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TOTAL FACTOR PRODUCTIVITY GROWTH AND EMPLOYMENT: A SIMULTANEOUS EQUATIONS MODEL ESTIMATE

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2005/06

Total Factor Productivity Growth and Employment: A Simultaneous Equations Model Estimate[*]

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July 2005

Abstract

This paper provides a structural estimation of the recent model proposed by Pissarides and Vallanti, a simplified equilibrium model which draws heavily on models with frictions and quasi-rents. The structural model is a system of three equations. The estimation method is a three-stage least squares. My empirical results find that although faster TFP growth temporarily decreases employment, most likely because job destruction reacts faster to schocks than job creation does, after the first year I do not find any statistically significant effect of growth on employment.

Keywords: Total Factor Productivity, Job Creation, Job Destruction, Employment

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1 Introduction

Equilibrium models of employment imply that the impact of Total Factor Productivity (TFP, hereafter) growth on employment is ambiguous: it could be positive or negative.[1] The conventional matching model with technological change (Pissarides, 1999 and 2000) shows that the rate of technical progress influences equilibrium labour market tightness (measured by number of vacant jobs ratio/unemployment rate). At higher growth, labour market tightness is higher, wages and vacancies are both higher and unemployment lower. This happens because the firm incurs in some hiring costs, in order to acquire workers who will yield some profit in the future. If the firm knows that in the steady state hiring costs rise at the same rate as profits, it can economize on future hiring costs by bringing forward some hiring. So at higher rates of growth, it goes into the market with more vacancies.

The effect of growth derived above is the "capitalization effect". At faster rate of technological progress all future income flows are discounted at a lower rate. Because the cost of creating a vacancy is borne now, whereas the profits from it accrue in the future, the lower discount rate increases job creation.

On the other hand, "Schumpeterian" models of growth (Aghion-Howitt, 1998) go in the opposite direction. In particular, Aghion-Howitt think that the question about the relationship between growth and unemployment in the long run is interesting because of the re-allocative aspect of growth. Faster economic growth must come from a faster increase in knowledge. If the advancement of knowledge is embodied in industrial innovations it is likely to raise the job destruction rate, through automation, skill obsolescence, and the bankruptcy associated with the process of creative destruction. So the increased growth is likely to produce an increased rate of job-turnover, and the search theories of Lucas and Prescott (1974) and Pissarides (1999, 2000) imply that an increased rate of job-turnover will result in a higher natural

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[1]Exceptions are represented by Phelps (1994) and Ball and Moffit (2002). They argue that the effects of growth on employment are unambigous but temporary.

rate of unemployment. The analysis of Aghion and Howitt uncovers two competing effects of growth on unemployment. The first is the "capitalization effect", whereby an increase in growth raises the rate at which the returns from creating a firm will grow, and hence increases the capitalized value of those returns. The "capitalization effect" encourages more firms to enter. This raises the number of job openings in the steady state equilibrium, as in Pissarides' analysis, thereby reducing the equilibrium rate of unemployment by increasing the job-finding rate.

The second effect is the "creative destruction", according to which an increase in growth may reduce the duration of a job match, which raises the equilibrium level of unemployment both directly, by raising the job-separation rate, and indirectly, by discouraging the creation of job vacancies and hence reducing the job-finding rate.

The apparent inconsistency between the point of view of Pissarides model and "Schumpeterian" models is simply resolved by Mortensen and Pissarides (1998). They show that both types of results can be obtained, depending on the particular technological assumptions adopted. The "capitalization effect" rests on the assumption that technology is disembodied, as in the Solow model. This means that all existing jobs can take full advantage of new technological improvements and there is no space for obsolescence. On the contrary, the "creative destruction" rests on the "Schumpeterian" assumption of embodied technology. This implies irreversibility in the firm's technological choices.

The above results are centered on long-run relationship between economic growth and employment. Postel-Vinay (2002) shows the short-run behavior of unemployment in a "creative destruction" context. He supposes the "correct" model is that of "Schumpeterian" inspiration and he shows that the short-run behavior of unemployment in response to a sudden change in the rate of technological progress is in some sense "perverse": it goes in the opposite direction to its own long-run tendency. In the long-run, faster tech-

nological change accelerates job obsolescence, while in the short-run it has a positive and potentially important effects on employment.[2]

This paper provides a structural estimation of Pissarides and Vallanti model (2004). This is a simplified equilibrium model which draws heavily on models with frictions and quasi-rents by Pissarides (1990, 2000), Aghion and Howitt (1998), Mortensen and Pissarides (1998). The model shows that the net impact of TFP growth on employment is negative when new technology is embodied in new jobs but positive when it is disembodied.[3]

My empirical results find that although faster TFP growth temporarily decreases employment, most likely because job destruction reacts faster to shocks than job creation does, after the first year I do not find any statistically significant effect of growth on employment.

The paper is organized as follows. Section 2 describes the theoretical model. Section 3 describes the three estimated equations. Section 4 describes the data. Section 5 presents the results of the econometrics analysis. Section 6 concludes.

2   The Model

Here I provide a complete description of the Pissarides and Vallanti model (2004). It is a balanced growth model with unknowns the rate of employment, the rate of unemployment, the capital stock and the wage rate, and exogenous variables TFP growth, the cost of capital and the labour force (and some institutional variables).

To derive the growth effects Pissarides and Vallanti assume that job creation requires some investment on the part of the firm, which may be a set-up

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[2]Postel-Vinay (2002) argues that this finding tends to partially reconcile the "Schumpeterian" view of the effects of technological progress on labour markets whith facts such as the impact of productivity slowdown on unemployment rates in the OECD countries in the 1970s.

[3]With embodied technology, Pissarides-Vallanti (2004) mean embodied in new jobs, not only in new capital.

cost or a hiring cost. Growth influences job creation through capitalization effects and job destruction through obsolescence. The precise influence on each depends on whether new technology can be introduced into ongoing job relationships, or whether it needs to be embodied in new job creation. Both types of results can be obtained, depending on the particular technological assumptions adopted. Following Mortensen and Pissarides (1998), Pissarides and Vallanti assume that there are two types of technology. One, denoted by A_1,can be applied in existing jobs as well as new ones: this is the disembodied technological progress, as in Solow model, and existing jobs can take full advantage of new technological improvements. The other, denoted by A_2, can only be applied in new jobs: this is the "Schumpeterian" assumption of embodied technology. Let the rate of growth of A_1be λa and the rate of growth of A_2 be $(1 - \lambda)a$, with $0 \leq \lambda \leq 1$,so the total rate of growth of technology is a. The parameter λ measures the extent to which technology is disembodied. If $\lambda = 0$, this implies the extreme "Schumpeterian" assumption of embodied technology and if $\lambda = 1$ we have the Solow disembodied case. The parameter a is the rate of growth of TFP in the steady state and is observable while the parameter λ is unobservable by the econometrician, but Pissarides and Vallanti calculate an approximate value for it from the empirical estimates of their model.

The production function in the model is represented by a Cobb-Douglas; the output per worker is denoted by $f(.,.)$. The first argument denotes the creation time of the job and the second the valuation time. At time τ, output per worker in new jobs is

$$f(\tau, \tau) = A_1(\tau)^{1-\alpha} A_2(\tau)^{1-\alpha} k(\tau, \tau)^{\alpha} \tag{1}$$

where $k(\tau, \tau)$ is the capital-labour ratio in new jobs at τ. But in jobs of vintage τ output per worker at time $t > \tau$ is

$$f(\tau, t) = A_1(t)^{1-\alpha} A_2(\tau)^{1-\alpha} k(\tau, t)^{\alpha} \tag{2}$$

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where in general $k(\tau, t)$ is different from $k(t, t)$.

The value of a job created at time 0 and lasting until T satisfies the following Bellman equation, for $t \in [0, T]$:

$$
\begin{aligned}
r(V(0, t) + k(0, t)) &= f(0, t) - \delta k(0, t) - w(0, t) \\
&\quad - sV(0, t) + \overset{\circ}{V}(0, t)
\end{aligned}
\tag{3}
$$
$$
V(0, T) = 0
$$

As we can see from the equation above, the value of a job consists of two parts: the value of its capital stock and a value $V(., .) \geqslant 0$, which is due to the frictions and the quasi-rents that characterize employment. The job can be destroyed either by an exogenous process, which occurs at rate s, or because of obsolescence, which occurs T periods after creation. Capital depreciates at rate δ and there is a perfect market for capital, in which the firm can re-sell its capital stock when the job is destroyed. There are no capital adjustment costs; r is the exogenous rental rate of capital and $w(0, t)$ is the wage rate at t in a job of vintage 0.

The interpretation of the Bellman equation derives from search theory: firm hires capital stock $k(0, t)$ and makes profit $V(0, t)$. The firm's controls at time 0 are whether or not to create a job; and once it has been created, when to terminate it, and the path of $k(0, t)$ for $t \in [0, T]$. It is assumed that the wage rate is jointly determined by the firm and the worker after a bargain.

2.1 Capital accumulation

Maximizing the Bellman equation above with respect to $k(0, t)$ we obtain:

$$
k(0, t) = A_1(t)A_2(0)(\alpha/(r + \delta))^{\frac{1}{1 - \alpha}}
\tag{4}
$$

$t \in [0, T]$. The path of capital-labor ratio in existing and new jobs is:

$$k(0, t) = e^{\lambda a t} k(0, 0) \tag{5}$$

$$k(t, t) = e^{a t} k(0, 0) \tag{6}$$

New jobs are technologically more advanced and have more capital than old jobs. The labour's marginal product is derived from (2) and (4):

$$\phi(\tau, t) \equiv f(\tau, t) - (r + \delta)k(\tau, t) \tag{7}$$

When technology on the frontier grows at rate a, output, the capital stock and labour's marginal product in existing jobs grow at a lower rate λa:

$$\phi(0, t) = e^{\lambda a t} \phi(0, 0), \tag{8}$$

$$\phi(t, t) = e^{a t} \phi(0, 0). \tag{9}$$

2.2 Wages

Wages play a key role in the transmission of the effects of growth on employment. Because of competition from new jobs, wages in existing jobs grow at a faster rate than the marginal productivity of labour, and so eventually jobs become unprofitable.

The equation for wage is derived by a Nash Bargaining solution:

$$w(\tau, t) = (1 - \beta)b(t) + \beta m(\theta)V(t, t) + \beta\phi(\tau, t) \tag{10}$$

where $b(t)$ is the unemployment income, which grows at rate a by assumption, $\theta \geqslant 0$ is a measure of market tightness, $m(\theta)$ is the rate at which new job offers arrive to unemployed workers, and $\beta \in [0, 1)$ is the share of

labour. There is no search on the job.

The reservation wage is defined as:

$$\omega(t) \equiv b(t) + \frac{\beta}{1 - \beta} m(\theta) V(t, t). \tag{11}$$

From (3), (10) and (11) follows that both $V(t, t)$ and $w(t, t)$ grow at rate a.

The reservation wage captures the external influences on wages, resulting from the attractions of quitting to search for alternative jobs. Therefore, we can write the wage equation as the sum of two components, an "inside" one that grows at rate λa and depends on the marginal product of labour inside the firm and the share of the worker β, and an "outside" one represented by the reservation wage, which grows at a rate a. For a job created at time 0 the wage equation is:

$$w(0, t) = (1 - \beta)\omega(0)e^{at} + \beta\phi(0, 0)e^{\lambda at}. \tag{12}$$

2.3 Job creation and job destruction

The present discounted value of profit from a job of vintage 0 is derived integrating (3):

$$V(0, 0) = \int_0^T e^{-(r+s)t}(\phi(0, t) - w(0, t))dt. \tag{13}$$

Using (8) and (12) we can re-write (13) as:

$$V(0, 0) = (1 - \beta) \int_0^T e^{-(r+s)t}(e^{\lambda at}\phi(0, 0) - e^{at}\omega(0))dt. \tag{14}$$

$V(0, 0)$, $\phi(0, 0)$ and $\omega(0)$ are all proportional to the level of aggregate technology, $A_1(0)A_2(0)$; because of that we can simplify 14 omitting the

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time notation:

$$V = (1 - \beta) \int_0^T e^{-(r+s)t}(e^{\lambda at}\phi - e^{at}\omega)dt. \tag{15}$$

We now differentiate (15) with respect to T to get the obsolescence date chosen by the firm to maximize the job's value:

$$T = \frac{\ln \phi - \ln \omega}{(1 - \lambda)a} \tag{16}$$

It follows from (16) that if all technology is of the Solow disembodied type, $\lambda = 1$, the firm will never want to destroy a job through obsolescence: job destruction in this case takes place only because of the exogenous separation process. But if $\lambda < 1$ faster growth leads to more job destruction:

$$\frac{\partial T}{\partial a} < 0.$$

We derive the equilibrium effect of growth by integrating (15):

$$V = (1 - \beta)\left(\frac{1 - e^{-(r+s-\lambda a)T}}{r + s - \lambda a}\phi - \frac{1 - e^{-(r+s-a)T}}{r + s - a}\omega\right). \tag{17}$$

The (17) can be re-written as:

$$V = (1 - \beta)(y(\lambda a)\phi - y(a)\omega), \tag{18}$$

where $y(\lambda a) \equiv \frac{1-e^{-(r+s-\lambda a)T}}{r+s-\lambda a}, \lambda \in [0, 1]$.
By differentiation,

$$y'(\lambda a) > 0, y''(\lambda a) < 0 \tag{19}$$

To derive the influence of the growth rate on job creation the model assumes that jobs are created at some cost, and that the cost increases in the number of jobs created at any moment in time. To justify this assumption, the model follows the search and matching literature, which assumes that

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at the level of the firm the cost of creating one more job is constant but marginal costs are increasing at the aggregate level because of congestion effects (see Pissarides, 2000). Let θ be the ratio of the total number of advertised vacant jobs to the number of unemployed workers. Then given the rate of arrival of jobs to workers, $m(\theta)$, the rate of arrival of workers to jobs is $m(\theta)/\theta$. Consistency requires that this rate decrease in θ: to be satisfied the elasticity of $m(\theta)$ (denoted by η) must be a number between zero and one.

The cost of creating one more job in period t is a flow cost $A_1(t)A_2(t)c$ for the duration of the firm's search for a suitable worker.[4]

The present value of creating one more vacant job $V^0(t)$ satisfies the Bellman equation:

$$rV^0(t) = -A_1(t)A_2(t)c + \frac{m(\theta)}{\theta}(V(t,t) - V^0(t)) + \mathring{V}^0(t). \qquad (20)$$

Under free entry search, $V^0(t) = \mathring{V}^0(t) = 0$, and so each new job yields positive profit. In period $t = 0$ the job creation condition is:

$$V(0,0) = A1(0)A2(0)\frac{c\theta}{m(\theta)}, \qquad (21)$$

or equivalently,

$$V = \frac{c\theta}{m(\theta)}. \qquad (22)$$

Substituting V from (18) into (22) gives:

$$(1 - \beta)(y(\lambda a)\phi - y(a)\omega) = \frac{c\theta}{m(\theta)}. \qquad (23)$$

Job creation at time t in this economy is given by $x(t) = \tilde{u}(t)m(\theta)$, where $\tilde{u}(t)$ is the predetermined number of unemployed workers and $m(\theta)$ is the matching rate for each worker.

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[4]The cost should be increasing at rate a for the existence of a steady state.

We now obtain the effect of TFP growth on job creation by differentiation of (23) with respect to a:

$$\left(\frac{c\beta y(a)}{1-\beta} + \frac{c(1-\eta)}{m(\theta)} \right) \frac{\partial \theta}{\partial a} = (1-\beta)(\lambda y'(\lambda a)\phi - y'(a)\omega). \qquad (24)$$

The coefficient on $\frac{\partial \theta}{\partial a}$ is positive but the right-hand side can be either positive or negative. By (19), if technology is embodied ($\lambda = 0$) the sign is negative; but if technology is disembodied ($\lambda = 1$) the sign is positive. If we further differentiate the right-hand side of (24) with respect to λ, we find that it is monotonically rising in λ. Therefore, there is a unique λ (λ^*) such that at value of $\lambda < \lambda^*$ faster growth reduces market tightness and at values of $\lambda > \lambda^*$ it increases it. At $\lambda = \lambda^*$ growth has no effect on θ.

2.4 Economy's steady state

Steady state equilibrium is defined by a path for the average capital-labour ratio, for the wage rate and for employment rate. The exogenous variables are TFP, population and real capital cost. Figure (1) shows the aggregation of the representative firm's equilibrium conditions to derive the economy's steady-state paths. Because of the Cobb-Douglas assumption, the path shown for $\phi(.,.)$ in Figure (1) is a displacement of the path of the capital stock and the one for output per worker, for each job. In steady state a job is created in period 0, it is destroyed in period T when a new one is created, which is destroyed and another one created in its place in period $2T$ and so on. The capital stock, output and labour's marginal product grow on average at rate a (see the broken line in Figure 1). If new jobs in the economy are created continually with the same frequency, the aggregate capital stock, output and marginal product will grow smoothly at rate a. The average wage rate also grows at rate a, because of the two components, $\phi(.,.)$ and $\omega(.)$, which grow at rate a.

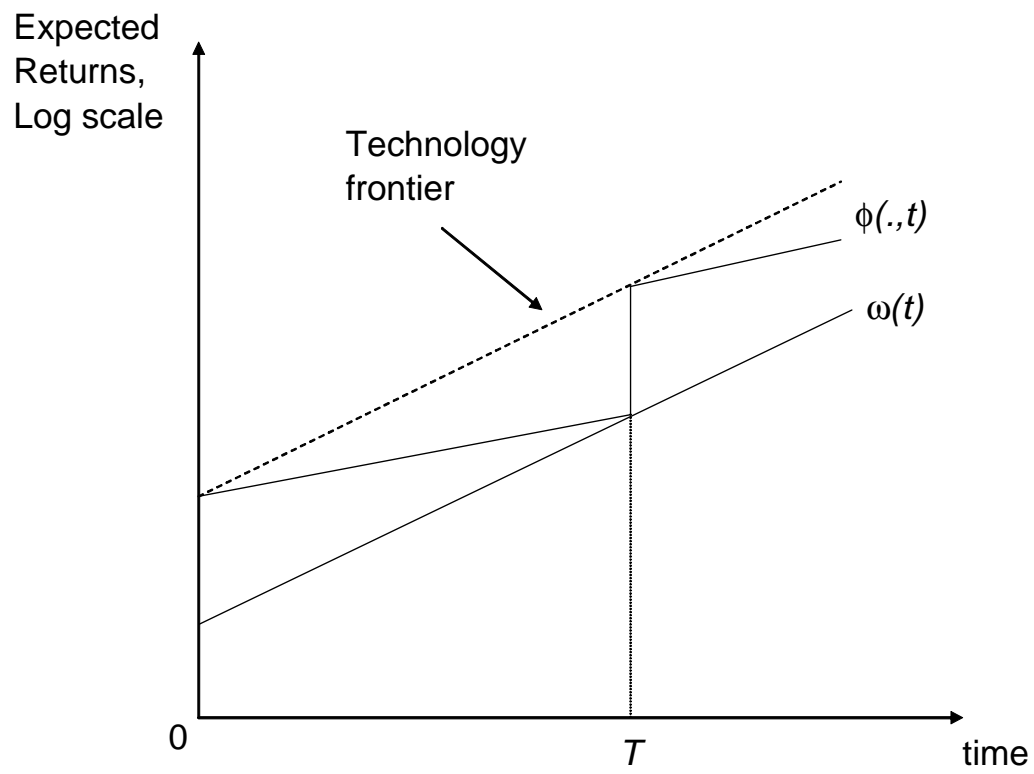Employment in the representative firm evolves on average according to

Expected
Returns,
Log scale

Technology
frontier

$\phi(.,t)$

$\omega(t)$

0

T

time

Figure 1: Expected returns

the difference between job creation and job destruction:

$$\mathring{L}(t) = x(t) - e^{-sT}x(t - T) - sL(t) \qquad (25)$$

where $x(t)$ is job creation, and $exp(-sT)$ is the fraction of jobs of vintage $t - T$ that survive to T. In the steady state $\mathring{L}(t)$ is equal to the rate of change of the population of working age, which is assumed to be exogenous and equal to n. $x(t)$ is given by $\tilde{u}(t)m(\theta)$ and so it grows at n, because the number of unemployed workers $\tilde{u}(t)$ grows at n, whereas θ and T are the solutions to (16) and (23).

3   Empirical Analysis

I estimate the structural equations for the capital stock, wages and employment to derive the effects of TFP growth on employment. Lags of the dependent variables and TFP are included in order to pick up any short-run dynamics. The structural model is a system of three equations, which contain endogenous variables among the explanatory variables. Furthermore, these endogenous variables are the dependent variables of other equations in the system. The disturbance are correlated with the endogenous variables and the error terms among the equations are expected to be correlated. So, to overcome these issues, I estimate the model by the three-stage least squares process, including fixed effects for each region and time dummies.[5]

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[5]Three-stage least squares estimation is a three-step process. Step 1 develops instrumented values for all endogenous variables. These values can be considered as the predicted values resulting from a regression of each endogenous variables on all exogenous variables in the system. Step 2 produces a consistent estimate for the covariance matrix of the equation disturbances. Finally, step 3 performs a GLS-type estimation using the covariance matrix estimated in the second step and the instrumented values for all endogenous variables, obtained in step 1.

3.1 The employment equation

The structural employment equation is represented by (25). Because of the absence of long time series for job creation and job destruction, only a single employment equation can be estimated. As a consequence, job creation and job destruction depend on the same variables because of the impossibility to identify them separately from a single employment equation. These variables are the level of marginal product (proxied by the level of TFP and the level of capital-labour ratio), the wage rate, the interest rate and the expected rates of growth of marginal product and the wage rate (both proxied by the rate of TFP growth).

In the estimated employment equation the dependent variable is the ratio of employment to population of working age and the independent variables the level and the rate of change of TFP, the level of the capital-labor ratio, the real cost of labor and the real interest rate. The capital stock and the real wage are treated as endogenous. The job creation and the job destruction are characterized by different adjustment lags and this implies differential short-run and long-run effects. TFP growth increases job destruction but may increase or decrease job creation. So the impact of productivity growth on employment may be negative, and either remain negative or turn positive in the medium to long-run, if job destruction reacts faster than job creation to shocks, as found in the data.

3.2 The wage equation

The structural wage equation is represented by (10). The estimated wage equation is an error-correction equation in wage growth. The ratio of compensation to mean wages and the duration of entitlement represent the unemployment income $b(t)$, while the parameter β (which stands for the share of labour in the wage bargain) is represented by the union density. The marginal product of labor and the expected returns from search are repre-

sented by the level and the rate of growth of the capital-labour ratio and TFP. Dividing the capital stock by employment may not give reliable results because of the possibility of spurious correlation due to cyclical noise in the employment series. I could deal with this problem by replacing employment by the labor force. But this was not possible because of not availability of labor force data at regional level.

3.3 The investment equation

Because of cyclicality problems of employment, as in the wage equation, estimating an investment equation by dividing the capital stock by employment does not give reliable results. I deal with this problem by estimating an error-correction equation for the capital stock and replacing employment by the real wage. The structural investment equation is derived by (4). The capital stock is proportional to TFP and the factor of proportionality depends on the cost of capital and the cost of labor. The cost of capital is represented by the real interest rate.

4 Data

The data come mainly from Cambridge Econometrics database with some adjustments. Some variables (at national level) are from the OECD database, various issues. Data are annual from 1981-1995 for a sample of European Regions.[6] The institutional variables (union density, benefit replacement ratio, benefit duration, employment protection and labor taxes) are from Nickell et al. (2001) and they are at national level.

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[6]The list of the Regions in the sample are in appendix. Tey are from the following European Countries: Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, United Kingdom. Greek regions and Luxembourg are excluded from the original sample because some of the institutional variables are missing.

The calculation of the capital stock is made according to the Perpetual Inventory Method:

$$K_t = (1 - \delta)K_{t-1} + I_{t-1} \tag{26}$$

where δ is the depreciation rate: it is assumed constant and equal to 8%, which is consistent with OECD estimates; I is the gross fixed capital formation.[7] The initial value of K is calculate as:

$$K_0 = \frac{I_0}{g + \delta} \tag{27}$$

where g is the average annual logarithmic growth of investment expenditure and I_0 is investment expenditure in the first year for which data on investment are available.

The Total Factor Productivity is calculated by estimating a production function with country fixed effects and time dummies for each year. [8]The aggregate production function is a Cobb-Douglas with the TFP picking up both types of TFP of the theoretical model: $A_{it} = A_{1it}A_{2it}$:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \tag{28}$$

The cost of capital is represented by the real long term interest rate, r, calculated deflating the long term nominal interest rate by the 3-year expected inflation rate:

$$r = i - E(d\ln p_{+1}) \tag{29}$$

$E(d\ln p_{+1})$ are fitted values from the regression:

$$d\ln p = \gamma_1 d\ln p_{-1} + \gamma_2 d\ln p_{-2} + \gamma_3 d\ln p_{-3} + \upsilon \tag{30}$$

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[7]See Machin and Van Reenen, (1998)

[8]The estimation method is a feasible fixed effect GLS, constructed assuming by country groupwise heteroskedasticity and a panel-specific (AR1) in the disturbances ε_{it}.

where $d \ln p$ is the inflation rate (OECD Economic Outlook). The coefficients on the right side are restricted to some to one, indicating inflation neutrality in the long-run.[9]

5   Results

The results of the estimation are reported in tables (1), (2) and (3). I compare my results with that one found by Pissarides-Vallanti (2004). They have estimated the model for a sample of 13 European countries, United States and Japan over the period 1965-1995.

Time dummies are introduced in all the three equations to remove the common trends and cycles in the regions of the sample and they avoid spurious correlations due to these comovements. The dependent variable in the employment equation is the employment rate, calculated as the ratio of employment to population of working age. The independent variables are the level and the rate of change of TFP, the level of the capital-labor ratio, the real cost of labor and the real interest rate. I find a significative negative influence of the rate of growth of TFP on employment in the first year, but from the second year this influence disappears (the coefficient of TFP growth is positive and insignificant).

The wage equation is an error-correction equation.[10] The capital stock influences the wage rate with positive coefficient, in both levels and rate of change, while TFP growth has a negative effect on wage. Institutional variables give an idea of their impact on wages. In the empirical specification of the wage equation I introduce the variable employment protection laws, unlike Pissarides and Vallanti (2004). Employment protection laws may reduce the efficiency of job matching because may tend to make firms more cautious

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[9]See Cristini (1999).

[10]The error-correction (ECM) approach overcomes problem of common trends and thus spurious regression, due of potential non-stationarity of a dynamic model. Furthermore, the ECM incorporates both short-run and long-run effects.

Table 1: The employment equation

Dependent variable: $\ln(\text{L/WP})_{it}$	
Independent variables	
$\ln(\text{L/WP})_{it-1}$	0.890
	(31.46)
$\ln(\text{L/WP})_{it-2}$	−0.074
	(−2.80)
$\ln\text{w}_{it-1}$	−0.001
	(−0.16)
$\ln(\text{K/WP})^*_{it}$	−0.022
	(−1.34)
$\ln\text{A}_{it}$	−0.037
	(−1.40)
dlnA_{it}	−0.276
	(−7.89)
dlnA_{it-1}	0.034
	(1.04)
r_{it}	0.000
	(0.18)
Year dummies (15 years)	yes
Region dummies (101 regions)	yes
Obs	1515
R^2	0.98

The estimation method is a three stage least squares.
Numbers in brackets are t-statistics. $(\text{L/WP})_{it}$ is the ratio
of employment to population of working age, in region i
in year t, (K/WP) is the ratio of the capital stock to the
population of working age, A is measured TFP progress,
w is the real wage rate and r is the real interest rate.
*Instrumented variables: the instruments used
are all the exogenous variables in the three
regressions and lags of the endogenous.

about filling vacancies.[11] Furthermore, employment protection may have a direct impact on wages because it can encourage employees to demand higher wages, since it raises the job security. However, my results do not show any effect of employment protection in increasing real wages.

I find that benefit duration has no effect on wages and this result is consistent with that one found by Nickell et al. (2000) for OECD countries. I do not find any significant effect of benefit replacement ratio and that taxes increases wage costs. My results are consistent with those ones found by Pissarides and Vallanti (2004). On the contrary, Nickell et al.(2000) find a direct impact on wages of benefit replacement ratio. Looking at the impact of union density on wages, I find that it increases wage costs as expected. Generally, greater union power and coverage can be expected to exert upward pressure on wages. Unfortunately, because of non availability of series on unemployment rates at regional level, I cannot control for the impact of unemployment on wages. Pissarides and Vallanti (2004) find that unemployment has a restraining influence on wages, as predicted by their model, but its influence is reduced in countries that have long durations of benefit entitlement.

The capital equation is also an error-correction equation. Long adjustment lags are included to pick-up any short-run dynamics. I find no influence of interest rate on private investment. TFP has a positive impact on investment in level, while in the rate of growth the effect is negative in the first year but turn positive in the second. As claimed the theoretical model TFP and its growth rate drive capital accumulation.

Summarizing, my results show that faster TFP growth temporarily decreases employment, but there is no effect after the first year. This kind of results is most likely due to the fact that job destruction reacts faster

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[11]However, this mechanism is not clear-cut. The introduction of employment laws can lead to an increased professionalisation of the personnel function within firms. This happened in Britain in the 1970s (Daniel and Stilgoe, 1978).

Table 2: The wage equation

Dependent variable: dlnw_{it}	
Independent variables	
dlnw_{it-1}	0.228
	(8.47)
dln(K/L)*_{it}	1.055
	(3.77)
dlnA_{it}	−0.215
	(−2.05)
lnw_{it-1}	−0.343
	(−14.87)
$\ln(K/L)_{it-1}$	0.053
	(0.84)
lnA_{it-1}	−0.052
	(−0.71)
BD	0.118
	(1.03)
union_{it}	0.008
	(3.82)
rer_{it}	−0.119
	(−1.53)
ep_{it}	0.057
	(0.66)
$\text{d}^2 \ln p_{it}$	−0.003
	(−1.52)
dtax	−0.003
	(−1.56)
Years dummies (15 years)	yes
Region dummies (101 regions)	yes
Obs	1515
R^2	0.40

See notes on table (1). All variable have been defined except:

BD the maximum duration benefit entitlement,

union the fraction of workers belonging to a union (union density),

rer the benefit replacement ratio, ep the employment protection, dtax first difference of tax wedge, $\text{d}^2 \ln p_{it}$ the first difference in the inflation rate.

Table 3: The investment equation

Dependent variable: dlnK_{it}

Independent variables

dlnK_{it-1}	0.896 (40.53)
dlnK_{it-2}	-0.217 (-12.50)
r_{it}	-0.000 (-0.44)
lnw*_{it}	0.004 (5.05)
lnA_{it}	0.030 (9.08)
dlnA_{it}	-0.050 (-11.49)
dlnA_{it-1}	0.079 (18.43)
$\ln(\text{K/WP})_{it-1}$	-0.017 (-11.13)
Years dummies (15 years)	yes
Region dummies (101 regions)	yes
Obs	1515
R^2	0.96

See notes to table (1)

to shocks than job creation does, as usually found in the data.[12] On the contrary, Pissarides and Vallanti found that the effects of TFP growth on employment is statistically significant and positive, after an initial period of not more than one year. The implication of their results is that all new technology is disembodied and "creative destruction" plays no role in the steady state employment dynamics of the sample considered, implying a high value for λ.

My results show that a faster technological change has a negative important short-run influence on the level of employment and this is consistent with Pissarides and Vallanti (2004) results, but I was not able to find any long-run compensating effect, unlike them. A possible explanation for this different result may be represented by the different level of territorial disaggregation considered: national in Pissarides and Vallanti (2004), and regional in my exercise. If the boundary of firms hiring decisions goes beyond local or regional context, while the negative shocks of job destruction have a local impact, the latter may be more evident than the former.

A final exercise that I make is to consider TFP as endogenous. I instrument it using all the exogenous variables and lags of TFP level and TFP growth Results do not show any sensible difference with respect to the case in which TFP is exogenous.[13]

6   Conclusions

Equilibrium models of employment imply that the effects of faster TFP growth can be either positive or negative and depend on the extent to which new technology is embodied in new jobs.

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[12]See Davies, Haltiwanger and Schuh (1996). However Boeri (1996) finds that in some European countries job creation sometimes reacts faster than job destruction because of firing restrictions but I do not find this kind of results in my estimates.

[13]Results are available upon request.

In this paper I have evaluated the relation between TFP growth and aggregate employment following the suggestions for the estimation of a model for employment, wages and investment proposed by Pissarides and Vallanti (2004). This model draws heavily on model with frictions and quasi-rents by Pissarides (2000), Aghion and Howitt (1998), Mortensen and Pissarides (1998) and others.

I have estimated the model for a sample of 101 European Regions over the period 1981-1995. I have excluded Greek regions and Luxembourg because some institutional variable were missing.

This paper has showed that faster TFP growth temporarily decreases employment but there is no effect after the first year. This kind of results is most likely due to the fact that job destruction reacts faster to shocks than job creation does, as usually found in the data. My results are different from that ones found by Pissarides and Vallanti (2004). In fact, they have found a significative influence from the rate of growth of TFP on employment, which are negative in the first year but turns positive in the second. On the contrary, my results have showed a negative and important short-run influence of faster technological change on the employment rate but I was not able to any long-run effect, implying that "job creation" plays no part in the employment dynamics of the regions in my sample. This may partially due to the fact that the time period analyzed is shorter (15 years) than that one used by Pissarides and Vallanti (2004). Moreover, this different result may be also represented by the different level of territorial disaggregation considered: national in Pissarides and Vallanti (2004), and regional in my exercise. If the boundary of firms hiring decisions goes beyond local or regional context, while the negative shocks of job destruction have a local impact, the latter may be more evident than the former. Also, assuming a more naive wage equation than the Nash sharing rule may increase the impact of growth on employment, as pointed out by Pissarides and Vallanti (2004). Finally, the finding of no long-run effect of growth on employment in my results could

mean that there are additional forces, beyond the *capitalization effect* and the *creative destruction effect*, which contribute to the relation between growth and employment.

Phelps (1994), Hoon and Phelps (1997) and Ball and Moffitt (2002) have identified labour supply forces which imply long lags in the effect of growth on employment. Ball and Moffitt (2002) claim that because of misperceiving of the change of TFP growth by workers, it takes many years to adjust perceptions of future wage growth.

In any case, more work is needed, both theoretical and empirical, to investigate the impact of growth on employment and to link the demand-side factors to the supply-side factors.

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A   Data definitions and source

Data are mainly from Cambridge Econometrics, a validated database of economic indicators for cities and regions. The database draws on the available official data at European and national levels and has undergone a substantial process of updating and quality checks to improve its consistency, timeliness and coverage. The current database includes output, employment, household expenditure, investment expenditure, demographic indicators (total and working population).

The regions in the sample are presented in tables (4), (5).

Y Gross Value Added in constant prices (base year 1995)

L Total Employment (source: Cambridge Econometrics)

P Working Population (source: Cambridge Econometrics)

w Real labor cost: it is computed from the compensation of employees data using 1995 as base year (source: Cambridge Econometrics)

K Real capital stock. The calculation of the capital stock is made according to the Perpetual Inventory Method. Data on investment expenditure are from Cambridge Econometrics

A Total Factor Productivity (TFP). It is obtained by estimating a production function over the period 1976-2000 from the original sample including greek regions and luxembourg. The estimation method is a feasible fixed effect GLS estimator, with a variance and covariance matrix that incorporates heteroskedasticity across countries.

r Real long term interest rate deflated by the 3-year expected inflation rate: $r = i - E(dlnp_{+1})$, where i is the long term nominal interest rate (source: OECD Economic Outlook, various issues). $E(dlnp_{+1})$ are fitted values from the regression: $d\ln p = \gamma_1 d\ln p_{-1} + \gamma_2 d\ln p_{-2} + \gamma_3 d\ln p_{-3} + \upsilon$, where $d\ln p$ is the inflation rate based on the consumer price index p, base year 1990 (source: OECD Economic Outlook, various issues)

union Net union density is constructed as the ratio of total reported union members (less retired and unemployed members) (source: Nickell et al. 2001)

tax Tax wedge consists of the payroll tax rate plus the income tax rate plus the consumption tax rate (source: Nickell et al. 2001)

rer Benefit entitlement before tax as a percentage of previous earnings before tax. Data are averages over replacement rates at two earnings levels and three family types (single, with dependent spouse, with spouse at work). They refer to the first year of unemployment (source: Nickell et al. 2001, constructed from OECD data sources)

BD Benefit duration defined as a weighted average of benefits received during the second, third, fourth and fifth year of unemployment divided by the benefits in the first year of unemployment (source: Nickell et al. 2001, constructed from OECD data sources)
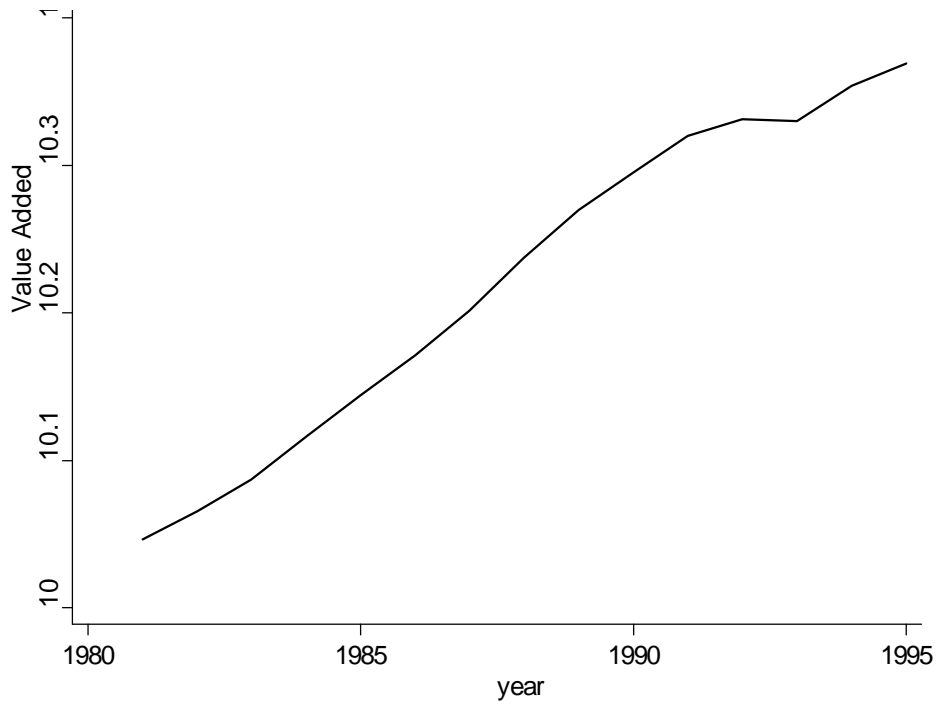
p Consumer price index

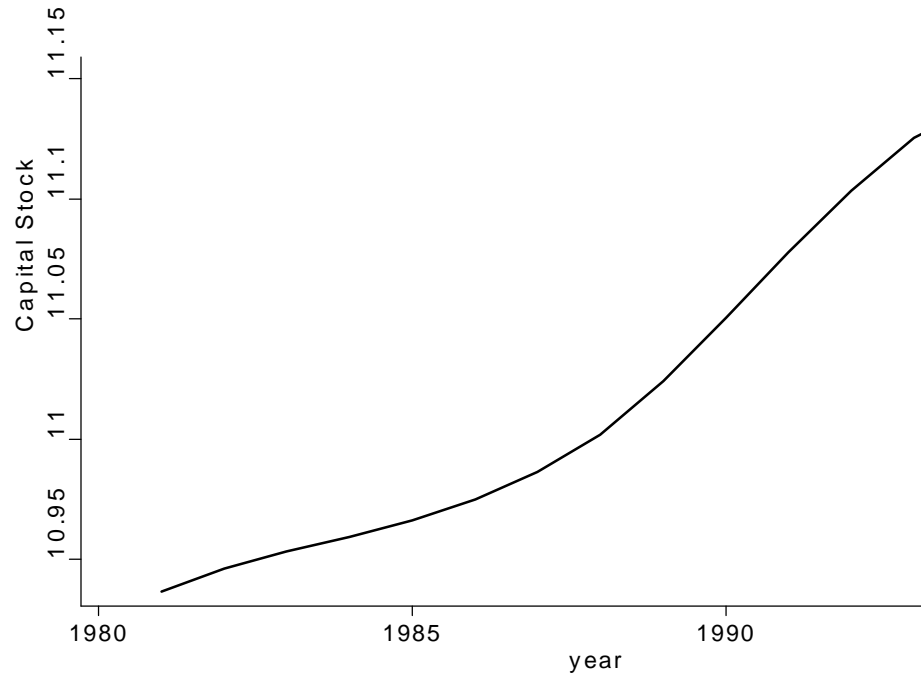Figure 2: Log Value Added

Figure 3: Log Capital Stock
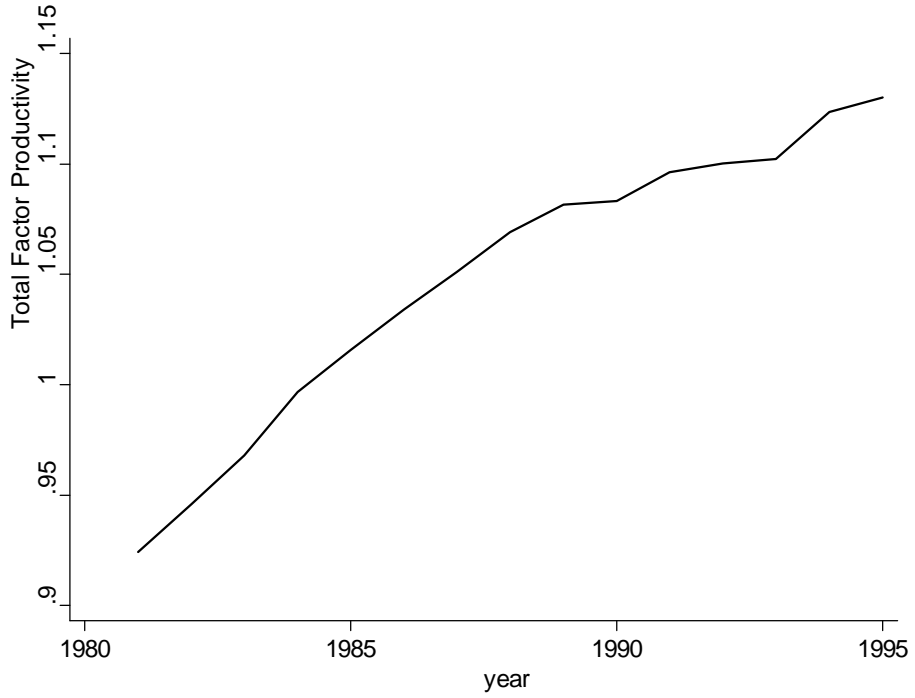
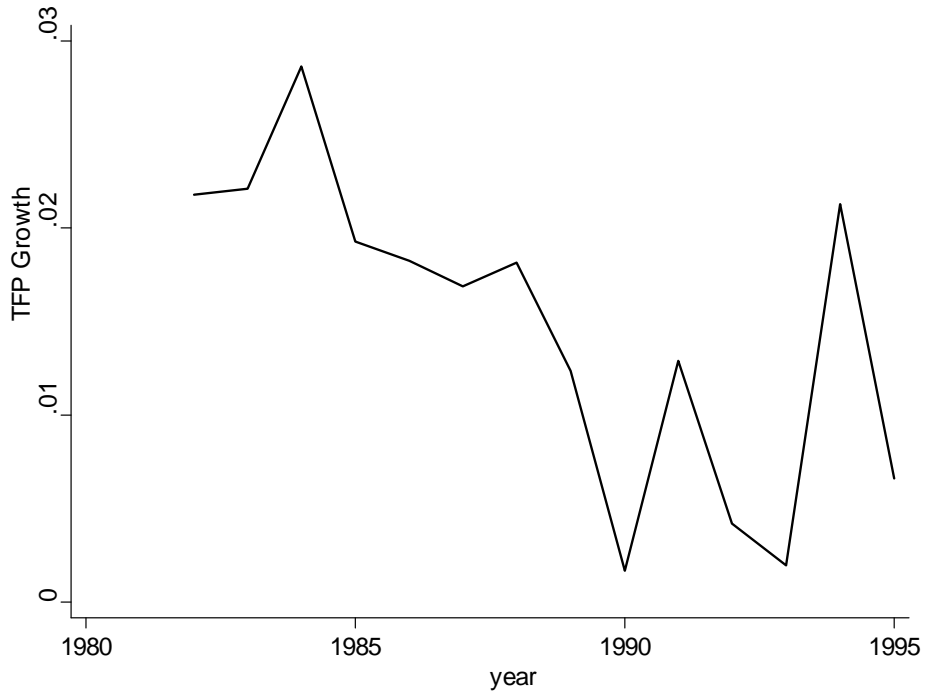Figure 4: Log Employment

Figure 5: Log Total Factor Productivity

Figure 6: Total Factor Productivity Growth

Table 4: Sample I
Regions

Bruxelles-Brussel (Be)	Extremadura (Es)
Vlaams Gewest (Be)	Cataluna (Es)
Region Walonne (Be)	Com. Valenciana (Es)
Denmark	Baleares (Es)
Baden-Wurttemberg (De)	Andalucia (Es)
Bayern (De)	Murcia (Es)
Berlin (De)	Ceuta y Melilla (Es)
Bremen (De)	Canarias (Es)
Hamburg (De)	Ile de France (Fr)
Hessen (De)	Champagne-Ard (Fr)
Niedersachsen (De)	Picardie (Fr)
Nordrhein-Westfalen (De)	Haute-Normandie (Fr)
Rheinland-Pfalz (De)	Centre (Fr)
Saarland (De)	Basse-Normandie (Fr)
Schleswig-Holstein (De)	Bourgogne (Fr)
Galicia (Es)	Nord-Pas de Calais (Fr)
Asturias (Es)	Lorraine (Fr)
Cantabria (Es)	Alsace (Fr)
Pais Vasco (Es	Franche-Comte (Fr)
Navarra (Es)	Pays de la Loire (Fr)
Rioja (Es)	Bretagne (Fr)
Aragon (Es)	Poitou-Charentes (Fr)
Madrid (Es)	Aquitaine (Fr)
Castilla-Leon (Es)	Midi-Pyrenees (Fr)
Castilla-la Mancha (Es)	Limousin (Fr)

Table 5: Sample II
Regions

Rhone-Alpes (Fr)	Sardegna (It)
Auvergne (Fr)	Noord-Nederland (Nl)
Languedoc-Rouss. (Fr)	Oost-Nederland (Nl)
Prov-Alpes-Cote d'Azur (Fr)	West-Nederland (Nl)
Corse (Fr)	Zuid-Nederland (Nl)
Ireland	Burgenland (At)
Piemonte (It)	Niederosterreich (At)
Valle d'Aosta (It)	Wien (At)
Liguria (It)	Karnten (At)
Lombardia (It)	Steiermark (At)
Trentino-Alto Adige (It)	Oberosterreich (At)
Veneto (It)	Salzburg (At)
Fr.-Venezia Giulia (It)	Tirol (At)
Emilia-Romagna (It)	Vorarlberg (At)
Toscana (It)	North East (GB)
Umbria (It)	North West (GB)
Marche (It)	Yorkshire and the Humb (GB)
Lazio (It)	East Midlands (GB)
Abruzzo (It)	West Midlands (GB)
Molise (It)	Eastern (GB)
Campania (It)	London (GB)
Puglia (It)	South East (GB)
Basilicata (It)	South West (GB)
Calabria (It)	Wales (GB)
Sicilia (It)	Scotland (GB)
	Northern Ireland (GB)