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Regional Inequality and Human Capital Quality: The Impact of Technology on the Arrival Rate of Employment Offers

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Regional inequality and human capital quality[*]

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Abstract. This paper aims to provide a conceptual and operational context for analysing regional inequalities. It does so by utilizing a ‘search & matching’ framework. The model, developed in this paper, maps the way in which individuals are distributed according to: 1) the abilities of individuals to perform certain, specified, tasks; and 2) the degree of regional specialization. The impacts of advances in information technology are examined explicitly in this model. While the relevant theoretical and empirical literature analyses the impact of technological progress with respect to changes in regional productivity, the present model takes an alternative perspective. This model is focused, explicitly, upon changes in the arrival of job offers and employment opportunities. The way in which individuals decide about employment, as an aftermath of changes in information technology, is constructed using the aforementioned framework. Consequently, this approach provides an account for the distribution of ‘human capital’ (from the perspective that individuals acquire jobs in sectors in which they are more productive) across regions, and, by extension, for the persistence of regional inequalities. Regional inequalities are attributed to possible mismatches, leading individuals to accept job offers from sectors in which they are less productive. Simulation experiments, then, complement the theoretical framework, while some preliminary empirical evidence using a sample of NUTS-2 and NUTS-3 regions in Europe, is also presented.

JEL classification: J24, J61, R10

Key words: Regional inequalities, human capital, technological progress, search & matching

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1 Introduction

Regional inequalities constitute one of the most debatable topics in the contemporary economics literature, generating an impressive number of empirical studies (e.g. Dunford, 1993, 1996; Dunford and Smith, 2000; Puga, 1999; Bracalente and Perugini, 2010; Galbraith, 2011, to name but a few). Broadly speaking, the effects of economic progress are not distributed evenly across regions, to the extent that, as Button and Pentecost (1999) aptly point out, '[T]hose in the poorer regions feel resentment at the prosperity of others' (p. 2), a situation which might generate instabilities in social cohesion.

Several factors have been suggested to account for regional inequalities. Predominant among them are human capital and technology. Indeed, it is almost an 'article of faith' that different levels of human capital across regions explain variations in regional disparities (e.g. Benabou, 1994, 1996). However, the existence of interregional differences in the levels of human capital alone, although a necessary condition, is nevertheless not sufficient to provide an adequate explanation for regional inequalities. There is, for example, the possibility of *mismatches* in regional labour markets, an equivalent to the ineffective use of human capital. In this context, the term 'mismatch' refers to the possibility that an individual is employed in a task (or a firm) in which his/her abilities are not fully utilized.

Why do such 'mismatches' occur? The question is simple and straightforward, the answer less so. In this paper we take as a working hypothesis that 'mismatches' can cause regional disparities. It follows, therefore, that the reasons underlying 'mismatches' might provide a valid explanation for the widening disparities across regions. Using the theory of 'equilibrium unemployment' as the vehicle of analysis, mismatches can be explained by the existence of frictions in the labour market. Spatial heterogeneities, informational imperfections and institutional differences in the labour market are included in the list of 'usual suspects' that cause such frictions. On the other hand, however, it is possible for these frictions to be smoothed through innovations, especially in information and communication technology[1], if they

[1] A good example in this respect is the development of the Internet. For a more detailed discussion, see Autor (2001).

increase the contact rate between individuals and firms. In this way, individuals find jobs and tasks corresponding to the 'maximum' of their productive abilities[2], which gradually might eradicate regional disparities. Attention should be drawn, however, to the fact that the *relative* regional concentration of firms[3] acts as a 'barrier' for regions to reap equally the positive effects of fewer mismatches as a result of technological progress.

These considerations will be the starting point for a more elaborate analysis in the next section using a 'search and matching' framework. An important hypothesis in our theoretical construction is that individuals are ex-ante heterogeneous with respect to their productive abilities[4]. This assumption allows for an alternative interpretation of the concept of human capital by considering differences in the productive abilities between individuals with similar socio-economic characteristics (within-group inequality)[5].

The theoretical model will be supplemented by an indicative empirical analysis using a data set from a sample of European regions. In this regard, a critical point should be addressed explicitly. The issue of regional inequalities is broadly concerned with the evolution of regional disparities in welfare through time. The concept of welfare is, however, wide and potentially vague, leading to a number of interpretations. For example, welfare could be addressed in terms of personal disposable income, employment opportunities, environmental conditions, and so forth. Usually, the level of welfare can be approximated by the measure of either *income per capita* or *output per worker*[6]. Given that these measures represent quite different aspects of regional

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[2] It has been argued that the higher contact rate, lower cost, and greater information content provided by this technology could lead to lower frictional unemployment (Mortensen, 2000) and higher average match quality (Krueger, 2000).

[3] The relation between concentration of firms and inequalities at various spatial levels has been examined extensively. Indicative studies include Ellison and Glaeser (1997, 1999), Henderson (1994), Henderson et al. (2001), Braunerhjelm and Borgman (2004). For a theoretical perspective, see Dicken and Lloyd (1990).

[4] Our formulation is based on a model developed by Burdett (2001), which can be thought as an extension of the basic matching model literature introduced by Mortensen (1980), Diamond (1982), and Pissarides (1990). It also captures the insights of the work by Lockwood (1986).

[5] The literature on 'within-group wage inequality' is extensive. For a more comprehensive review, see Acemoglu (2002).

[6] Such data are widely available from official statistical agencies throughout the world.

performance, it is important to be clear about which particular measure is being used and why. For example, output or income per capita is a measure of standard of living in economic terms, while output per worker, the ratio of regional output to regional employment, measures labour productivity. The latter measure is a major component of the differences in the economic performance of regions and a direct outcome of the various factors that determine regional *competitiveness* (Martin, 2001). Labour productivity is, therefore, chosen to be the key variable in both our theoretical and empirical analysis. A further justification of this choice is that our analysis is focused upon technological innovations in conjunction with the utilization of human capital.

The structure of this paper is as follows. First, the structure of the model is outlined in Section 2. The steady-state equilibrium is examined in Section 3 supplemented by a set of simulation experiments in Section 4. In Section 5, the theoretical framework is empirically tested using a data set from a sample of NUTS-2 and NUTS-3 regions from 8 EU countries. Section 6 concludes the paper by suggesting directions for future research.

2 The model

Consider an economy divided into n interrelated spatial units, that is to say, regions. This economy is comprised of a large, fixed number of workers and a fixed number of firms (both normalized to 1). Firms and workers are distributed across the regional system. The region in which an individual is employed is regarded as his region of residence; this simplified assumption means that there is no commuting across regional boundaries[7]. It is also implies that an unemployed individual living in a region, say *A*, who receives a job-offer from another region, say *B*, will move to the latter region, which now becomes his region of residence. The taxonomy (demography) of firms in this model can be described as follows. In each region the fraction of firms is determined exogenously and is equal to p_i, $i = 1 \ldots n$, where $n \geq 2$ ($\sum_{i=1}^{n} p_i = 1$). Each firm can create one job and employ only one worker, and vice

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[7] This is not an unrealistic assumption for large or geographically remote regions. Clearly, there may be the case of commuting between neighbouring regions, in which the region of employment differs from that of residence. However, in this model we assume there is no commuting. This assumption can be justified in the case where individuals attach a high opportunity cost to commuting (in terms of, for example, loss of leisure).

versa. Individuals are ex-ante heterogeneous regarding their productive abilities. In particular, before entering the labour market, each worker is endowed with a $1\times n$ vector of skills[8] $\mathbf{s}=[s_1\, s_2\, \ldots\, s_n]$, where $s_1,\ldots,s_n$ are independent random variables, uniformly distributed over the interval $[0,1]$. Output is produced by an individual employed in a region i, i.e. $\pi_i(\mathbf{s})=s_i$. This implies that each region is specialized in producing a given output utilizing a certain kind of individual's ability. Firms and workers discount the future at the same rate *r*. Unemployed workers meet vacancies at rate m_U (a parameter of a Poisson process). For simplicity, we assume that the value of leisure is equal to zero. The recruiting process has two phases: First, a firm in any region i decides whether to employ, or not employ, an individual with skills ***s***. If the decision is positive, then $w_i(\mathbf{s})$ is determined through a symmetric Nash bargaining process. In the opposite case, individuals remain unemployed. Job destruction, *q*, is determined exogenously. When an employer/worker match is destroyed, then the worker becomes unemployed, while the firm leaves the market and is replaced by an identical clone, which offers a new vacancy. Vacant jobs meet unemployed individuals at rate m_V. The equality between the number of firms and the number of individuals, combined with the exogenously-determined job destruction rate and the constant fraction of region-i firms, implies that $m_V=m_U=m$. The assumptions of the model imply that the meeting rate of a region i vacancy will be equal to mp_i. For a worker with skills $\mathbf{s}$, $U(\mathbf{s})$ is the value of unemployment; $W_i(\mathbf{s})$ is the value of employment in region i; $J_i(\mathbf{s})$ is the value to a firm in region i of filling a job; and V_i is the value of a vacancy in region i.

The Bellman equation for an unemployed individual with skills ***s*** acceptable to employers in every region is:

$$rU(\mathbf{s})=\sum_{i=1}^{n} mp_i[W_1(\mathbf{s})-U(\mathbf{s})]. \qquad (1)$$

[8] This assumption incorporates the notion of skill 'bundling'. A more detailed exposition of this notion, together with its implications in workers' decisions, can be found in the early work of Roy (1951) and its subsequent extensions by Heckman and Sedlacek (1985) and Heckman and Scheinkman (1987).

The flow value of employment in region i is:

$$rW_i(\mathbf{s}) = w_i(\mathbf{s}) + q[U(\mathbf{s}) - W_i(\mathbf{s})]\,. \qquad (2)$$

Assuming that an individual with skills $\mathbf{s}$ is not acceptable to firms in region i, then $W_i(\mathbf{s}) = 0$. Having a vacancy in region i implies an expected discounted profit, which is given by:

$$rV_i = m[E_s \max\{J_i(\mathbf{s}) - V_i, 0\}]\,. \qquad (3)$$

Employers are not aware of $\boldsymbol{s}$ prior to their contact with workers. Therefore, firms form expectations (E_s) about their capital gain from having their vacancy filled.

Clearly, a region i firm hires workers if $J_i(\mathbf{s}) \geq V_i$, with a given $w_i(\mathbf{s})$. The flow value to a job in region i filled by a worker with skills $\mathbf{s}$ is given as follows:

$$rJ_i(\mathbf{s}) = s_i - w_i(\mathbf{s}) + q[V_i - J_i(\mathbf{s})]\,. \qquad (4)$$

Combining equations (1), (2), (3) and (4) we obtain the following set of relations:

$$U(\mathbf{s}) = \frac{m\sum_{i=1}^{n} p_i w_i(\mathbf{s})}{r[r+m+q]} \quad ; \qquad (5)$$

$$W_i(\mathbf{s}) = \left[\frac{1}{r+q} + \frac{mp_i q}{r(r+q)(r+m+q)}\right] w_i(\mathbf{s}) + \sum_{\forall\, j \neq i} \frac{mp_j q w_j(\mathbf{s})}{r(r+q)[r+m+q]} \quad ; \qquad (6)$$

$$J_i(\mathbf{s}) = \frac{s_i - w_i(\mathbf{s}) + qV_i}{r+q} \quad . \qquad (7)$$

A match between a worker, with skills $\mathbf{s}$, and a firm in region i produces a surplus, which is equal to:

$$S_i(\mathbf{s}) = J_i(\mathbf{s}) + W_i(\mathbf{s}) - V_i - U(\mathbf{s}) \quad . \qquad (8)$$

If equations (5) to (7) are inserted into (8), then the expression describing the surplus can be written as follows:

$$(r+q)S_i(\mathbf{s}) = s_i - rV_i - rU(\mathbf{s})\,. \qquad (9)$$

Under the assumption that there is a reservation vector, let $\mathbf{s}_R = [s_{1R}\ s_{2R}\ \ldots\ s_{iR}]$, such that $S_i(\mathbf{s}_R) = 0$, then this implies that a worker with $s_i \le s_{iR}$, is not acceptable to a firm in region i (i.e. $V_i = J_i(\mathbf{s}_R)$). This assumption modifies equation (9) as follows:

$$\frac{s_{iR}}{r} = V_i - U(\mathbf{s}_R). \qquad (10)$$

Bearing in mind that $V_i = J_i(\mathbf{s}_R)$ and (7) and (10), then:

$$U(\mathbf{s}_R) = \frac{w_i(\mathbf{s}_R)}{r}. \qquad (11)$$

Substituting equation (11) into (10) yields $V_i = \dfrac{s_{iR} - w_i(\mathbf{s}_R)}{r}$, and therefore $W_i(\mathbf{s}_R) = U(\mathbf{s}_R) = w_i(\mathbf{s}_R) = 0$. Symmetric Nash bargaining implies that:

$$\frac{1}{2}S_i(\mathbf{s}) = W_i(\mathbf{s}) - U(\mathbf{s}) = J_i(\mathbf{s}) - V_i. \qquad (12)$$

The wage received by a worker with $s_i > s_{iR}$ can be derived from the discussion above. More specifically, using equations (5), (6), (7) and (12), we obtain:

$$w_i(\mathbf{s}) = \frac{m\sum_{\forall\ j\neq i} k_j p_j (s_j - s_{jR}) + \left[2(r+q) + 2mp_i + m\sum_{\forall\ j\neq i} k_j p_j\right] \times (s_i - s_{iR})}{2\left\{2(r+q) + mp_i + m\sum_{\forall\ j\neq i} k_j p_j\right\}}. \qquad (13)$$

In equation (13), $k_j = 0$ if a worker is not accepted in a region-*j* job, i.e. when $s_j \le s_{jR}$. Conversely, if $s_j > s_{jR}$, then $k_j = 1$.

From what has been said in this section, and with the aid of equation (3), it is possible to obtain an expression for s_{iR}: namely, the reservation productivity of firms located in any region i. Thus,

$$s_{iR} = m \times \sum_{(k_1,k_2,\ldots,k_{-i},k_{+i},\ldots,k_n)\in\{0,1\}^{n-1}} \left\{ \begin{array}{l} \underbrace{\int_{s_{nR}k_n}^{s_{nR}+k_n(1-s_{nR})} \cdots \int_{s_{-iR}k_{-i}}^{s_{-iR}+k_{-i}(1-s_{-iR})} \int_{s_{iR}}^{1} \int_{s_{+iR}k_{+i}}^{s_{+iR}+k_{+i}(1-s_{+iR})} \cdots \int_{s_{1R}k_1}^{s_{1R}+k_1(1-s_{1R})}}_{n\ terms} \left[\frac{s_i - w_i(\mathbf{s}) + q(s_{iR}/r)}{r+q} - \frac{s_{iR}}{r} \right] \times \\ f_{k_1,\ldots,k_{-i},k_{+i},\ldots k_n}(\mathbf{s}) \underbrace{ds_1 \ldots ds_n}_{n\ terms} \end{array} \right\}, \quad (14)$$

where $f_{k_1,\ldots,k_{-i},k_{+i},\ldots k_n}(\mathbf{s})$ is the steady-state probability density distribution function of skills among unemployed workers.

3 Steady-state equilibrium

Let $\lambda_t(\mathbf{s})$ and $g_t(\mathbf{s})$ be the densities at a given point in time (*t*) of, respectively, unemployed and employed individuals with a skill vector $\mathbf{s}$. Given the assumptions of the model, the two densities are subject to the restriction $\lambda_t(\mathbf{s}) + g_t(\mathbf{s}) = 1$. If a group of individuals rejected by firms in some regions (i.e. in a subset of the *n* regions) and accepted in the remaining regions, then, during an infinitely small time interval dt, the unemployed individuals in this group change their status to employment at a rate $m\left[\sum_{i=1}^{n} k_i p_i\right] dt$, where $k_i = 0$, if a worker is not accepted in a region i job, i.e. when $s_i \le s_{iR}$. In the opposite case ($s_i > s_{iR}$), $k_i = 1$. Conversely, the employed individuals of the group become unemployed at a rate qdt. Therefore, the evolution of employed individuals within the group in question is given by $m\left[\sum_{i=1}^{n} k_i p_i\right] \times \lambda_t(\mathbf{s})dt - qg_t(\mathbf{s})dt$.

The evolution of unemployed individuals can be obtained in a similar way. In steady-state, the flow of workers out of unemployment should be equal to the flow of workers back to unemployment. Therefore, the steady-state value of unemployment in the economy portrayed in our model is given by:

$$u = \sum_{(k_1,\ldots,k_n)\in\{0,1\}^n} \left\{ \underbrace{\int_{s_{nR}k_n}^{s_{nR}+k_n(1-s_{nR})} \cdots \int_{s_{1R}k_1}^{s_{1R}+k_1(1-s_{1R})}}_{n-terms} \frac{q}{q + m\left[\sum_{i=1}^{n} k_i p_i\right]} \underbrace{ds_1 \ldots ds_n}_{n-terms} \right\}. \quad (15)$$

The analysis thus far implies that:

$$f_{k_1,\ldots,k_{-i},k_{+i},\ldots k_n}(\mathbf{s}) = \frac{q}{\left\{q + m\left[p_i + \sum_{\forall j \neq i} k_j p_j\right]\right\} \times u} \quad , \tag{16}$$

where $k_j = 0$, if a worker is not accepted in a region j job, i.e. when $s_j \leq s_{jR}$, while if $s_j > s_{jR}$, then $k_j = 1$.

Inserting equation (16) into (14), we obtain a system of $n \times n$ equations. The solution of this system determines the vector of reservation productivities in steady-state: $\mathbf{s}^*{}_R = [s^*{}_{1R} \; s^*{}_{2R} \; \ldots \; s^*{}_{iR}]$.

The equilibrium output per worker is defined as the ratio $y_i = \dfrac{Y_i}{N_i}$, where the expected total output of region i in equilibrium is defined as:

$$Y_i = \sum_{(k_1,k_2,\ldots,k_{-i},k_{+i},\ldots,k_n)\in\{0,1\}^{n-1}} \left\{ \underbrace{\int_{s^*{}_{nR}k_n}^{s^*{}_{nR}+k_n(1-s^*{}_{nR})} \cdots \int_{s^*{}_{-iR}k_{-i}}^{s^*{}_{-iR}+k_{-i}(1-s^*{}_{-iR})} \int_{s^*{}_{iR}}^{1} \int_{s^*{}_{+iR}k_{+i}}^{s^*{}_{+iR}+k_{+i}(1-s^*{}_{+iR})} \cdots \int_{s^*{}_{1R}k_1}^{s^*{}_{1R}+k_1(1-s^*{}_{1R})}}_{n\ terms} s_i \times m \times \frac{p_i}{q + m\left(p_i + \sum_{\forall j \neq i} k_j p_j\right)} \underbrace{ds_1 \ldots ds_n}_{n\ terms} \right\}$$

, while the population of workers in a region i in equilibrium is given by:

$$N_i = \sum_{(k_1,k_2,\ldots,k_{-i},k_{+i},\ldots,k_n)\in\{0,1\}^{n-1}} \left\{ \underbrace{\int_{s^*{}_{nR}k_n}^{s^*{}_{nR}+k_n(1-s^*{}_{nR})} \cdots \int_{s^*{}_{-iR}k_{-i}}^{s^*{}_{-iR}+k_{-i}(1-s^*{}_{-iR})} \int_{s^*{}_{iR}}^{1} \int_{s^*{}_{+iR}k_{+i}}^{s^*{}_{+iR}+k_{+i}(1-s^*{}_{+iR})} \cdots \int_{s^*{}_{1R}k_1}^{s^*{}_{1R}+k_1(1-s^*{}_{1R})}}_{n\ terms} m \times \frac{p_i}{q + m\left(p_i + \sum_{\forall j \neq i} k_j p_j\right)} \underbrace{ds_1 \ldots ds_n}_{n\ terms} \right\}$$

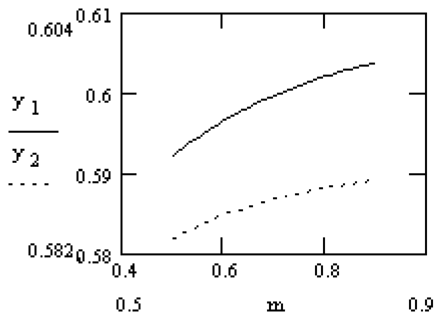
.

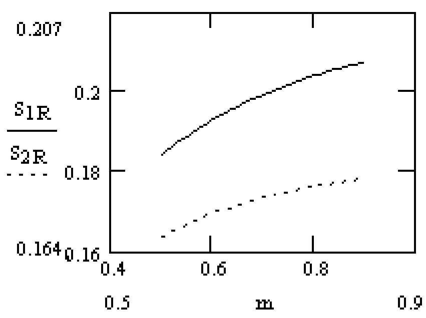
Having established a description of the steady-state equilibrium, the following section examines the issue of regional inequalities, expressed in terms of labour productivity (output per worker) implied by our model. The analysis is conducted using some illustrative simulation experiments.

4 Regional inequalities in labour productivity: simulation experiments

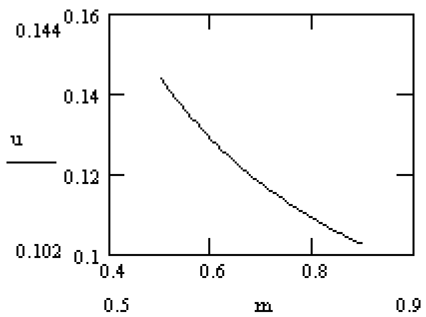
Consider first a simulation experiment for two regions ($n = 2$). Despite the restrictive nature of this experiment, it allows for an indication of the evolution of relative regional labour productivities. The simulation exercise is conducted for certain parameter values, i.e. $r = 0.1$ and $q = 0.1$, while the m takes values from the range 0.5 to 0.9. A random selection process[9] is applied in order to determine the values of the p_i's.

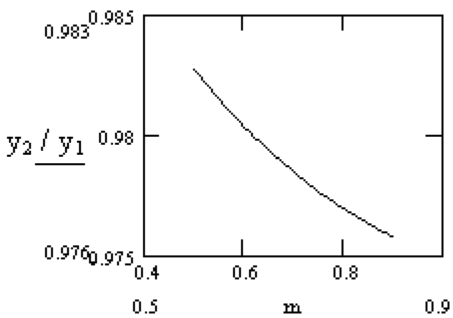
p = 0.36





(a) **(b)**





(c) **(d)**

Fig. 1. (a) Labour productivity in Regions 1 and 2, **(b)** Reservation productivity in Regions 1 and 2, **(c)** Unemployment rate, **(d)** Relative regional labour productivity [p = 0.36]

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[9] Random draws from a uniform distribution between 0 and 1.

p = 0.54

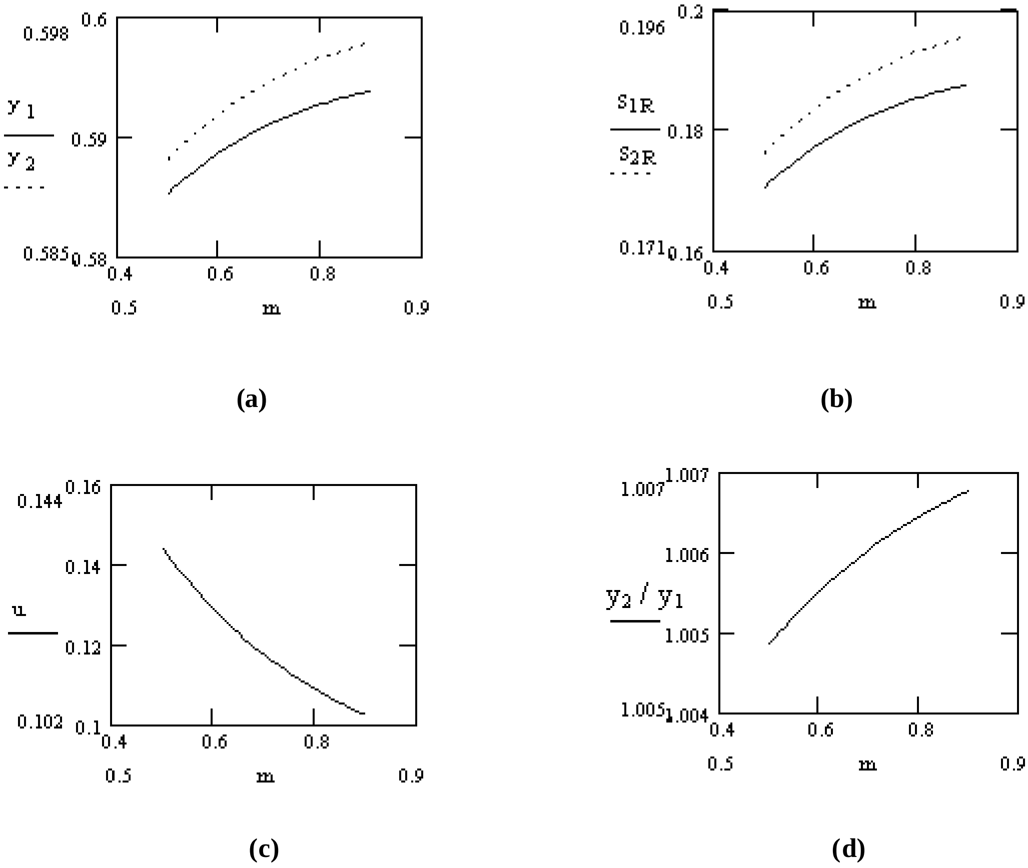
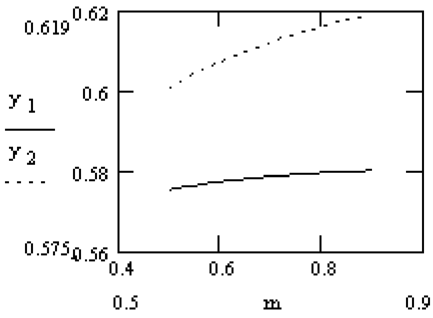
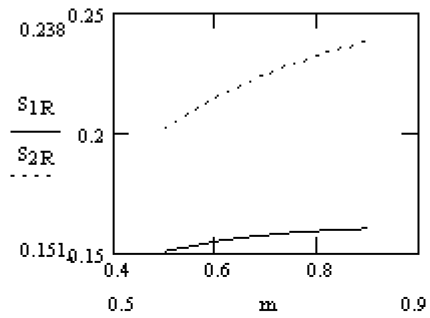


Fig. 2. (a) Labour productivity in Regions 1 and 2, **(b)** Reservation productivity in Regions 1 and 2, **(c)** Unemployment rate, **(d)** Relative regional labour productivity [p = 0.54]

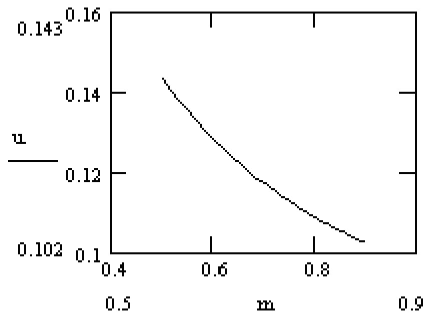
***p* = 0.81**



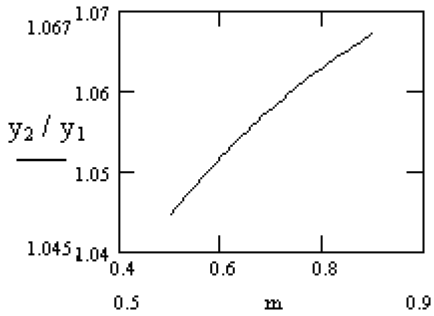
(a)



(b)



(c)



(d)

Fig. 3. (a) Labour productivity in Regions 1 and 2, **(b)** Reservation productivity in Regions 1 and 2, **(c)** Unemployment rate, **(d)** Relative regional labour productivity [p = 0.81]

It is clear from Figures 1 to 3 that both labour and reservation productivities (unemployment) increase (decrease) as the meeting rate increases. It is also noticeable that the relative regional labour productivity diverges from 1 as *m* increases; a fact which suggests widening disparities across regions. Estimation of the Coefficient of Variation (CV) supports this argument (Figure 4).

***p* = 0.36** ***p* = 0.54** ***p* = 0.81**

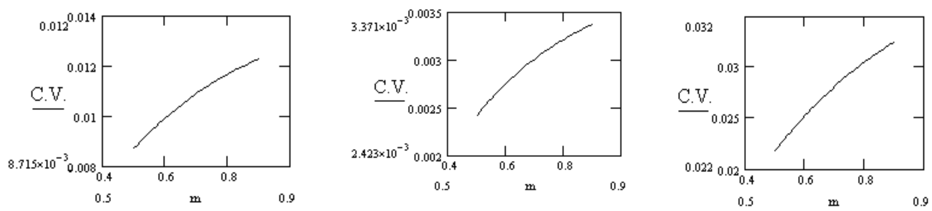


Fig. 4. Evolution of regional inequalities in labour productivity

A more detailed simulation experiment using $n = 5$, provides further support to the argument put forward by our model (Table 1).

Table 1. Results of simulation experiments on the basis of a taxonomy of firms (n=5)

	p_1=0.194, p_2=0.049, p_3=0.191, p_4=0.534, p_5=0.032				p_1=0.324, p_2=0.227, p_3=0.175, p_4=0.105, p_5=0.169				p_1=0.047, p_2=0.347, p_3=0.179, p_4=0.084, p_5=0.34			
	m=0.65	m=0.75	m=0.85	m=0.9	m=0.65	m=0.75	m=0.85	m=0.9	m=0.65	m=0.75	m=0.85	m=0.9
s_{1R}	0.2145	0.2238	0.2314	0.2348	0.2028	0.2108	0.2176	0.2205	0.2238	0.2345	0.2436	0.2477
s_{2R}	0.2267	0.2379	0.2474	0.2517	0.2097	0.2185	0.2259	0.2291	0.2013	0.2091	0.2155	0.2184
s_{3R}	0.2148	0.2241	0.2318	0.2351	0.2133	0.2226	0.2303	0.2337	0.2142	0.2235	0.2313	0.2347
s_{4R}	0.1866	0.1928	0.1979	0.2001	0.2181	0.2279	0.2361	0.2398	0.2213	0.2316	0.2403	0.2441
s_{5R}	0.2280	0.2394	0.2492	0.2536	0.2138	0.2230	0.2308	0.2342	0.2019	0.2097	0.2162	0.2190
u	0.1799	0.1629	0.1491	0.1431	0.1727	0.1555	0.1417	0.1357	0.1759	0.1588	0.1449	0.1389
y_1	0.6073	0.6119	0.6157	0.6174	0.6014	0.6054	0.6088	0.6103	0.6119	0.6173	0.6218	0.6238
y_2	0.6133	0.6189	0.6237	0.6259	0.6048	0.6092	0.6129	0.6145	0.6007	0.6045	0.6078	0.6092
y_3	0.6074	0.6120	0.6159	0.6176	0.6067	0.6113	0.6151	0.6169	0.6071	0.6118	0.6156	0.6173
y_4	0.5933	0.5964	0.5989	0.6000	0.6090	0.6139	0.6181	0.6199	0.6106	0.6158	0.6201	0.6221
y_5	0.6140	0.6197	0.6246	0.6268	0.6069	0.6115	0.6154	0.6171	0.6009	0.6048	0.6081	0.6095
$I_{C.V.}$	1.3719	1.5317	1.6735	1.7385	0.4728	0.5228	0.5658	0.5850	0.8717	0.9761	1.0690	1.1117
I_{R-S}	0.4533	0.5028	0.5496	0.5726	0.1756	0.1940	0.2091	0.2170	0.3589	0.4053	0.4379	0.4562
I_G	0.6246	0.7009	0.7717	0.8045	0.2285	0.2530	0.2749	0.2832	0.4236	0.4793	0.5206	0.5425
I_{TH}	0.0075	0.0094	0.0113	0.0122	0.0009	0.0011	0.0013	0.0014	0.0030	0.0038	0.0045	0.0049
I_A	0.0038	0.0047	0.0056	0.0061	0.0004	0.0005	0.0006	0.0007	0.0015	0.0019	0.0023	0.0025

Notes: Figures were obtained by simulation using the "Mathematica" software. The parameters r and q are assumed to be equal to 0.1. The values for the taxonomy of firms were obtained by random draws from a uniform distribution between 0 and 1. $I_{C.V.}$, I_{R-S}, I_G, I_{TH}, I_A denote the Coefficient of Variation, Ricci-Schutz coefficient, Gini coefficient, Theil's entropy measure and Atkinson's measure (parameter=0.5), respectively. The aforementioned measures of inequality are expressed in percentages, and were obtained using the 'R' software, with the exception of the Coefficient of Variation, for which the "Mathematica" software was deployed.

The set of inequality-measures in this simulation exercise includes some of the most widely used in the relevant literature (e.g. the Gini coefficient, the Theil entropy index, etc), together with some indices, such as the Ricci-Schutz coefficient. The use of these indices as measures of inequalities is rather rare. The reason for such treatment is that each measure has certain limitations and shortcomings[10]. Therefore, if different measures suggest an increasing tendency in inequalities of labour productivity among regions, then this can be considered as a validation of the arguments put forward in our model.

As the meeting rate between individuals and firms follows a positive trend, the simulation experiment in Table 1 allows three immediate conclusions to be reached. First, the reservation productivities increase. Second, the unemployment rate of the economy as a whole reduces. Third, the inequality measures indicate an increase in the disparities of the distribution of output per worker across regions. It is important to note, that these conclusions hold for various degrees of spatial concentration of firms, as indicated by the p_i's in each case. It is also evident that a high degree of 'concentration' goes hand-in-glove with high levels of regional inequality. Of course, it is easy to grasp that a zero degree of firm's concentration across space (i.e. the p_i's are equal) will lead to a perfect equality in terms of regional labour productivity.

At this juncture, it is instructive to provide a description of the mechanisms in our theoretical construction that shape regional inequalities. A high number of firms located in a region is associated with a low level of reservation productivity. This is quite reasonable, if we consider a '*crowding-out*' effect, in the sense that the degree of competition increases with the number of firms in a particular region. In terms of our model, this reduces the value of holding a vacancy, and firms in that region adopt a less picky attitude[11]. As the probability of an individual 'meeting' a vacancy in any region of the system (m) increases, following improvements in technology (e.g. internet), positive changes in the reservation productivity are realized in the selection process of firms. This is equivalent to a higher degree of competition among individuals, and firms, consequently, become pickier. In this context a critical issue arises. What are the effects of increases in the meeting rate upon the degree of regional inequalities? Before answering this cumbersome question, some additional

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[10] The reader interested in these issues can refer, for instance, to a thoughtful review by Cowell (2000), while a critical treatment of the inequality measure at the spatial level can be found in Rietveld (1991).

[11] The capital gain of a vacancy to become filled is equal to the value of a filled-job, less the value of holding a vacancy. Therefore, in the case of a low value of holding a vacancy, firms obtain a capital gain from filling a vacancy using more elastic criteria in their recruitment process.

remarks are necessary. To be more precise, a 'mismatch' occurs when an individual endowed with a vector of skills $\mathbf{s} = [s_1\, s_2\, \ldots\, s_n]$ is employed by any firm located in a region i, where his/her productivity is $\mathbf{s}_i \neq \max[s_1\, s_2\, \ldots\, s_n]$. Greater levels of reservation productivity due to increases in the meeting rate serve to mitigate the probability of a mismatch taking place. This is reflected by increases in regional output. However, and this is a point that needs emphasising, output grows faster in regions in which firms with higher reservation productivity are located, i.e. regions with a relatively lower number of firms. On the other hand, regions where firms with lower reservation productivity are located will attract more individuals. Given the aforementioned analysis, the natural outcome is a worsening of regional inequalities when the meeting rate is enhanced by advances in technology. At the same time, a decrease in unemployment in the economy as a whole is taking place. This is the outcome of two effects: a 'direct' and an 'indirect' effect. While an increase in the meeting rate reduces unemployment (the 'direct' effect), firms acquire a picky attitude (the 'indirect' effect), increasing unemployment. The former effect seems to dominate the latter, and consequently unemployment in the economy as a whole decreases[12].

5 Empirical application

This section puts the conceptual model developed thus far into operational terms with the use of a formal econometric model. The application is carried out for the period 1995 to 2006. Data on regional labour productivity were constructed using regional Gross Domestic Product (GDP) and employment[13], at the NUTS-2 and NUTS-3 levels. To be more precise, the sample includes 105 NUTS-2 regions from eight countries of the EU; these are France (22 regions), Germany (16 regions), Ireland (2 regions), Italy (21 regions), Portugal (7 regions), Spain (19 regions), Sweden (8 regions), and the UK (10 regions)[14]. The choice of the NUTS-2 level is justified on

[12] Burdett (1981) claims, however, that under certain conditions, the increase in reservation match quality can fully offset the unemployment reductions that would otherwise accrue.

[13] GDP is expressed in millions of US$ at constant PPP and constant (real) prices; with base year 2000. Employment is measured in persons employed in all sectors of a regional economy. Both time series were obtained from the OECD database.

[14] Because of a break in the regional labour force series, two UK regions were excluded (Scotland and Northern Ireland).

the grounds that the EU uses this level as the 'geographical level at which the persistence or disappearance of unacceptable inequalities should be measured' (Boldrin and Canova, 2001, p. 212). The empirical analysis is supplemented by a more extensive sample, which includes 521 NUTS-3 regions: France (96 regions), Germany (90 regions), Ireland (8 regions), Italy (99 regions), Portugal (30 regions), Spain (49 regions), Sweden (21 regions) and the UK (128 regions)[15]. A final point should be noted. National data on the meeting rate (*m*), measured in percentages were obtained from Elsby et al. (2008).

Our argument can be specified in testable terms by a cross-section fixed-effects and a one-way (cross-section) random-effects model[16], given by equations (17.1) and (17.2), respectively.

$$RI^{\mu}_{c,t} = \delta + \beta_1 m_{c,t} + \psi_c + \varepsilon_{c,t}, c = 1,\ldots,M;\; t = 1,\ldots,T;\; \mu = C.V., R-S, G, TH, A. \quad (17.1)$$

$$RI^{\mu}_{c,t} = \alpha + \gamma_1 m_{c,t} + \omega_c + \varepsilon_{c,t}, c = 1,\ldots,M;\; t = 1,\ldots,T;\; \mu = C.V., R-S, G, TH, A. \quad (17.2)$$

In equations (17.1) and (17.2) the subscript *c* refers to a given country; *t* denotes a specific time-period; ψ_c is the unobserved individual effect; ω_c stands for the unobserved individual-specific random effects with $\sim IID(0,\sigma^2_{\omega})$; and $\varepsilon_{c,t}$ is the remaining error term distributed as $\sim IID(0,\sigma^2_{\varepsilon})$. The dependent variable (RI) measures the extent of regional inequalities in each country using the five selected indices of inequalities (μ), expressed in percentages. The choice between the two specifications is made using a methodology proposed by Hausman (1978), and subsequently extended by Baltagi (2005). The results obtained appear in Tables 2 and 3.

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[15] Because of missing data on the regional labour force statistics and the economic accounts of the OECD database, some NUTS-3 regions were excluded: the six German DE31-Altmark, DE34-Halle/S., DE57-Westsachsen, DE58-Oberes Elbtal/Osterzgebirge, DE59-Oberlausitz-Niederschlesien, DE61-Südwestsachsen; the eight Italian ITG25-Sassari, ITG26-Nuoro, ITG27-Cagliari, ITG28-Oristano, ITG29-Olbia-Tempio, ITG2A-Ogliastra, ITG2B-Medio Campidano, ITG2C-Carbonia-Iglesias; the ten Spanish ES531-Eivissa y Formentera, ES532-Mallorca, ES533-Menorca, ES703-El Hierro, ES704-Fuerteventura, ES705-Gran Canaria, ES706-La Gomera, ES707-La Palma, ES708-Lanzarote, ES709-Tenerife; the five British UKM50-Aberdeen City and Aberdeenshire, UKM61-Caithness & Sutherland and Ross & Cromarty, UKM62-Inverness & Nairn and Moray Badenoch & Strathspey, UKM63-Lochaber Skye & Lochalsh Arran & Cumbrae and Argyll & Bute, UKM64-Eilean Siar (Western Isles).

[16] The random-effects specification is based on the assumption that the explanatory variables are uncorrelated with the random effects.

Table 2. Specification tests, NUTS-2 Regions

Measure of Inequality	Correlated Random-Effects-Hausman Test			Cross-section Random-Effects Test Comparisons			
	χ^2 Statistic	Degrees of Freedom	Prob. [P-value]	Fixed	Random	Var (Diff.)	Prob. [P-value]
$RI_{C.V.}$	4.148	1	0.042	0.437	0.396	0.000	0.042
RI_{R-S}	0.017	1	0.896	-0.091	-0.105	0.001	0.896
RI_{G}	6.859	1	0.009	0.161	0.131	0.000	0.009
RI_{TH}	4.723	1	0.030	0.043	0.035	0.000	0.030
RI_{A}	4.706	1	0.030	0.021	0.017	0.000	0.030

Note: In the Correlated Random Effects-Hausman Test the null hypothesis points to the superiority of the random-effects specification. The Cross-section Random Effects Test Comparisons use the coefficient estimates from both the random and the fixed effects estimators, together with the variance of the difference between the random and fixed effects coefficients. In this case, the null hypothesis is that the variance of the difference is zero.

Table 3. Specification tests, NUTS-3 Regions

Measure of Inequality	Correlated Random-Effects-Hausman Test			Cross-section Random-Effects Test Comparisons			
	χ^2 Statistic	Degrees of Freedom	Prob. [P-value]	Fixed	Random	Var (Diff.)	Prob. [P-value]
$RI_{C.V.}$	2.103	1	0.147	0.187	0.164	0.000	0.147
RI_{R-S}	1.800	1	0.180	0.045	0.039	0.000	0.180
RI_{G}	1.900	1	0.168	0.067	0.057	0.000	0.168
RI_{TH}	1.018	1	0.313	0.014	0.011	0.000	0.313
RI_{A}	1.034	1	0.309	0.007	0.005	0.000	0.309

Note: In the Correlated Random Effects-Hausman Test the null hypothesis points to the superiority of the random-effects specification. The Cross-section Random Effects Test Comparisons use the coefficient estimates from both the random and the fixed effects estimators, together with the variance of the difference between the random and fixed effects coefficients. In this case, the null hypothesis is that the variance of the difference is zero.

With the exemption of the Ricci-Schutz coefficient, the tests referring to the NUTS-2 division indicate a preference towards the fixed-effects model (Table 2). Conversely, both tests for the NUTS-3 regions point towards the random-effects specification (Table 3). This is somehow expected, given the following arguments. If sampled cross-sectional units were drawn from a large population, then individual specific constant terms were considered as randomly distributed: a condition applicable to the NUTS-3 regions, which include a larger number of observations. Furthermore, the fixed-effects model might be more suitable for the NUTS-2 regions, given that, for each country in our sample, their size is somehow homogeneous. On the other hand, a considerable degree of heterogeneity characterizes the NUTS-3 regions. Tables 4 and 5 report the estimation results for the NUTS-2 and NUTS-3 regions, respectively[17].

Table 4. Meeting rate and regional inequalities, EU NUTS-2 Regions, 1995-2006

	Dependent variables				
	$RI_{C.V.}$	RI_{R-S}	RI_{G}	RI_{TH}	RI_{A}
Independent variables	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	10.048*** (0.771)	6.306*** (0.987)	5.025*** (0.323)	0.489*** (0.093)	0.246*** (0.045)
m	0.437*** (0.079)	-0.105 (0.118)	0.161*** (0.033)	0.043*** (0.009)	0.021*** (0.005)
Total pool (unbalanced) Obs.	95	95	95	95	95
R^2	0.927	0.026	0.908	0.869	0.873
Adjusted R^2	0.920	0.015	0.900	0.857	0.861
Effects specification					
Cross-section random SD/Rho		2.187/0.666			
Idiosyncratic random SD/Rho		1.548/0.334			

Notes: In the fixed-effects specification, the estimation method is pooled least squares with Cross-section SUR (PCSE) standard errors & covariance, whereas the random-effects model is estimated by pooled EGLS (cross-section random effects) with Cross-section SUR (PCSE) standard errors & covariance. Rho indicates the respective portion of the sum of Standard Deviations (SD) squared. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 5. Meeting rate and regional inequalities, EU NUTS-3 Regions, 1995-2006

	Dependent variables				
	$RI_{C.V.}$	RI_{R-S}	RI_{G}	RI_{TH}	RI_{A}
Independent variables	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	13.510*** (1.916)	5.311*** (0.888)	7.327*** (1.132)	1.153*** (0.387)	0.566*** (0.190)
m	0.164*** (0.061)	0.039 (0.024)	0.057* (0.030)	0.011 (0.010)	0.005 (0.005)
Total pool (unbalanced) Obs.	94	94	94	94	94
R^2	0.042	0.019	0.021	0.006	0.006
Adjusted R^2	0.031	0.008	0.010	-0.005	-0.004
Effects specification					
Cross-section random SD/Rho	7.276/0.951	2.938/0.961	3.811/0.956	1.284/0.947	0.626/0.946
Idiosyncratic random SD/Rho	1.646/0.049	0.588/0.038	0.813/0.043	0.305/0.053	0.149/0.054

Notes: The estimation method is pooled EGLS (cross-section random effects) with Cross-section SUR (PCSE) standard errors & covariance. Rho indicates the respective portion of the sum of Standard Deviations (SD) squared. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Estimating the model for the NUTS-2 regions yields a positive and statistically significant coefficient for the explanatory variable (m) for four measures of inequality. A negative relation between regional inequalities and the meeting rate is

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[17] Panel unit root tests were also performed to examine the hypothesis of spurious results. The associated tests indicate that the variables can be used in levels. The relevant results are available upon request.

indicated when the Ricci-Schutz coefficient is used, although, it is statistically insignificant. For each measure of inequality applied at the NUTS-3 level, the coefficient of the meeting rate is positive. However, statistically significant coefficients were obtained only for two measures: the Gini coefficient and the Coefficient-of-Variation. In short, when the model is applied at the NUTS-2 level, m has a statistically significant impact on most of the measures of regional inequalities. This can be partly explained by the fact that the meeting rate refers to the *national* level. This level is closer to the aggregation of the NUTS-2 regions than to that of the NUTS-3 regions.

At this point, an important observation should be made. The assumption in our theoretical model, that there is no commuting across regional boundaries, seems to be apt at the NUTS-2 level, where there is less probability for commuting to take place. In this light, the NUTS-2 regions can be conceived as a 'yardstick' for the predictions of our model.

Summarizing the main findings of the empirical application, it might be argued that our preliminary empirical exercise provides ample support for the simulation experiments of the model developed in Section 2: an increase in the meeting rate, in fact, enhances regional inequalities.

6 Conclusion

It is beyond argument that, although there is a vast and fast growing literature on the relation between regional inequalities and technology, the impact of technological progress, encapsulated in terms of smoothing frictions in regional labour markets, has so far received limited attention. To examine this possibility, a model of regional inequalities has been developed in this paper. Regional inequalities are attributed to the degree to which the regional concentration of firms shapes their recruitment process, as technological innovations improve the meeting rate between individuals and firms. This view is tested for a sample of NUTS-2 and NUTS-3 regions of eight European countries. An important conclusion to emerge from the empirical application of this model is that technology, as reflected in reduction of frictions in the labour market, has negative effects on the regional distribution of labour productivity: namely, regional disparities become more intense. Clearly, such results should be considered no more than indicative and call for more profound field work.

While the empirical results are significant for the case of the European regions in their own right, they should nevertheless be placed in perspective. Indeed, it is not claimed that the foregoing analysis has provided an exhaustive account of all the factors that shape the pattern of regional inequalities. Moreover, improving the theoretical model by adding more assumptions, such as on-the-job search, free entry of firms, and so forth, will add an extra injection to understanding of the complex phenomenon of regional disparities. Against this background, an important contribution of this paper is to encourage further work on the impact of underlying mechanisms of technological progress upon regional inequalities.

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