Innovation and Human Capital: Theory and evidence from Italy

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January 8, 2014

Abstract

The aim of this paper is to study the relationship between skilled labor and innovation. I build a continuous time model à la Redding (1996) in which workers' investment in human capital and firms' investment in R&D display productive and strategic complementarities. On the one hand, high recruiting costs associated to scarcity of skilled labor weakens the incentive to innovate, on the other hand, lower innovation and less productive technology reduce the economic return to human capital. Strong labor market frictions might therefore generate multiple equilibria, possibly trapping the economy in a "low skills-low innovation" equilibrium. I structurally estimate the model to fit European data in order to shed some light on the determinants of Italian gap in both educational achievement and innovation activity. I find that Italy differs from other European countries in two dimensions: i) a more costly matching process in the labor market, ii) a specialization toward unskilled labor intensive sectors. The former generates a vicious circle between demand and supply of skilled labor that can explain, *per se*, almost half of differences in innovation rates, while the latter can account for less than 30% of the gap.

Keywords: innovation, skilled labor, human capital, R&D expenditure

JEL Classification: J21, J22, H31

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1 Introduction

The available empirical evidence show how both innovative activity and human capital investment are less intense in Italy than in all other leading economies. For example, only 1.3 per cent of Italian GDP was spent in R&D, against an average of 1.9 per cent in the Euro Area; similar gaps can be observed by looking at the share of firms that invest in R&D, or at the propensity to patent. Italy also displays the lowest share of graduates amongst all major European countries: less than one fifth of workers holds a college degree, against almost one third in the Euro Area. The causal relationship between these two economic variables, innovation and human capital, can actually go both ways. On the one hand, lack of skilled labor might reduce firms' incentive to innovate; on the other hand, low technological growth can curb economic returns to human capital. The aim of this paper is to understand whether in Italy only one of these two economic mechanisms is at work or their interaction trapped the economy in a "low skill-low innovation" equilibrium.

We estimate a dynamic model in which workers invest in human capital to acquire skills and firms invest in R&D to increase their total factor productivity. The two types of investment display not only productive but also strategic complementarity: the former implies that firms with a larger share of skilled labor enjoy higher productivity gains from innovation, while the latter follows from labor market frictions, namely recruiting costs decrease as the number of workers looking for a job increases. From a theoretical point of view, we find that multiple equilibria and "low skill-low innovation" traps can arise when the matching process between labor demand and supply is very costly or when the production function exhibits high substitutability between the two types of labor input. In a frictionless market, with no significant recruiting costs, labor demand , and consequently innovation incentive, would be independent of labor supply; likewise high complementarities require a constant share of skilled labor. I estimate the model with both household and firms' survey data from four leading European countries: Italy, France,Spain and Germany. The model fits the data and is able to explain the differences in innovation rates without assuming any significant difference in efficiency of the human capital accumulation process (i.e. college quality) or production technologies.

In particular I find that Italy differs significantly from the others countries in two dimensions. First Italian labor market is characterized by a more costly matching process: a 1% increase of the labor supply reduces the associate recruiting cost by around 2% against 1% in Spain and 0.2% in France and Germany. Second, Italian system exhibits a bias toward sectors with a relatively low skilled labor productivity. I successively perform a counterfactual simulation, and I find that these two factors can explain respectively almost 50% and 30% of the Italian gap in graduation and innovation rate. While a vast literature investigated the effect of firms' size on skilled labor demand (Black et al. (1999), Fulghieri et al. (2009), Amatori et al.(2011), this paper identifies a possible source of reverse casuality: low human capital investment has a negative impact on firms' size as it reduces average labor productivity. I find that with a skilled labor intensity comparable to European level, Italy could almost close the its gap with France in terms of number of workers per enterprise. In the 90's Acemoglu (1994) and Redding (1996) built models integrating in a single framework endogenous innovation and human capital accumulation - until then studied only separately with the notable exception of Phelps and Nelson (1996) - starting a new rich branch of literature (Blackburn et al. (2000), Zeng (2003), Bucci (2003), Tournemain et al. (2012), Scicchitano (2010), Stadler (2012)). On the empirical side, many authors investigated complementarities between innovation and human capital at a micro level, employing reduced form econometric techniques; to the best of my knowledge no attampt to estimate a structural macro model, testing the hypothesis of "low skills-low innovation" traps has been made yet. The remainder of the paper is organized as follows. In section 1) the theoretical model is built and solved while in section 2) data and possible identification strategies are presented. Section 3) is devoted to discussion of the results and, finally section 4) is reserved to conclusions. Technical Appendix follows.

2 The Model

We use a continuous time model la Redding **?** in which workers invest in human capital to acquire skills and firms invest in R&D to acquire a productivity-augmenting innovation. The two types of investment display not only productive but also strategic complementarities: on the one hand scarcity of the former might weaken firm's inventive to innovate because of higher recruitment cost of skilled workers, on the other hand low innovation rate reduces more intensively productivity of skilled labor, diminishing therefore economic return of human capital. While in the appendix the full dynamics will be derived, we are now interested in solving the model in steady state, and therefore we omit the time index t in order to keep a lighter notation. All technical details are in Appendix A.

2.1 Workers

Each period a measure γ of new workers are born: at birth each worker is unskilled ($i = u$) and decides whether to invest in human capital and acquire skills ($i = s$) paying a multiplicative utility cost $p \in [0, 1]$, randomly distributed with cumulative function $G(p)$. The labor market is structured as in the classical model: job offers accrue to an unemployed workers at an endogenous Poisson rate λ_i, while employed workers receives a flow of earnings w_i and are laid off a constant rate δ when the firm exits the market. Finally each worker faces, unconditionally on her employment status, a death rate γ so that the total measure of workers is constantly equal to one. For simplicity we assume linear utility function, no saving technologies and a constant discount rate $r = 0$ The expected value of unemployed V_i, employed workers W_i, can be expressed as:

$$\gamma V_i = \lambda_i(W_i - V_i) + \dot{V}_i \tag{1}$$

$$\gamma W_i = w_i + \delta(V_i - W_i) + \dot{W}_i \tag{2}$$

$$\tag{3}$$

At birth each worker chooses wether to invest in human capital by solving:

$$\max\{[V_s - p, V_u\}, \tag{4}$$

2.2 Firms

There is a measure one of firms producing an homogenous final good with the a CES production function $\theta F(s,u) = \theta[hs^\rho + u^\rho]^{\frac{1}{\rho}}$ where, with an abuse of notation, s and u denote the number of respectively skilled and unskilled workers employed, θ is the traditional total factor productivity and h is the relative efficiency of skilled to unskilled labor. We assume the former to be, *per se*, more productive, that is $h > 1$. Each period a measure δ of new firms enters the market and a measure δ of existing firms exits it. At entry each firm pays (i) a cost $k(q)$ to set its capacity q, that is the maximum number of workers able to operate in its plant $(s + u \leq q)$ (ii) an R&D cost per worker $c(\theta)$ to implement a technology θ. Finally the the recruiting process is costly: firms bear a cost μ_i to fill a single vacancy for a i type worker. Firm will then maximize:

$$\Pi(\theta, q, s, u) = \int_0^\infty e^{-\delta t} \left[\theta F(S, U) - w_s s - w_u u - \mu_s v_s - \mu_u v_u\right] \tag{5}$$

$$\dot{s} = -\gamma s + v_s; \dot{u} = -\gamma u + v_u; u + s \leq q \tag{6}$$

while innovation and capacity decision can be expressed respectively as:

$$\max_\theta \left[\Pi_h(\theta, q) - c(\theta)q\right] \tag{7}$$

$$\max_q \left[\Pi_h(\theta, q) - k(q)\right] \tag{8}$$

$$\tag{9}$$

where $c(q)$ and $k(q)$ are increasing and convex functions.

2.3 Wage Setting and Labor Market frictions

Under a standard assumption of continuous negotiation between firms and workers wages are proportional to marginal productivity:

$$w_i = \alpha\theta^j F_i; \text{ i=s,u} \tag{10}$$

As discussed earlier we want this model to capture the strategic complementarities between innnovation and human capital, through frictions in the labor market. We assume that recruiting cost is a decreasing convex function of the number or unemployed workers $f_s - s$ and $f_u - u = (1-f_s)-(q-s)$

$$\mu_i = \mu(f_i - i)^{-\beta}, \text{i=s,u} \tag{11}$$

the larger is the number of skilled workers, the smaller would be the firm's cost to recruit them and, therefore, higher the incentive to innovate.

2.4 Steady state Equilibrium

2.4.1 Labor Demand

We solve the equilibrium backwards, by starting with firm's hiring problem. The Hamiltonian function associated with 5 is[1]:

$$\theta F(s,u) - w_s s - w_u u - \mu_s v_s - \mu_u v_u + \eta_s(-\gamma s + v_s) + \eta_u(-\gamma u + v_u) + \eta_q(q - s - u) \tag{12}$$

First order condition for the control variable v_s, v_u and state variable s, u yield respectively:

$$\eta_i = \mu_i, \text{ i=s,u} \tag{13}$$

$$\delta\eta_i = \theta F_i - w_i - \gamma\eta_i - \eta_q + \dot{\eta}_i \tag{14}$$

[1] See Appendix A for technical details

By rearranging them we obtain that in steady state:

$$\theta(F_s - F_u) = (w_s - w_u) + (\delta + \gamma)(\mu_s - \mu_u)) \tag{15}$$

The RHS and the LHS of equation 15 equates the marginal benefit to the marginal cost of replacing an unskilled worker with an unskilled. The first is represented by the marginal gain in output $(F_s - F_u)$, while the last is composed by the differential in terms of wage paid$(w_s - w_u)$ and recruiting costs $((\delta + \gamma)(\mu_s - \mu_u))$. Let's notice that the problem can be formulated in terms of skilled labor share σ and profit per worker $\pi = \frac{\Pi}{q}$ since both production function and vacancy costs are linear in q [2]. Plugging wage equations 10, and the vacancy cost equations 11 in 15 we obtain the following equality:

$$(1-\beta)\theta[F_s(\sigma, 1-\sigma) - F_u(\sigma, 1-\sigma)] = \mu(\delta + \gamma)\left[\mu(f_s - \sigma q)^{-\beta} - \mu((1-f_s)_(1-\sigma)q)^{-\beta}\right] \tag{16}$$

that implicitly define skilled labor demand as a function of productivity and skilled labor supply, namely $\sigma = \sigma(\theta, f_s)$. Firms will use skilled labor more intensively if more productive (higher θ) or if skilled labor supply is more abundant:

$$\frac{\partial \sigma}{\partial \theta} > 0; \frac{\partial \pi}{\partial \theta} > 0 \tag{17}$$

$$\frac{\partial \sigma}{\partial f_s} > 0; \frac{\partial \pi}{\partial f_s} > 0 \tag{18}$$

The first inequality follow from the afrometioned *productive* complemetaries between human capital and innovation: more productive firms will demand a larger fraction of skilled workers since the output gain becomes larger relative to the differential of recruiting costs. Property 18 comes instead from the *strategic* complementarities discussed earlier: a firm will find it convenient to post a larger number of vacancies for skilled labor if the relative number of workers is higher. The behaviour of

[2]Given constant return to scale the production function the problem can indeed be easily rewritten in terms of σ: $F(s, u) = F(q\sigma, q(1-\sigma) = qF(\sigma, (1-\sigma))$

the profit function follows directly.

Optimal technology $\theta^*(\sigma)$ is independent of capacity q and can now be expressed as a function of skilled labor share σ:

$$\pi'(\theta^*, \sigma) = c'(\theta) \tag{19}$$

$$F(\sigma, (1-\sigma)) = c'(\theta^*(\sigma)) \tag{20}$$

l where the last equality follows from traditional envelope theorem. Let's notice that firm with an higher share of skilled labor will invest more in R& D and choose an higher productivity:

$$\frac{\partial \theta}{\partial \sigma} > 0 \frac{\partial \theta}{\partial f_s} = \frac{\partial \theta}{\partial \sigma}\frac{\partial \theta}{\partial f_s} > 0 \tag{21}$$

The intuition goes as follows: the incentive to innovate increases with the number of skilled workers, since innovative firms, by hiring a larger share of skilled labor, benefit more from a reduction of the relative recruiting cost. Viceversa, withe a larger number of unskiled workers, firms will find it more convenient to keep less productive technology. Finally optimal capacity $q^*(\sigma)$ will solve:

$$\theta^*(\sigma)F(\sigma, (1-\sigma)) = c'(q^*(\sigma)) \tag{22}$$

c Notice that even if innovation decision is *per se* independent on capacity size, a more productive firm will choose a larger size, since the profit per worker is higher. We can now state define our labor demand function $\sigma(f_s)$

Definition 1. *Labor demand function $\sigma^*(f_s)$ is a continuous function $\sigma^* : [0,1] \to [0,1]$ such that for every value of skilled labor supply f_s, $\sigma^*(f_s)$ solves 16 with $\theta = \theta^*(\sigma)$ and $\theta = \theta^*(\sigma)$ solving respectively 20 and 22*

2.4.2 Labor Supply

In steady state the solution of the problem for worker yields

$$V_s = \frac{w_s s}{\gamma f_s} \tag{23}$$

$$V_u = \frac{w_s u}{\gamma f_u} \tag{24}$$

$$\tag{25}$$

This allows us to completely describe worker's optimal policy by defining a treshold probability $p^* = \frac{V_u}{V_s}$ such that an agent will decide to become skilled if and only if $p < p^*$. The number of workers evolves according to the following law of motion:

$$\dot{f}_s = -\gamma f_s + \gamma(1 - \phi(p^*)) \tag{26}$$

$$\dot{f}_u = -\gamma f_u + \gamma\phi(p^*) \tag{27}$$

where $1 - \phi(p^*) = \int_{p^*}^{1} dG(p)dp$ is the share of agents successfully engaging in human capital accumulation. We can now express the number of i type workers $f_s(\cdot), f_u(\cdot)$ as a function of the ratio $\frac{V_u}{V_s}$. By imposing steady state conditions $\dot{f}_u = \dot{f}_s = 0$ we find:

$$f_s = G(V_s - V_u) = 1 - f_u \tag{28}$$

$$\tag{29}$$

By plugging 23 and 24 we obtain

$$f_s = G\left(\theta q\left(\frac{F_s(\sigma,(1-\sigma))\sigma}{f_s} - \frac{F_u(\sigma,(1-\sigma))(1-\sigma)}{1-f_s}\right)\right) \tag{30}$$

that implicitly defines labor supply share f_s^* as a function of θ, q, σ.

Definition 2. *Labor supply function $f_s^*(\sigma)$ is a continuous function $f_s^* : [0,1] \to [0,1]$ such that for* *every value of skilled labor demand σ, $f_s^*(\sigma)$ solves 30 with $\theta = \theta(\sigma)$ and $q = q(\sigma)$ solving respectively 20 and 22*

We can now describe a steady state equilibrium as a skilled labor supply σ^{SS} and skilled labor demand f_s^{SS} such that

1. Given skilled labor supply f_i, $\sigma^{SS} = \sigma^*(f_s^{SS})$ solves firm's problem

2. Given skilled labor demand σ^{SS}, $f_s^{SS} = f_s^*(\sigma^{SS})$ solves worker's problem 30

In order to fully characterize equilibria we can study separate labor and demand function.

Theorem 1. *Labor demand σ^* is an increasing function of f_s such that $\sigma^*(0) = 0$ and $\sigma^*(1) = 1$. Moreover for small enough values of f_s:*

$$\frac{\partial \sigma^*}{\partial \mu} < 0 \tag{31}$$

$$\frac{\partial \sigma^*}{\partial \beta} < 0 \tag{32}$$

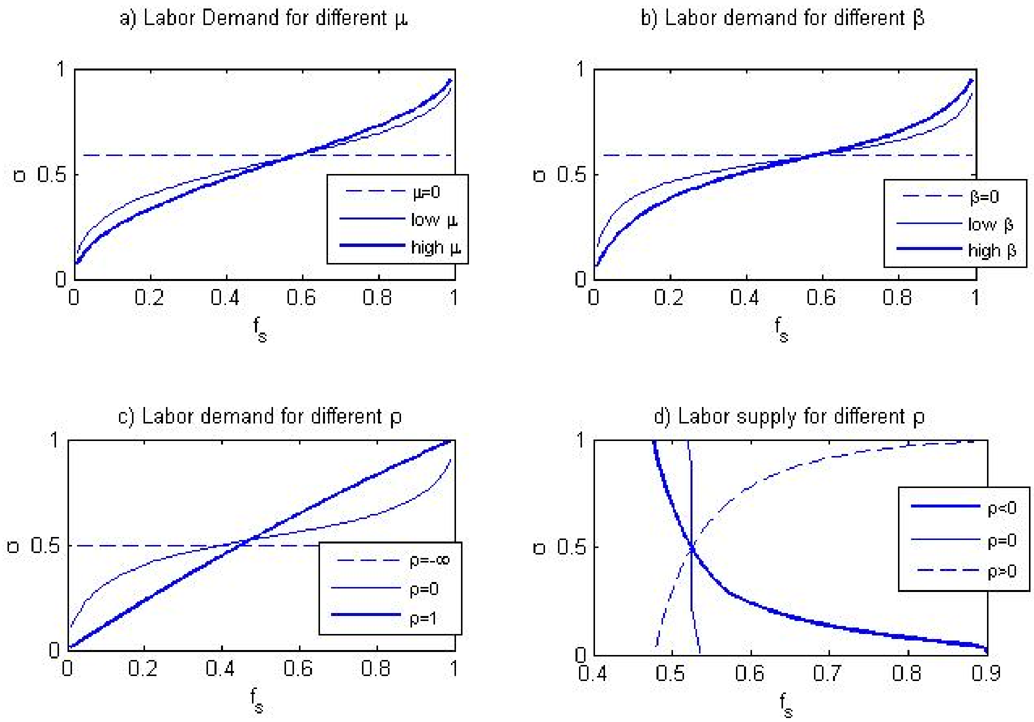
$$\frac{\partial \sigma^*}{\partial \rho} < 0 \tag{33}$$

$$\tag{34}$$

Theorem 1 is depicted in figure 1 a), b) and c). An higher μ or β implies and higher recruiting cost and therefore lower demand for the relative scarce labor. Notice that if $\mu = 0$ or $\beta = 0$ labor demand σ^* would be independent of labor supply f_s. Finally labor demand is more elastic to labor supply whenever skilled and unskilled labor are more substitutable.

Theorem 2. *Labor supply f_s^* is function of σ. Moreover if production function displays enough substitutability between skilled and unskilled labor ($\rho > 0$), then skilled labor supply is increasing in skilled labor demand. Viceversa, Skilled labor supply is decreasing in skilled labor demand if production function displays enough complementarity between skilled and unskilled labor ($\rho < 0$).*

Figure 1: Comparative Statics



Source: Authors' simulations

Rigorous proof is presented in the Appendix, but we can here hint simple economic intuition. If the two inputs are substitutable (i.e production function is linear *enough*, income share ratio $\frac{V_s}{V_u} = \frac{w_s s}{w_u u} \gg 0$, the incentive to acquire skills, will increase with σ. We can now finally state our finally proposition, discussing steady state equilibrium:

Proposition 1. *There is always a steady state equilibrium. Multiple equilibria can occur only if production function displays complementarity between skilled and unskilled labor.*

3 Data and estimation

We use micro data from the EU-SILC, the Community Statistics on Income and Living Conditions. The survey collects information relating to a broad range of issues in relation to income and living conditions. SILC is conducted by the Statistics Offices of the European countries involved in the project on an annual basis, in order to monitor changes in income and living conditions over time.

Every person aged 16 years and over in a household is required to participate to the survey. Two different types of questions are asked in the household survey: household questions, and personal questions. The former covers details of accommodation and facilities together with regular household expenses (mortgage repayments, etc.). This information is supplied by the Head of the Household. The latter covers details of items such as work, income and health, and are obtained from every household member aged 16 years and over.

We focus on the cross-sectional information of the years 2004-2011.[3] We identify skills acquisition with college graduation (ISCED 5): we exclude those who didn't complete secondary school to focus on tertiary education decision. We restrict the sample to individuals aged 26-54 years, to avoid the modeling of time-to graduate and retirement decisions. Finally The main demographic statistics are summarized in Table 1.

Table 1: Main Statistics, 2004-2011

Country	Population Graduates Share,%	Employment Graduates Share,%	College Wage Premium %
Italy	10.48	16.56	40,28
Germany	32.27	41.61	40,17
France	22.69	33.20	33,69
Spain	22.74	35.04	54,92

Source: Authors' computations from EU-SILC data (2004-2011).

There are large cross-country differences: Italy stands out for a low shares of graduates workers. Nevertheless, Italian college wage premium is substantially in line with Euro average. EU-SILC provides also data on firm's characteristics: geographical position (NUTS 2 level), size and NACE sector.

[3]EU-SILC provides two types of data: (1) cross-sectional data pertaining to a given time or a certain time period with variables on income, poverty, social exclusion and other living conditions; (2) longitudinal data pertaining to individual-level changes over time, observed periodically over a four years period.

Table 2: Employment distribution, percentage 2004-2011

	Country			
	Italy	Germany	France	Spain
By economic sector				
Agriculture	4.6	1.48	5.36	3.97
Manufacture, Mining and Fishing	23.15	19.47	17.36	16.43
Construction	7.88	5.19	10.68	8.47
Trade	14.38	12.77	13.97	13.07
Transport and Communication	4.68	5.3	5.39	5.03
Hotel and Restaurants	4.14	2.25	6.59	2.97
Information and Communication	0.86	1.34	1.05	1.06
Finance	3.04	5.08	2.62	3.47
Real Estate, Professional and Administrative Activities	8.65	8.95	6.96	6.21
Public Administration	7.13	12.00	9.02	12.16
Education	7.12	7.19	6.59	7.29
Health	7.14	12.52	6.54	12.20
Other	7.22	6.46	7.87	7.68
By firms size				
0-10	47.17	23.80	43.65	30.03
10-19	15.85	11.52	14.58	9.80
20-49	11.45	13.54	13.30	14.47
50+	25.54	51.15	28.47	45.70

Source: Authors' computations from EU-SILC data (2004-2011).

Italian production structure exhibits distinctive features: a sectoral bias towards traditional manufacturing - mostly to the detriment of more innovative sectors such as Information and Communication and Health - and a relatively smaller firms' size.

4 Estimation method

I estimate the model, separately fitting data from five main European economies: Italy, France, Germany, Spain and United Kingdom. Since EU-SILC data contain information on geographical residence (NUTS 2 level) firms' size and sector for employed workers we can estimate a version of the model the accounts for possible size, region and sector effects. From EU-SILC we can easily compute, for each firm's size-region-sector cell, average wages w_s, w_u, skilled labor demand, σ and for each region skilled labor supply f_s. Eurostat provides data of $R\&D$ expenditure only at national and sectoral level θ. Parameters are estimated with a non linear GMM method. The moments to match are chosen to balance all the information in the data related to the main feature of the model: labor supply, labor demand and wage setting. First of all I consider moments relative to labor demand: I assume a quadratic cost for both R&D investment and capacity ($c(q) = c^q q^2; c(\theta) = c^\theta \theta^2$.

$$w_s - w_u = \frac{\alpha}{1-\alpha}\widehat{\mu}\left[(f_s - \sigma q)^{-\widehat{\beta}} - ((1-f_{s,i}) - (1-\sigma)q))^{-\widehat{\beta}}\right] \tag{35}$$

$$\tag{36}$$

Equation identifies search friction parameters, μ and β by looking respectively average wage differentials and their correlation with unemployment differentials. In particular β will be higher in countries where,at regional level, a larger share of unemployed graduated workers is associated with a smaller college wage premium. Notice that μ can not be separately separated by α that is exogenously set to 0.5

Second, I include moments relative to labor supply: I assume probability p is distributed according to a β function:

$$f_s = \int_{p^*}^{\infty} p\widehat{g}(p)dp \tag{37}$$

$$p^* = \frac{w_u(1-\sigma)}{f_s}\frac{1-f_s}{w_s\sigma} \tag{38}$$

In equation the correlation between income share ratio and skilled labor supply identifies the parameters of probability distribution p, that represents a measure of human capital accumulation cost. Finally, I use wage setting equation to pin down the shape of the production function:

$$\frac{w_s}{w_u} = \widehat{h}\left[\frac{\sigma}{1-\sigma}\right]^{\widehat{\rho}-1} \tag{39}$$

$$\tag{40}$$

While $\widehat{h}$'s capture average college premia, elasticity of substitution ρ is pinned down by the curvature of the wage function using sectorial, geographical and firm's size variance. Finally we estimate endogenous choice of innovation rate and firm's size by equations:

$$\alpha y_i = 2\widehat{c^\theta}\theta^2 \tag{41}$$

$$\alpha y_i = 2\widehat{c^q}q^2 \tag{42}$$

Parameters c^θ and c^q are defined by the correlation between employees compensation and $R\&D$ expenditure and size respectively. In particular, separately for each country, I use a N-steps procedure, to update the weighting matrix. In order to compute the standard errors I estimate the asymptotic variance of the estimator, using consistent estimators for the Jacobian function. Details are discussed in the appendix.

4.1 Results

In the main findings are summarized. On the demand side, It should be noticed that, in comparison with other European countries, Italy is characterized by a very high high elasticity of labor demand to labor supply, that is a high β. As discussed earlier this implies skilled labor supply being more heavily limited by labor demand. On the supply side Italy show an implicit college cost lower than France, but in line with Germany and Spain. Finally, looking at the production function, all countries show a level of higher substitutability between skilled and unskilled labor, close to 0.8. The model is able to fit closely all significants moments observed (See Table 3).

Table 3: Main results

Country	Labor demand		Labor supply		Production function	
	β	μ	$E(p)$	$Var(p)$	ρ	h
Italy	2.00	3,141	0.75	0.28	0.82	1.27
	(0.111)	(112)	(0.021)	(0.012)	(0.023)	(0.010)
Germany	0.91	2,956	0.79	0.29	0.78	1.32
	(0.125)	(124)	(0.027)	(0.011)	(0.024)	(0.012)
France	0.80	2,606	0.81	0.31	0.76	1.30
	(0.131)	(117)	(0.009)	(0.011)	(0.024)	(0.012)
Spain	0.84	2,923	0.73	0.14	0.77	1.27
	(0.141)	(134)	(0.018)	(0.014)	(0.028)	(0.009)

Source: Authors' computations from EU-SILC data (2004-2011).

In the next table Sector and size effect on skilled labor productivity are reported: manufacturing exhibits a low skilled labor marginal productivity in all countries, and even more in Italy, where accounts for almost one fourth of employment in Italy. On the other hand of the spectrum in the Health and Education Sectors gradutaes workers seems to have, per se, a larger productivity advantage. Also, firm's size seems to have a direct impact on skill intensity in all countries but in Italy: graduates workers are 10 per cent relatively more productive in firm wwith more than 50 employees.

Table 4: Employment distribution, percentage 2004-2011

	Country			
	Italy	Germany	France	Spain
By economic sector				
Agriculture	0.040	-0.008	-0.018	0.115
Manufacture. Mining and Fishing	-0.030	-0.018	0.000	-0.065
Construction	0.004	-0.022	-0.037	-0.061
Trade	-0.023	-0.038	0.002	-0.105
Tranport and Communication	-0.054	-0.044	-0.130	-0.137
Hotel and Restaurants	0.006	-0.024	0.084	0.099
Information and Communication	-0.045	-0.068	0.025	0.048
Finance	-0.048	0.016	-0.064	-0.085
Real Estate. Professional and Administrative Actitivities	0.062	0.091	-0.014	0.048
Public Administration	-0.063	0.092	-0.055	-0.004
Education	0.007	0.076	0.018	-0.017
Health	0.030	0.021	0.100	0.140
Other	-0.024	-0.024	0.055	-0.008
By firms size				
0-10	-0.000	0.021	-0.006	0.010
10-19	-0.063	-0.079	-0.027	-01.138
20-49	-0.048	0.031	0.031	-0.177
50+	0.12	0.042	0.042	-0.024

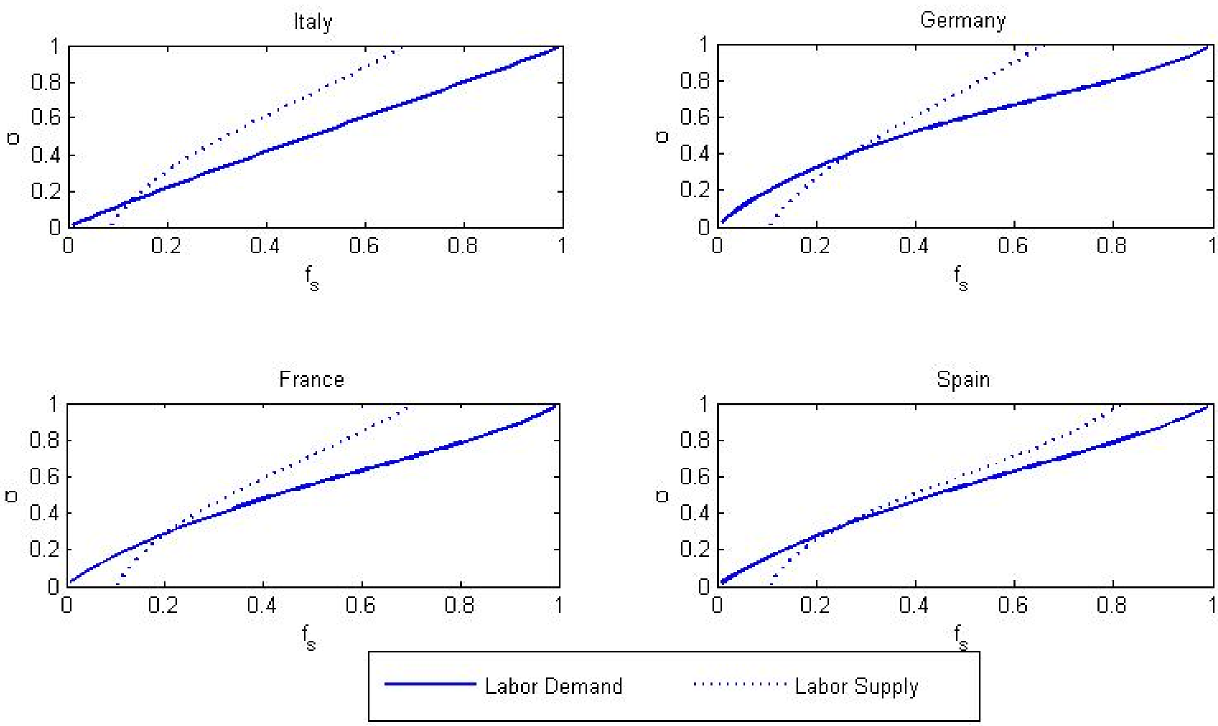
Source: Authors' computations from EU-SILC data (2004-2011).

Figure show labor demand and labor supply for all countries.

5 Discussion and Counterfactual exercises

Finally, I perform several counterfactual exercise: I simulate Italian Economy, borrowing from other European countries, first labor demand parameters (β, μ figa)) and then parameters shaping labor supply (figb)). The impact on the number of individual with a college degree would be similar in both simulation: with German parameters I obtain an increase of roughly five percentage points . Nervetheless, the share of skilled labor actually employed by firms reacts very differently to a shift of labor demand or labor supply: rising by ten percentage points, up to 27%, in the first case - in particular with an elasticity β at German level - and by only five percent in the second. The dynamic of the expenditure in $R\$D$ of Italian firms, in terms of GDP, is similar: an increase of almost 0.4 %,

Figure 2: Comparative Statics



Source: Authors' simulations

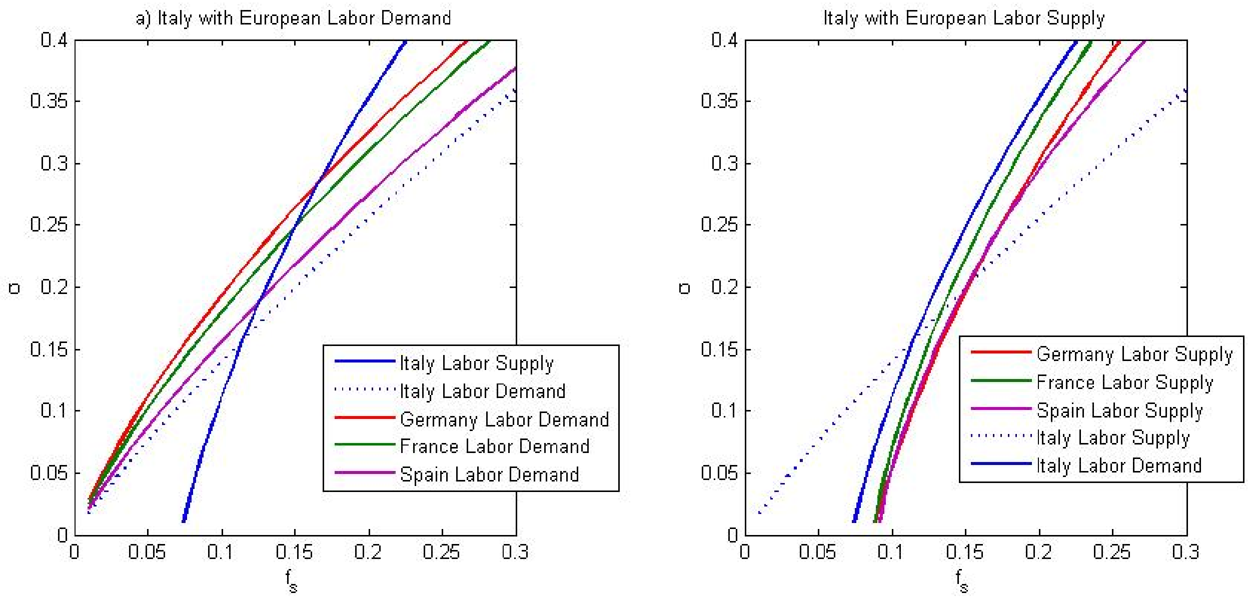
halving the gap with Germany, after a shift in the demand and an increase of 0.2% with a supply shift. Results are summarize in table and displayed in figure

Table 5: Main Statistics, 2004-2011

	Country				
	Italy	Germany	Italy with German		
			Labor Demand	Labor Supply	Sector& specialization
Population Graduates Share	10.48	32.27	15.23	15.31	14.32
Employment Graduates Share	16.56	41.61	21.37	28.01	23.23
College Premium	40.28	40.17	36.14	38.23	41.12
R&D expenditure, % of GDP Data	1.26	2.84	1.42	1.99	1.66

Source: Authors' computations from EU-SILC data (2004-2011).

Figure 3: Comparative Statics



Source: Authors' simulations

6 Conclusions

This paper represents a first attempt to build a structural model aiming at empirically testing the hypothesis of strategic complementarities between innovation and human capital, and at identifying possible "low-skill-low-innovation" trap. We extend the static model from Redding (1996) to a more general dynamic framework able to fit observed macro patterns. Our estimation reveals that a large part of the innovation between Italy and other leading European countries can be explained by labor market frictions.

Estimates show for Italy a higher elasticity of skilled labor demand to skilled labor supply. This finding can justify 1) bias toward labor intense technology; 2) low R&D investment, 3) smaller firm's size. In the model such elasticity is exogenous, but the results suggests that policies and other institutions affecting the matching mechanism between labor demand and supply can play a pivotal role in shaping firms' innovation activity. For instance I find a much higher matching cost in southern Italy - almost twice than in Northern regions- where public employment services are considered to be highly ineffective and informal network connections prevail both in job search and job hiring. I believe that a model able disentangle different features of the matching process could provide a further interesting contribution in shedding light on the relationship between innovation and human capital accumulation.

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