers are more likely to open their own businesses. The current wage in the formal sector still enters ambiguously, again, as predicted, and is not significant. This is to be expected given that a rise both increases the attractiveness of formal sector employment, and raises the savings rate making a move into self-employment possible. Finally, the interest rate is strongly significant and of the predicted sign suggesting that a rise in the opportunity cost of the capital used for start up discourages opening up a business. In all cases, the sign is the opposite of that predicted by conventional dualistic views of informal self-employment.

Appendix II derives the cross section marginal effects and Table 2 calculates them for the regression above. In each panel of the table, k represents the period in which the individual moved and h the period corresponding to the variables observed. Of greatest importance, the diagonals of the tables are both relatively stable and of the sign found in table 1. Calculating the marginal effects has not reversed the effect as is sometimes found and the theoretical framework remains supported. The off-diagonal elements (symmetric) are less intuitive. In every case the impact of the variable one period forward or backward has the reverse impact of the contemporaneous effect.

Table 2: Cross Section Marginal Effects

Self-Employed Earnings

$dPjt(k)/dX^i_h$

k \ h	1	2	3	4
1	0.6978200	-0.1989130	-0.2283948	-0.2705122
2		0.6957832	-0.2274624	-0.2694078
3			0.7651952	-0.3093380
4				0.8492580

Formal Sector Wage

$dPjt(k)/dX^i_h$

k \ h	1	2	3	4
1	-0.0617104	0.0175905	0.0201977	0.0239222
2		-0.0615302	0.0201152	0.0238246
3			-0.0676686	0.0273557
4				-0.0751025

Interest Rate

$dPjt(k)/dX^i_h$

k \ h	1	2	3	4
1	-0.0004693	0.0001338	0.0001536	0.0001819
2		-0.0004680	0.0001530	0.0001812
3			-0.0005147	0.0002081
4				-0.0005712

Interest Rate Lagged

$dPjt(k)/dX^i_h$

k \ h	1	2	3	4
1	-0.0006628	0.0001889	0.0002169	0.0002569
2		-0.0006609	0.0002160	0.0002559
3			-0.0007268	0.0002938
4				-0.0008066

Table 3 derives the marginal effects over time, which are calculated by taking the difference between the maximum and the minimum value of each variable. As with the cross sectional marginal effects, the signs are those predicted and expected self-employed earnings is the most important variable to explaining the transitions change from formal to informal sector.

Table 3: Marginal Effects Over Time

	Variable Variation	Probability Variation
Formal Sector Wage	0,3654	-0,0315
Self-Employed Earnings	0,2411	0,2913
Interest Rate	57,83	-0,0377
Interest Rate Lagged	64,03	-0,0429

VI. Conclusion

The paper has derived a methodology for analyzing logit models in a rotating panel context. Using data from Mexico, it then applied the technique to test between two theories of why salaried workers enter the informal self-employed sector. The evidence supports a view that self–employment is a desirable destination, but one that in the presence of credit constraints requires accumulated capital before the business is opened, over the more traditional view of self-employment as a safety net for those losing preferred formal sector jobs.

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Appendix I

Theorem: Individual j enters the rotating sample of size N in period t only if:

$$(z-1)m+1 \leq j-(t-1)m \leq N \qquad (2)$$

Demonstration: The last m entries of the sample of size N=zm can be written as

$$\{ y_{(z-1)m+1,t}, y_{(z-1)m+2,t}, \ldots, y_{N,t} \}$$

For individual j to be one of these entries, condition (1) implies condition (2). If (2) holds we can also show that $\bar{y}_{jt}$ has an entry and that at time t, the individual has just entered the sample of size N.

Observation: Only for **t** $\in$ **{1,2,...,T-z+1 }** are the last m individuals entering the sample of size N observed for all z periods. There are

$$(T-z+1)(N-(z-1)m) = \frac{(T-z+1)N}{z} = (T-z+1)m$$

such individuals of the H total.

Corollary: For **t** $\in$ **{1,2,...,T-z+1 }** condition (2) is necessary and sufficient for individual j to be observed for z periods.

Appendix II

The sequence of decisions to stay or move for each individual is the vector

$$\bar{Y}_{jt} = [y_{j-(t-1)m,t}, y_{j-tm,t+1}, \ldots, y_{j-(t+z-2)m,t+z-1}]$$

and the set of variables that determine that choice:

$$\bar{X}_{jt} = \begin{bmatrix} X^1_{j-(t-1)m,t} & X^2_{j-(t-1)m,t} & \cdots & \cdots & X^P_{j-(t-1)m,t} \\ X^1_{j-tm,t+1} & & & & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & \\ X^1_{j-(t+z-2)m,t+z-1} & \cdots & \cdots & & X^P_{j-(t+z-2)m,t+z-1} \end{bmatrix}$$

We distinguish two types of marginal effect, across the individuals and across time.

Cross Section Marginal Effect

The cross section marginal effect measures the change in the probability of a move due to individual differences in the independent variables. For each individual we can write:

$$\frac{\partial p_{jt}}{\partial X^i} \equiv \left(\frac{\partial p_{jt}(k)}{\partial X^i_{j-(t-1)m,t}}, \frac{\partial p_{jt}(k)}{\partial X^i_{j-tm,t+1}}, \cdots, \frac{\partial p_{jt}(k)}{\partial X^i_{j-(t+z-2)m,t+z-1}} \right) \in \Re^5$$

or h = 1, 2, . . . , z

$$\frac{\partial p_{jt}(k)}{\partial X^i_{j-(t+h-2)m,t+h-1}} = \frac{\partial \frac{1}{s_{jt}(k)}}{\partial X^i_{j-(t+h-2)m,t+h-1}} = -\frac{1}{s^2_{jt}(k)} \frac{\partial s_{jt}(k)}{\partial X^i_{j-(t+h-2)m,t+h-1}}$$

$$= -\frac{1}{s^2_{jt}(k)} \frac{\partial \left[e^{-\beta[\pi_k X_{jt}]'} \sum_{r=1}^{z} e^{\beta[\pi_r X_{jt}]'} \right]}{\partial X^i_{j-(t+h-2)m,t+h-1}}$$

$$= -\frac{1}{s^2_{jt}(k)} \left[\left[\sum_{r=1}^{z} e^{\beta[\pi_r X_{jt}]'} \right] * \frac{\partial e^{-\beta[\pi_k X_{jt}]'}}{\partial X^i_{j-(t+h-2)m,t+h-1}} + e^{-\beta[\pi_k X_{jt}]'} * \sum_{r=1}^{z} \frac{\partial e^{\beta[\pi_k X_{jt}]'}}{\partial X^i_{j-(t+h-2)m,t+h-1}} \right]$$

$$= -\frac{1}{s^2_{jt}(k)} \left[\left[\sum_{r=1}^{z} e^{\beta[\pi_r X_{jt}]'} \right] * e^{-\beta[\pi_k X_{jt}]'} * \frac{\partial [-\beta \pi_k X_{jt}]'}{\partial X^i_{j-(t+h-2)m,t+h-1}} + e^{-\beta[\pi_k X_{jt}]'} * \sum_{r=1}^{z} e^{\beta[\pi_k X_{jt}]'} \frac{\partial [\beta \pi_k X_{jt}]'}{\partial X^i_{j-(t+h-2)m,t+h-1}} \right]$$

we know that:

$$\frac{\partial [\beta \pi_r X_{jt}]'}{\partial X^i_{j-(t+h-2)m,t+h-1}} = \frac{\partial \left[\beta_1 X^1_{j-(t+r-2)m,t+r-1} + \beta_2 X^2_{j-(t+r-2)m,t+r-1} + \cdots + \beta_P X^P_{j-(t+r-2)m,t+r-1} \right]'}{\partial X^i_{j-(t+h-2)m,t+h-1}}$$

$$= \begin{Bmatrix} \beta_i & \forall r = h \\ 0 & \forall r \neq h \end{Bmatrix} = \beta_i \delta_{rh}$$

where: $\delta_{rh} = \begin{cases} 1 & \forall r = h \\ 0 & \forall r \neq h \end{cases}$

therefore

$$\frac{\partial p_{jt}(k)}{\partial X^i_{j-(t+h-2)m,t+h-1}} = -\frac{1}{s^2_{jt}(k)} \left[e^{-\beta[\pi_k X_{jt}]'} * [-\beta_i \delta_{kh}] \left[\sum_{r=1}^{z} e^{\beta[\pi_r X_{jt}]'} \right] + e^{-\beta[\pi_k X_{jt}]'} * [\beta_i \delta_{rh}] \left[\sum_{r=1}^{z} e^{\beta[\pi_r X_{jt}]'} \right] \right]$$

$$= -p^2_{jt}(k) \sum_{r=1}^{z} \beta_i (\delta_{rh} - \delta_{kh}) e^{\beta[(\pi_r - \pi_k) X_{jt}]'}$$

<u>Marginal Effect Over Time (MEOT)</u>

The marginal effect over time measures the change in the probability of a move with diffferent levels in an independent variable. Given that we work in discrete time, for each individual we can write:

Marginal Effect Over Time $= \left(p_{jt}(k+1) - p_{jt}(k) \middle| X^i_{j(k+1)} \neq X^i_{jk} \right), \quad \forall k = 1,2,\cdots,z-1$

We have that:

$$p_{jt}(k+1) = \frac{e^{\beta[\pi_{k+1} \bar{X}_{jt}]'}}{\sum_{h=1}^{z} e^{\beta[\pi_h \bar{X}_{jt}]'}}, \quad and \quad p_{jt}(k) = \frac{e^{\beta[\pi_k \bar{X}_{jt}]'}}{\sum_{h=1}^{z} e^{\beta[\pi_h \bar{X}_{jt}]'}}$$

Therefore:

$$\text{MEOT} = \frac{\left[e^{\beta_i X^i_{j-(t+k-1)m,t+k}} - e^{\beta_i X^i_{j-(t+k-2)m,t+k-1}} \right] \left[e^{\sum_{r \neq i, r=1}^{p} \beta_r X^r_{j-(t+k-2)m,t+k-1}} \right]}{\sum_{h=1}^{z} e^{\beta[\pi_h \bar{X}_{jt}]'}}$$

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