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Labour and Capital Adjustment Dynamics Using Bivariate Random Probit

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Abstract

This paper provides empirical evidence on the interrelationship between employment and capital adjustment decisions using a sample of Italian firms during the period 1989-1997. A dynamic bivariate probit model is estimated using a short-cut in the spirit of Heckman estimator. Unobserved heterogeneity and state dependence is found to play an important role for both hiring and investment equations. The estimates of the state dependence are significant and positive for both capital and labour implying that the convex components of adjustment costs are important for the adjustment process of capital and labour. The significant positive correlation between random effects and errors is a strong evidence of the simultaneous interrelationship between factor demand adjustment processes. A positive relation is found only between the occurrence of hiring spikes in one year and the investment spikes in the next year (and not vice-versa) which can be due to the fact that firms need anticipation of skilled labour and training in order to appropriately challenge investment strategies.

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Introduction

The economic literature on adjustment processes of the most important determinants of production function supports the existence of lumpiness at micro level. Firms are inclined to adjust their factor demand at infrequent steps. Several studies provide empirical evidence with respect to the reluctance of firms to adjust their stock of capital due to uncertainty and irreversibility conditions.[3] Their reluctance lasts until the deviation of the actual capital stock from its optimal value reaches a certain threshold. Such a threshold is imposed by the demand and the degree of irreversibility and uncertainty. Hamermesh and Pfann (1996) provide a rich summary with reference to adjustment costs in factor demand introducing all functional forms these costs are supposed to take and draw the conclusion that factor demand adjustment at firm level is slow and not characterized by symmetric quadratic costs. Doms and Dunne (1998), Cooper and al. (1999), Nilsen and Schiantarelli (2003) and Letterie and Pfann (2002) show evidences that investment process is nonconvex and irreversible at firm level probably due to the presence of the fixed component in the adjustment cost function.[4] Thus, firms do not invest smoothly, but wait until sufficiently big changes are needed to make capital adjustment profitable. [5]

The literature of labor markets recognizes the sluggish behaviour of adjustment process also under the traditional justification of adjustment costs.[6] Davis and Haltiwanger (1992), Caballero et al. (1995, 1997), Rota (2004) report large employment changes at the plant level whose behaviour could be undoubtedly depicted by a model of adjustment which includes non-convexities and non-differentiability in the adjustment costs function, or simply a fixed cost component. Hamermesh (1989) depicts a model of labour dynamics where firms decide either to not change the employment level or to adjust it completely to the static level derived by the profit optimization firm problem in the presence of fixed adjustment costs. Thus, the overall literature of factor adjustments costs is in favour of the importance of fixed component in the adjustment cost function as a considerable reason of the lumpy behaviour of these factor demands and consent to use a "spike" definition to capture large adjustment episodes of capital and labour.

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[3] See Ricardo Caballero (1999) for an overview of this topic.

[4] See also Goolsbee and Gross (1997), Barnet and Sakellaris (1998) and Abel and Eberly (1999) for further evidences on the importance of lumpiness and irreversibility in capital adjustments process.

[5] See Dixit and Pyndick (1994).

[6] See also Alonso-Borrego (1998), Hamermesh (1989, 1993), Hamermesh and Pfann (1996), Bentolila and Saint-Paul (1994), Abowd and Kramarz (2003), Cambell and Fisher (2000a) and Pfann and Palm (2003).

The above empirical works have been performed based on models with a single quasi fixed input factor (either investment or employment). It seems that all investment (labour) studies have been done at expense of labour (investment). So, in one-factor adjustment models, the other factor is considered as fully flexible (either there are no labour costs or the stock of capital is exogenous). However, intuition suggests that the adjustment process of one factor should be dependent on the other's process. The cross-dependence of investment and employment is known in the economic literature as interrelation. Nadiri and Rosen (1969, 1973) constructed the first model of interrelation where the firm controls the investment, labour and utilization rates of both inputs. Each variable is assumed to be endogenous and all variables are directly or indirectly interrelated through the production function. They find significant cross-dependence among employment and investment. Shapiro (1986) estimates a model of the dynamically interrelated demand for capital and labour where the use of the first-order conditions allows a random rate of return and a flexible specification of the technology. He concludes that as adjustment is estimated to be rapid, there is, contrary to the standard view, scope for factor-prices to affect investment at relatively high frequencies. Abel and Eberly (1994, 1998, 2002) show that when employment decision depends on capital stock, employment may perform in the same lumpy way as investment.[7] Sakellaris (2004) using a sample of US firms, find that firms tend to hire more employees before an investment spike and at the time the spike is generated. Letterie et al. (2001) found that in periods of major capital adjustments and immediately after or just before such episodes, firms increase their labour force while Polder and Verick (2004) don't find any evidence that labour market regulations in Netherlands and Germany affect the dynamics of capital adjustment.

In this paper, we use several dynamic bivariate probit models in order to analyze the dynamics of the interrelationship between labour and capital adjustment processes. There are few studies where this econometric approach is employed and this is mainly because of the lack of the existing statistical routines. Instead, we use a short-cut in the spirit of Heckman estimator and allow for interactions between these events in a dynamic dimension. While the univariate dynamic random probit allows to single out the state dependence from the unobserved heterogeneity, in addition, the bivariate dynamic probit count for the correlation between the unobserved heterogeneity and error terms across the equations of labour and capital adjustment. To get out of the complexity of these integration computations, we use a standard trick of fitting the bivariate dynamic probit model by the

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[7] The fact that labour hoarding can arise without direct costs of adjusting employment casts doubts on any attempt to measure the costs of employment adjustment simply by focusing on the behaviour of employment without looking at other factors of production.

GLLAMM routines for univariate multilevel model. Differently saying, the bivariate random probit is expressed as a univariate three-level model.

The data used in this paper are extracted from PANEL97, waves 1989-1997 which is a panel of Italian firms.

The aim of this paper is twofold: first to contribute to the literature built on the dynamics of factor demands based on a discrete process, secondly to show simple econometric approaches which consent us to get out of the complexity of bivariate dynamic probit models. In this view, we address several questions: Do firms adjust simultaneously labour and capital? If yes, is this correlation due to the cross-effects between factor adjustments or is it biased? Is the state dependence important? Do firm characteristic determine labour and capital adjustment?

This paper is organized as follows. Section II sheds light on the descriptive statistics of employment adjustment and investment spikes. In the Section III a bivariate dynamic probit is presented. Section IV contains estimate results and comments. Section V concludes accordingly.

II. Descriptive Statistics

The data set used in this study is extracted from a large dataset (PANEL97) of Italian firms constructed by CERIS-CNR using data published by Mediobanca, a large investment bank (annual directory "Le Principali Societa"). It provides firm-level information with respect to firms' primary industry, ultimate ownership, group affiliation, location, foundation year, Istat group, business activity and sector data for the firm's primary industry (e.g. production and price indexes, turnover etc.). Also it sheds light on the main firm's activity variables as employment, labour costs, sales, value added, fixed investment, stock of capital at replacement cost.[8], [9], [10] These data are provided on an annual basis and therefore probably this time aggregation could disguise other forms of employment and capital adjustment which could be frequent for quarterly data. All variables are deflated by producer price.

To establish whether firms perform large investment during a certain year, several spike definitions can be used even if several empirical results have demonstrated that the interrelation behaviour does not change on the spike definition. However we have used the

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[8] Labour costs are calculated as the sum of nominal wages and firing costs and consequently I cannot spell out them separately.

[9] Appendix 1 shows how missing values of stock of capital and investment are constructed.

[10] This variable has been computed using perpetual inventory technique.

same definition as in Power (1998) which is supposed to make a robust estimation of spikes: the combined investment spike. This spike occurs when the investment rate behaves either as absolute or as relative spike. Power (1998) used the definition of relative investment spike to denote the investment rate observations which exceed 1.75 times the median of investment rates. Following Cooper et al. (1999) an observation is called an absolute investment spike if the investment rate exceeds 20 percent.[11] On the other hand, to check for employment spikes, Sakellaris (2001) define an observation as a positive employment spike if the current adjustment rate of employment exceeds 10 percent and the past rate does not exceed 10 percent, and as negative employment spike if it is less –10 percent at the current period and more than –10 percent at the precedent period.[12] [13][14] The definition used in this paper is based on the combined spikes, thus observations with investment (employment growth) rates bigger than the absolute threshold (0.2 for employment and 0.09 for investment) or the 1.75 time the median of the investment (employment growth) rates.

Figures 1 and 2 show the density functions of employment growth and investment rates. It is obvious that the employment growth rates are more normally distributed than the investment rates around zero. Moreover, the distribution of investment rates exhibits a considerable kurtosis, being peaked in the centre and with fat tails. Also it exhibits some skewness which is justifiable by the relative small number of observations of disinvestments. With respect to the employment growth rates, the kurtosis is still crucial (many observations with very low employment changes) but the skewness is less pronounced than for investment rates. However, the employment growth rates density exhibits some skewness towards the negative side as there are much more values of negative rates.

Looking at the data, there are 22 percent of observations with investment spikes (for the US data used by Cooper and Haltiwanger (2003), there are almost 18 percent of observations denoting investment rates higher than 0.2) where there are 9 percent of the observations generated as positive employment spikes. With respect to the negative employment spikes, there are 14 percent negative employment spikes.

The figure 3 shows the persistence of employment and investment spikes over 5 periods. The number 1, 2, 3, 4 and 5 in the X-Axes signify respectively the percentage of subsequent spikes in five, four, three, two and one periods (points 5, 4, 3, 2, 1 show the percentage of spikes performed in 1 year, 2 up to 5 subsequent years). It is obvious that

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[11] See Cooper et al. (1999).

[12] Letterie and Pfann (2001) use a switching regime to estimate the probabilities that an observation belongs to a high or low regime. When it is higher than 0.5, they say that, firms have done a switching investment spike.

[13] A positive employment spike corresponds to the hiring process. A negative employment spike corresponds to the firing process.

[14] See Laura Power (1998).

investment spike graph is much smoother than hiring and firing graphs implying that a huge investment process takes place in more than one period, while a huge employment adjustment process is lumpier. This implies that convex components besides fixed component are encompassed in the adjustment cost of capital. Also it shows that it is costly to adjust capital within one year. On the other hand this implication is a little imprudent as spikes occurring in several consecutive years would stand for a multi-year spike. With respect to employment spikes, negative employment adjustment (employment reduction) occurs in a smoother way than positive employment adjustment (employment expansion). This loosely implies that firing process takes more time than hiring process.

Table 1 shows the frequencies of observations of some possible combination between the past, current and future investment spikes and the positive and negative employment spikes. With respect to the simultaneous combinations, the observations with neither investment nor positive employment spikes are most frequent (73.55%). The observations with only investment spikes (no positive or employment spikes) come next (17.32%) followed by the observations with only positive employment spikes (5.34). The observations with both investment and positive employment spikes are less observed (3.79%). The same hierarchy of frequencies can be noticed when the frequencies of the employment spikes with the past and future investment spikes are taken into consideration, with a slight decrease of the highest frequencies and a slight increase of the second ranked frequencies. The other spike definitions show the same picture.

As it is noticeable from the Table 1, there are more observations when firms adjust only one factor than when adjust both factors. It seems that these summary statistics are at odds with the conclusion of a theoretical study performed by Dixit (1997) at the firm level. He considers a model with separate linear cost of adjustment and concludes that episodes where firms adjust the less flexible factor will be much rarer than those where they change the two factors together. On the other hand, the observations of factor adjustment in my study are based on the assumption that the fixed cost component is a driving component in the composition of the adjustment costs. The assumption of linear adjustment costs allows Dixit to pass the homogeneity, concavity and supermodularity features from the production function F(A,K,L) on the Bellman function V(A,K,L) and therefore to derive the slopes of the inaction range of factor demands. Nevertheless, these nice features do not hold when the fixed component of adjustment costs (as such is my case) is taken into consideration rendering impossible accordingly the Dixit conclusions. On the other hand, he says: “But we can make some general inferences. An increase in the costs of increasing or decreasing one factor, other things equal, will contribute to making that factor the less flexible one. If the crucial dividing line is crossed, the qualitative nature of the firms' policies changes. From a policy where labor is adjusted only at two isolated points, the optimal policy becomes the other way round." Thus, the summary statistics of factor demands spikes derived in this paper actually are not at odds with Dixit conclusion. They can simply justify a shift in the flexibility status whenever that government reforms make easier to hire or fire workers or to facilitate the investment procedures.

All these statistics show that, if the "spikes" definitions fit quite well the adjustment in factor demands, then there is a certain relationship (not random at all) between the adjustment episodes in employment and capital demands. Moreover, these simple statistics illustrate that this relationship between factor demand spikes would hold even when these spikes are not contemporaneous. This suggests that the past and the future decisions of the firms with respect to the labour and capital adjustment are highly correlated with the current decisions.

IV. Econometric Model

The summary statistics simply demonstrate that firms do not adjust randomly their factor demand. In fact, they behave under a set of strategies which include several combinations in the employment and capital adjustment. In this section I use a shortcut to implement a dynamic bivariate probit estimator in order to statistically support the existence of any interrelationship event between employment and capital adjustment over time. The model is based on the studies presented in Alessie et. al (2005) and Stewart (2007) where random effects of two endogenous variables (here, employment and investment spikes) are allowed to be correlated.

Let $y_{1it} = 1$ if the firm *i* performs a hiring spike at period t and $y_{1it} = 0$ otherwise. Let $y_{2it} = 1$ if the firm *i* performs an investment spike at period t and $y_{2it} = 0$ otherwise. The model can be written as:

$$(1)\quad \begin{cases} y^*_{1it} = x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1} + \alpha_{1i} + \varepsilon_{1it} \\ y^*_{2it} = x'_{2it}\beta_2 + \gamma_{21}y_{1it-1} + \gamma_{22}y_{2it-1} + \alpha_{2i} + \varepsilon_{2it} \end{cases}$$

$$y_{1it} = \begin{cases} 1 \text{ if } y^*_{1it} > 0 \\ 0 \text{ otherwise} \end{cases} \qquad y_{2it} = \begin{cases} 1 \text{ if } y^*_{2it} > 0 \\ 0 \text{ otherwise} \end{cases}, \quad \text{i=1:N, t=1:T}$$

where

- the random firm effects $(\alpha_{1i}, \alpha_{2i})$ are assumed to follow a bivariate normal distribution with respective variances $\sigma^2_{\alpha 1}$ and $\sigma^2_{\alpha 2}$ and correlation ρ_α,

- the error terms $(\varepsilon_{1it}, \varepsilon_{2it})$ are assumed independent over time and follow a bivariate standard normal distribution with correlation ρ,

- x_{it} is a vector of independent variables used in both equations and assumed as strictly exogenous.

If $\gamma_{12} = 0$, the hiring equation does not include the lagged dummy of investment equation and its other parameters can be estimated consistently separately from the other equation as s standard univariate panel data probit with state dependence (its own lagged value) and unobserved heterogeneity (the random effects). The same logics holds also if $\gamma_{22} = 0$. If $y_{2it-1} \neq 0$ but error terms and random effects of the first equation are independent of error terms and random effects of the second equation, then y_{2it-1} is weakly exogenous in the hiring equation. Heckman (1981) proposed to estimate the above univariate model by specifying a reduced form equation for the first period.

In order to estimate this bivariate dynamic random probit by counting for unobserved heterogeneity, state dependence and correlated errors I use a shortcut in the spirit of Heckman estimator. Before describing the method used in this paper, a description of the Heckman's estimation of a dynamic random effects probit must be given.

Heckman estimator

To tackle the initial condition problem, Heckman (1981b) suggested the specification of reduced form equation for the initial period. According to that, the set of equations (1), for the period t=1, can be expressed as:

$$(2) \quad \begin{cases} y^*_{1i1} = z'_{i1}\lambda_1 + \zeta_{1i} \\ y^*_{1i2} = z'_{i2}\lambda_2 + \zeta_{2i} \end{cases}$$

Where (z'_{i1}, z'_{i2}) include x and exogenous instruments and (ζ_{1i}, ζ_{2i}) are respectively correlated with $(\alpha_{1i}, \alpha_{2i})$ but uncorrelated with $(\varepsilon_{1it}, \varepsilon_{2it})$ for $t \geq 2$. Then, assuming that the error terms in the initial period satisfy the same distributional assumptions as in the other periods, using an orthogonal projection we can write:

$$(3)\quad \begin{cases} \zeta_{1i} = \theta_1 \alpha_{1i} + \varepsilon_{1i1} \\ \zeta_{2i} = \theta_2 \alpha_{2i} + \varepsilon_{2i1} \end{cases}$$

Then, the reduced form for the initial period is then given as follows:

$$(4)\quad \begin{cases} y^*_{1i1} = z'_{1i}\lambda_1 + \theta_1 \alpha_{1i} + \varepsilon_{1i1} \\ y^*_{2i1} = z'_{2i}\lambda_2 + \theta_2 \alpha_{2i} + \varepsilon_{2i1} \end{cases}$$

The likelihood function for the complete model is then:

$$(5)\quad \begin{cases} L_{1it} = \int (\Phi[(z'_{i1}\lambda_1 + \theta_1\alpha_{1i})(2y_{1i1} - 1)]\prod_{t=2}^{T_i} \Phi[(x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1} + \alpha_{1i})(2y_{1it} - 1)]g(\alpha_{1i})d\alpha_{1i} \\ L_{2it} = \int (\Phi[(z'_{i1}\lambda_2 + \theta_1\alpha_{2i})(2y_{2i1} - 1)]\prod_{t=2}^{T_i} \Phi[(x'_{1it}\beta_2 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1} + \alpha_{2i})(2y_{2it} - 1)]f(\alpha_{2i})d\alpha_{2i} \end{cases}$$

Where $g(\alpha_{1i})$ and $f(\alpha_{2i})$ are the probability density functions of the $(\alpha_{1i}, \alpha_{2i})$ which in turn are taken as normally distributed and the above integrals can be evaluated using Gaussian-Hermite quadrature (Butler and Moffit, 1982).

A Shortcut for Bivariate Dynamic Random Probit

Integrating out the random effect is computationally difficult if we consider the dimensionality and the order of integrals in a bivariate random probit model. A simple way to get out of the complexity of these integration computations is using an estimation procedure of fitting the bivariate random probit model by the GLLAMM routines for univariate multilevel model.[15] In other words, a bivariate random probit can be considered as a univariate two-level model where the first level is set up by the two main dependent variables (hiring and investment spikes) and the second level comprise the observations of the first period and those of the other periods for each dependant variable.

This procedure is based in the construction of two dummy variables, d_{1it} and d_{2it} which take value 1 if the observations belong to the first period and zero otherwise,

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[15] See Grilli and Rampachini (2002).

respectively for the hiring and investment equation. Using these dummies the equations 1 and 2 can be expressed as:

$$(6)\quad \begin{cases} y^*_{1it} = d_{1it}(z'_{i1}\lambda_1 + \theta_1\alpha_{1i} + \varepsilon_{1i1}) + (1-d_{1it})(x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1} + \alpha_{1i} + \varepsilon_{1it}) \\ y^*_{2it} = d_{2it}(z'_{21}\lambda_2 + \theta_2\alpha_{2i} + \varepsilon_{2i1}) + (1-d_{2it})(x'_{2it}\beta_2 + \gamma_{21}y_{1it-1} + \gamma_{22}y_{2it-1} + \alpha_{2i} + \varepsilon_{2it}) \end{cases}$$

And then re-written as:

$$(7)\quad \begin{cases} y^*_{1it} = [1 + d_{1it}(\theta_1 - 1)]\alpha_{1i} + d_{1it}z'_{i1}\gamma_1 + (1-d_{1it})(x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1}) + \varepsilon_{1it} \\ y^*_{2it} = [1 + d_{2it}(\theta_2 - 1)]\alpha_{2i} + d_{2it}z'_{i2}\gamma_2 + (1-d_{2it})(x'_{2it}\beta_2 + \gamma_{21}y_{1it-1} + \gamma_{22}y_{2it-1}) + \varepsilon_{2it} \end{cases}$$

Each of these equations can be considered as standard random effect specification with a heteroscedastic factor loading θ_1 (in case of labour equation) and θ_2 (in case of investment equation) for the random effects in the first period and a loading fixed to one on the other periods. The conditional polichoric correlation is $\rho_\alpha = \dfrac{\sigma_{\alpha_1\alpha_2}}{\sqrt{\sigma^2_{\alpha_1} * \sigma^2_{\alpha_2}}}$.

Let's rewrite this set of equations in a simple way:

$$(9)\quad \begin{cases} y^*_{1it} = \Pi_{1it}\alpha_{1i} + \Phi_{1it} + \varepsilon_{1it} \\ y^*_{2it} = \Pi_{2it}\alpha_{2i} + \Phi_{2it} + \varepsilon_{2it} \end{cases}$$

$$\text{Where}\quad (10)\quad \begin{cases} \Pi_{1it} = 1 + d_{1it}(\theta_1 - 1) \\ \Pi_{2it} = 1 + d_{2it}(\theta_2 - 1) \\ \Phi_{1it} = d_{1it}z'_{i1}\gamma_1 + (1-d_{1it})(x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1}) \\ \Phi_{2it} = d_{2it}z'_{i2}\gamma_1 + (1-d_{2it})(x'_{1it}\beta_1 + \gamma_{11}y_{1it-1} + \gamma_{12}y_{2it-1}) \end{cases}$$

If we define a new dummy variable D_{it} such that it takes value one for the investment equation and zero for the hiring equation, the equations can be written as a single equation:

$$(11)\quad y^*_{jit} = D_{it}y^*_{1it} + (1-D_{it})y^*_{2it} \quad \text{where } j = 1,2$$

If we further decompose the error terms in the following way:

$$(12)\quad \begin{cases} \varepsilon_{1it} = u_{it} + e_{1it} \\ \varepsilon_{2it} = \lambda u_{it} + e_{2it} \end{cases}$$

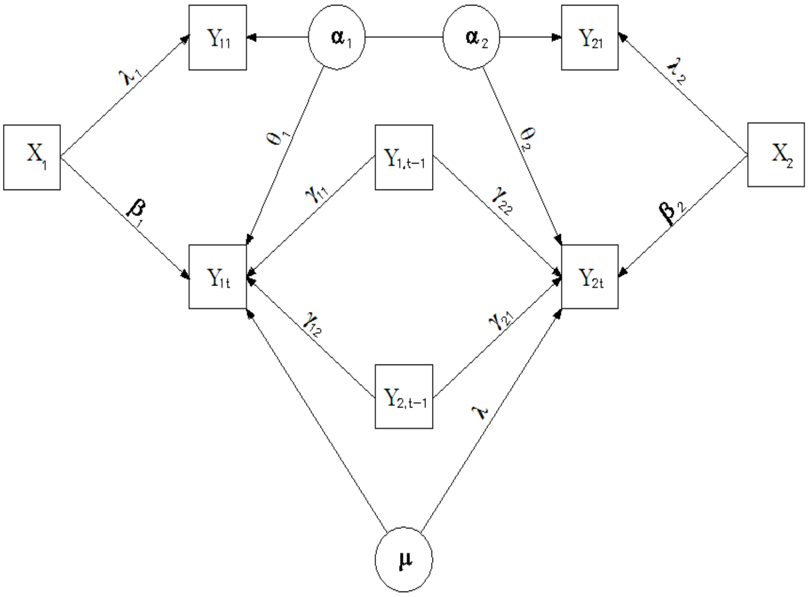
Where e_{1it}, e_{2it} are i.i.d normally distributed with zero mean and variance one the equation (8) can be written as:

$$(13)\quad y^*_{jit} = D_{it}(\Pi_{1it}\alpha_{1i} + \Phi_{1it} + e_{1it}) + (1 - D_{it})(\Pi_{it2}\alpha_{2i} + \Phi_{2it} + e_{2it}) + D_{it}\mu_{it} + (1 - D_{it})\lambda\mu_{it})$$

$$(14)\quad y^*_{jit} = D_{it}\Pi_{1it}\alpha_{1i} + (1 - D_{it})\Pi_{2it}\alpha_{2i} + D_{it}(\Phi_{1it} + e_{1it}) + (1 - D_{it})(\Phi_{2it} + e_{2it}) + [1 + D_{it}(1 - \lambda)\mu_{it}]$$

The last equation (14) is described in the following scheme where the random effects are put into circles and the observed variables into boxes.

Figure 1: Path diagram of DBP



Comprising the set of equation (6) into a single equation (11) helps to fit the bivariate dynamic probit into the GLLAMM framework. In this way, this final single equation can be considered as a standard random-effect specification with heteroscedastic factor loading θ_1 and θ_2 in period $t = 1$ respectively for the hiring and investment equation and another heteroscedastic factor loading λ for the investment equation. If we allow the random effect in both equations to be correlated, the correlation between random effects can be estimated simulatenously with the variances of the random effects. The correlation between the error terms is given as: $\rho = \frac{\lambda}{\sqrt{2(\lambda^2+1)}}$.

I use the Stata program GLLAMM which is based on maximum likelihood method where the unobserved terms are integrated out.[16] For that reason, either Gauss-Hermitte quadrature or adaptive quadrature can be used such that adaptive quadrature modifies the locations and weights of the Gauss-Hermite quadrature points by using the posterior distribution of the unobserved heterogeneity terms. In this paper, I have used only adaptive quadrature as they help to get more precise estimations than the Gauss-Hermite. Despite this accurate method, GLLAMM doesn't offer itself friendly to the researchers as it is a program where data must be arranged properly and preparing them under correct syntax is not easy.

V. Estimation Results

In this section, we show the results obtained by 3 specifications of bivariate dynamic probit: 1) DPB with correlated random effects and errors, 2) DPB with only correlated errors, 3) DPB with only correlated random effects. In addition, alternative estimators such as univariate random effect probit, bivariate probit and pooled probit are presented. The same explanatory variables are used for both hiring and investment equations save the exclusion restriction variables.

Table 2 gives the results for the first specification, DPB with correlated random effects and errors. The estimated standard deviations of the random effects are 1.26 and 1.02 respectively for hiring and investment spikes. This shows that unobserved heterogeneity explains more than half of the unsystematic variation and need to be considered in the model. According to the specification II, when we let only the correlated random effects be correlated, the estimated standard deviations of the random terms are 1.14 and 1.02. When only the errors are allowed to be correlated as in the specification III, the standard deviations of random terms are 1.35 and 1.02. The standard deviation presents a higher variation across specification in the hiring equation while in the investment equation almost doesn't change.

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[16] See GLLAMM Manual, Arulampalam & Stewart (2007)

The estimated correlation between random terms is significantly positive and ranges from 0.52 in the specification I to 0.534 in the specification II. On the other hand, if we consider the estimated correlation between the errors, it ranges from 0.26 in the specification I to 0.31 in the specification III. The correlation coefficient between random terms and errors is constrained to 0 respectively for the specification III and II. The significant positive correlation between random terms indicates that firms with strong preferences to incur hiring spikes are the same as those who incur investment spikes. This is a robust evidence of simultaneous interrelationship between hiring and investment spikes which is caused to a great extent by the positive correlation in unobserved heterogeneity rather than the positive correlation between errors terms.

The estimates of lagged dependent variables seem to be significantly positive either in hiring or investment equation, supporting in this way the hypothesis of state dependence.[17] This can be explained by the presence of adjustment costs and especially the convex components which is encompassed in the adjustment cost function of capital and labour. In other words, it shows that it is costly to adjust capital or labour within one year. However, both the size and the statistical significance of state dependence are higher in the investment equation than in the hiring equation and this means that firms find more difficult to adjust capital than labour for this sample of Italian firms.

As regards the dynamics of each of the factor adjustment processes, only the cross-effect of lagged hiring spike on the investment spike is significantly positive while the other one (the cross-effect of lagged investment spike on the hiring spike) is insignificant across all specifications. Ceteris paribus, this means that firms who perform an investment spike are more likely to have performed a hiring spike in the previous period than those who don't perform.

The fact that firms prefer to anticipate the investment spikes by hiring substantially employees one year before can be grounded on the human capital theory. According to this theory, firms possess a plant-specific asset that allows them to use a higher technology level than the others. [18] In turn, this higher technology level will require more skilled labor and therefore it is worthwhile to provide training for workers in order to develop their human capital and use it efficiently in their organizational structure. Therefore, firms tend to plan carefully their investment decisions and hiring (expansion) strategies on a longer term period. Also it may indicate that these firms have superior management expertise that allows

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[17] Sakellaris (2001), Letterie and Pfann (2001) demonstrate the same relationship.

[18] See Parsons (1986), Gorg & Strobl (2003) and Hymer (1976).

them to predict market fluctuations and plans the expansion and investment strategies in advance.

Comparing the dynamic bivariate probit with simple models such as pooled probit and bivariate probit, the estimate of lagged dependent hiring spike in the hiring equation is much lower (0.19 compared to 0.37) while the estimated lagged investment spike in the investment equation doesn't vary as much (0.36 compared to 0.39). As regards the cross-effects of one factor to the other, the effect of hiring at time t on the event of incurring an investment spike at time t+1 varies also across different model specifications (the estimate varies from 0.30 for specification I to 0.33 for pooled and bivariate probit). Thus, if we don't allow for correlation between unobserved heterogeneity, the estimates of either cross-effects may be upwardly biased and lead to erroneous implications and conclusions as regards the importance of state dependence and cross-effects in the hiring and investment spikes. On the other hand, allowing only for correlation between errors, the state dependence of hiring is downwardly biased while the state dependence of investment doesn't vary.

In addition, even if the purpose of this paper is simply to show evidence of interrelationship between factors demand dynamics, in this section we add some comments on other explanatory variables. Firms who don't invest in R&D are more likely to incur hiring spikes compared to others who don't invest and firms who don't have a public ownership are more inclined to hire than those who operate under a public ownership. As regards the investment equation, most of the estimates on the firm characteristics are not statistically significant. Estimates of size and age have both positive sign but without a statistical significance.

Table 2: Dynamic Bivariate Probit

	I -Correlated random effects and errors				**II-Only correlated random effects**				**III-Only correlated errors**			
	Hiring		**Investment**		**Hiring**		**Investment**		**Hiring**		**Investment**	
Variables	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Hiring(t-1)	0.1961	0.0996	0.3004	0.0947	0.2148	0.1091	0.2971	0.0949	0.1683	0.0984	0.3170	0.0941
Spike(t-1)	-0.0279	0.0765	0.3590	0.0676	-0.0386	0.0852	0.3557	0.0676	0.0058	0.0740	0.3550	0.0676
Year	-0.0075	0.0176	-0.0844	0.0134	0.0195	-0.3700	-0.0842	0.0134	0.0171	-0.4100	0.0134	-6.2700
Constant	-1.5574	0.3898	-0.6949	0.2022	-1.6978	0.4160	-0.6982	0.2021	-1.4975	0.3853	-0.7079	0.2017
Labour cost	-0.0031	0.0009			-0.0035	0.0011			-0.0031	0.0009		
Sales	0.0092	0.0071	0.0042	0.0035	0.0093	0.0080	0.0043	0.0035	0.0085	0.0069	0.0043	0.0035
Age												
Age<11	0.0301	0.1510	0.1397	0.1374	0.0392	0.1677	0.1380	0.1377	0.0413	0.1467	0.1445	0.1371
10<Age<26	0.1315	0.0932	0.0322	0.0854	0.1531	0.1037	0.0346	0.0856	0.1362	0.0906	0.0294	0.0852
25<Age<51	0.0749	0.0877	0.0905	0.0793	0.0910	0.0976	0.0898	0.0795	0.0959	0.0852	0.0870	0.0792
Ownership												
Small national	0.7764	0.3931	0.0415	0.2274	0.8489	0.4257	0.0511	0.2271	0.6877	0.3850	0.0472	0.2269
Medium national	0.7972	0.3912	0.0760	0.2352	0.8463	0.4231	0.0706	0.2355	0.8132	0.3825	0.0738	0.2346

Big national	0.6299	0.3637	0.1137	0.1869	0.6679	0.3915	0.1146	0.1867	0.5873	0.3571	0.1255	0.1865
MNEs	0.7349	0.3623	-0.0348	0.1863	0.7794	0.3894	-0.0380	0.1862	0.6920	0.3563	-0.0222	0.1859
Other	0.7451	0.3599	0.0524	0.1806	0.7934	0.3864	0.0519	0.1805	0.6954	0.3540	0.0661	0.1803
R&D												
Low R&D	-0.1356	0.0719	0.0437	0.0639	-0.1491	0.0797	0.0470	0.0640	-0.1402	0.0697	0.0451	0.0637
Size												
Size	0.1117	0.0707	0.0569	0.0628	0.1220	0.0786	0.0573	0.0629	0.1042	0.0689	0.0579	0.0627
Random Effect												
sigma	1.2617	0.0879	1.0169	0.0107	1.1450	0.0493	1.0195	0.0107	1.3469	0.1213	1.0247	0.0151
rho_sigma	0.5193	0.0627			0.5340	0.0604						
rho	0.2632	0.0559							0.3083	0.0599		
log likelihood	-3871.419				-3882.041				-3895.9			
Number of observations		2068			2068				2068			

Table 3: Pooled, Univariate and Bivariate Probit

	IV -Pooled Probit				**V-Univariate Random Probit**				**VI-Bivariate Probit**			
	Hiring		**Investment**		**Hiring**		**Investment**		**Hiring**		**Investment**	
Variables	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Hiring(t-1)	0.3782	0.1081	0.3334	0.0947	0.1986	0.1101	0.3186	0.0944	0.3768	0.1075	0.3308	0.0947
Spike(t-1)	-0.0031	0.0865	0.3893	0.0672	0.0002	0.0847	0.3558	0.0677	0.0019	0.0860	0.3890	0.0671
Year	-0.0148	0.0198	-0.0858	0.0134	-0.0064	0.0195	-0.0838	0.0134	-0.0168	0.0198	-0.0858	0.0134
constant	-1.9233	0.4367	-0.7123	0.2031	-1.6889	0.4196	-0.7157	0.2022	-1.9455	0.4489	-0.7083	0.2034
Labour cost	-0.0032	0.0011			-0.0035	0.0011			-0.0032	0.0011		
Sales	0.0086	0.0078	0.0038	0.0035	0.0085	0.0080	0.0044	0.0035	0.0095	0.0077	0.0038	0.0035
Age												
Age<11	0.1651	0.1693	0.1807	0.1372	0.0620	0.1672	0.1485	0.1376	0.1541	0.1684	0.1760	0.1373
10<Age<26	0.1463	0.1063	0.0375	0.0860	0.1620	0.1036	0.0328	0.0856	0.1392	0.1057	0.0355	0.0859
25<Age<51	0.1361	0.0995	0.1266	0.0792	0.1203	0.0973	0.0908	0.0796	0.1249	0.0989	0.1220	0.0791
Ownership												
Small national	0.7908	0.4477	-0.0204	0.2279	0.7671	0.4274	0.0500	0.2273	0.8142	0.4606	-0.0200	0.2283
Medium national	0.9746	0.4442	0.0900	0.2369	0.8919	0.4243	0.0702	0.2358	1.0107	0.4561	0.0942	0.2366
Big national	0.8072	0.4125	0.1047	0.1875	0.6412	0.3940	0.1265	0.1869	0.8440	0.4260	0.1051	0.1879
MNEs	0.9517	0.4104	-0.0291	0.1871	0.7573	0.3922	-0.0230	0.1863	0.9884	0.4239	-0.0277	0.1873
Other	0.9716	0.4072	0.0500	0.1814	0.7659	0.3894	0.0665	0.1807	1.0056	0.4208	0.0503	0.1817
R&D												
Low R&D	-0.1537	0.0814	0.0383	0.0643	-0.1572	0.0795	0.0477	0.0640	-0.1559	0.0812	0.0358	0.0642
Size												
Size	0.1296	0.0802	0.0480	0.0632	0.1163	0.0786	0.0575	0.0630	0.1303	0.0798	0.0487	0.0631
Random Effect												
sigma					1.1736	0.0626	1.0218	0.0128				
rho_sigma												
rho									0.2582	0.0488		
log likelihood	-3938.639				-3909.227				-3925.632			
Number of observations	2068				2068				2068			

Note: Reference groups are: Age > 50, Public, Invetsment in R&D, less than 250 employees. Sigma refer to standard deviations of random effects, rho_sigma to correlation between random random effects in both equation and rho to the correlation coefficient between error terms.

VI. Conclusion

In this paper we analyse the dynamics of the interrelationship between episodes when firms perform hiring and investments spikes. We have estimated three dynamic bivariate probit models in order to enlighten the dynamics of these adjustment processes using a sample of Italian firms. We find that both state dependence and unobserved heterogeneity are important to explain the way the firms follow when adjusting their factor demands. The adjustment cost can be an explanation for the significance of state dependence for both factors but at a larger extent for the capital. The unobserved heterogeneity explains more than half of the unsystematic variation and need to be considered in the model. The estimated correlation between random terms is significantly positive indicating that firms with strong preferences to incur hiring spikes are the same as those who incur investment spikes. This supports the hypothesis of the simultaneous interrelationship between hiring and investment spikes which is caused to a great extent by the positive correlation in unobserved heterogeneity rather than the positive correlation between errors terms.

As regards the dynamics of each of the factor adjustment processes, only the cross-effects of lagged hiring spike on the investment spike is significantly positive while the other one is insignificant across all specifications. Ceteris paribus, this means that firms who perform an investment spike are more likely to have performed a hiring spike in the previous period than those who don’t perform. The fact that firms prefer to anticipate one year the investment spikes by hiring employees one year before can be grounded on the human capital theory which says that firms possessing plant-specific asset use a higher technology level which in turn requires more skilled labour and advanced training for workers.

If we don’t allow for correlation between unobserved heterogeneity, the estimates of either cross-effects may be upwardly biased and lead to erroneous implications and conclusions as regards the importance of state dependence and cross-effects in the hiring and investment spikes. On the other hand, allowing only for correlation between errors, the state dependence of hiring is downwardly biased while the state dependence of investment doesn’t vary.

What does this noticeable dynamic interrelationship between labour and capital adjustment processes implies? It implies that any policy affecting labour adjustments directly would affect the performance of capital indirectly. For example, if capital costs are lowered, firms might be encouraged to make excessive capital investment whose contribution reflects in output expansion. If labour productivity is unchanged, normally extra workers would be hired to satisfy the new capacity. Employment adjustment would be associated with capital adjustment asserting the interrelationship phenomena in these markets. From a macro standpoint, any government policy that makes capital costly induce labour market rigidity and the opposite also holds as long as employment will mimic capital adjustment patterns. From a micro standpoint, a firm's strategy of hiring would make the other firms deduce that in a near future will hire also capital while when a firm sheds capital, it would make the others think that it will shed labour sooner. Thus, employment strategies of a firm would convey some information on its investment strategies to the other firms and vice-versa.

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Appendix 1

Description of the variables

Labor costs: They are calculated as the sum of firing cost and wages. Therefore I can not measure the separate effect of each component on the probability to adjust employment and capital.

Investment: It denotes Gross Investments. Up to 1994 they are computed based on the formula:

$IL_t = (ITL_t - ITL_{t-1}) + FC_t - (RIV_t - RIV_{t-1})$

Where ITL: gross technical fixed assets; RIV: revaluation fund Visentini bis

$FC = FA + Q - FA$

Where FA: amortization fund; Q = Quota of Amortization

From 1995 and on, Investment is calculated as:

$IL_t = (ITN_t - ITN_{t-1}) + Q_t$

Where $ITN_t = ITL_t - FA_t$

Stock of Capital Net of Sunk Costs: Stock of Capital net of Sunk Costs is defined as:

For the years after a given benchmark BM:

$ITNEW_{t+1} = ITNEW_t (1-\delta) (p_{t+1} / p_t) + IL_{t+1}$

For the years after a given benchmark BM:

$ITNEW_{t-1} = [(ITNEW_t - IL_t)/(1-\delta)] (p_{t-1} / p_t)$

Employment Growth Rate: The Employment Growth Rate is defined as the difference between the log value of employment at time t and the log value of employment at time t-1

Investment Rate: Investment rate is defined by the ratio of fixed investment in year by the stock of capital net of sunk cost at the end of the year t-1.

Firms' Age: The age variable is generated as the deviation of the firm's foundation year variable from year 1977 which is the initial year of our data.
All these variables have been deflated by the Producer Price Index.

Appendix 2

Fig.1

Employment Growth Rate Density

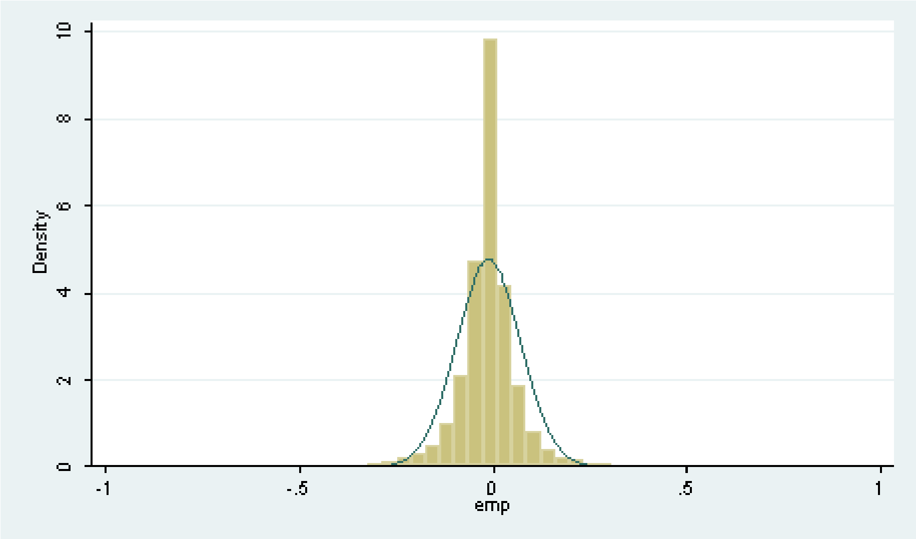

Fig.2
Investment Rates Density

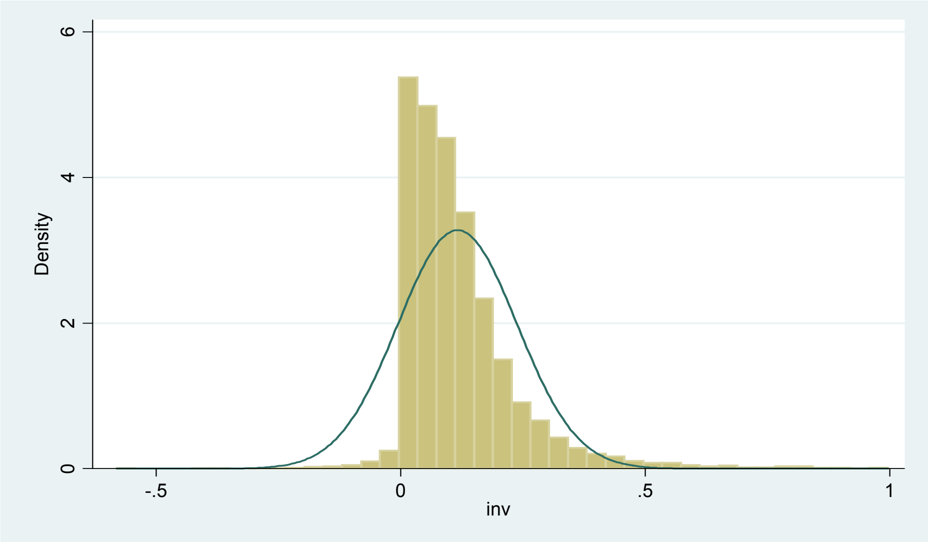

Fig.3

Investment and Employment Spike Persistence over 4 periods

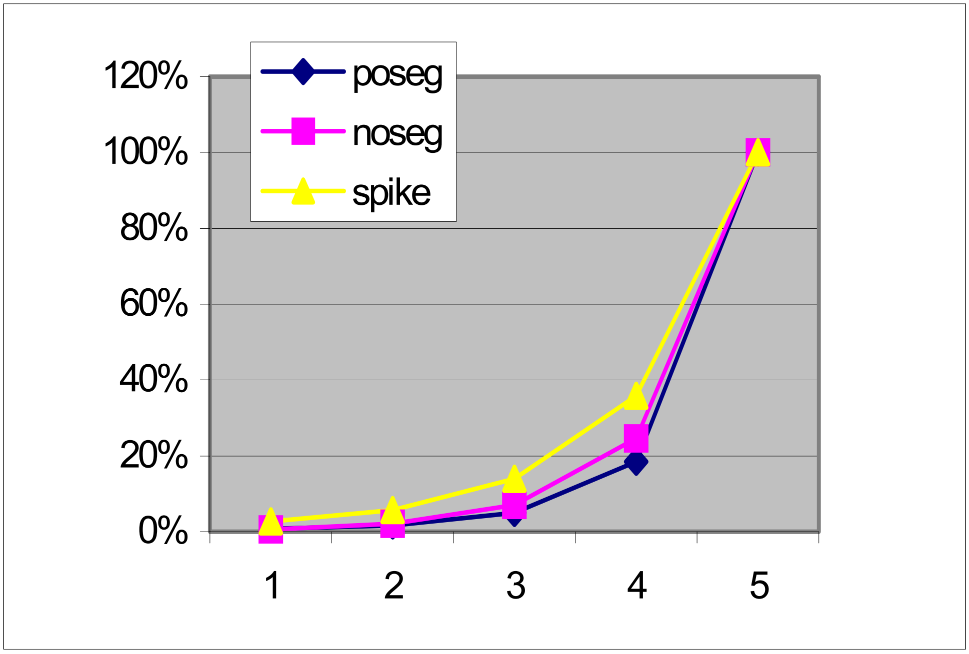

Table 1
Percentage of Investment and Employment using 4 thresholds definitions

		Spike (t)		Spike(t-1)		Spike(t+1)	
		0	**1**	**1**	**1**	**0**	**1**
Poseg	**0**	73.55	17.32	73.98	16.89	72.97	17.90
	1	5.34	3.79	6.53	2.60	6.15	2.98
Noseg	**0**	67.23	18.94	69.43	16.74	66.98	19.20
	1	11.66	2.16	11.08	2.74	12.14	1.68