Chicken or the Egg?: Human Capital Demand and Supply

Fabrizio Colonna*

December 12, 2016

Abstract The aim of this paper is to study the relationship between demand for skilled labor and human capital accumulation. I build a simple model à la Redding (1996) in which workers' investment in education and firms' skill intensity decisions display strategic complementarities. On the one hand, high recruiting costs associated to scarcity of qualified labor weakens firms' incentive to open vacancies for high-skill jobs, on the other hand, less skill intense technology reduce the economic return to human capital. The model has some empirical productions: (i) strong labor market frictions yields a "feedback" effect between demand and supply that can significantly curb human capital accumulation, (ii) if high and low-skill labor are good substitutes multiple equilibria can arise, possibly confining the economy in a "low-skill/low education" trap. Finally some suggestive empirical evidence is provided: using Italian data it is shown that at regional level, firms assign a larger share of workers to skilled jobs whenever the average educational attainment of the local labor force is higher.

Keywords: skilled labor, human capital, matching function.
JEL Classification: J21, J22, H31

*Banca d'Italia, Economic Structure and Labor Market Division, Department for Structural Economic Analysis, via Nazionale 91, 00184 Roma, IT. Email: fabrizio.colonna@bancaditalia.it

1 Introduction

The available empirical evidence show how both skill intensity of production technologies and human capital investments are lower in Italy than in other leading economies. For example, according to the OECD classification, Italian firms employ only roughly 15 per cent of Italian workers in high-skilled jobs, against an average of 24 per cent in the other four main countries of the European Union: France, Germany, Spain and United Kingdom; 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, skilled content of labor demand and human capital, can actually go both ways. On the one hand, lack of qualified labor might reduce firms' incentive to use innovative technologies requiring skilled work; 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 human capital" equilibrium.

We build a simple model in which workers invest in human capital and firms choose the optimal demand share of skilled labor. The two types of decisions display strategic complementarity following from labor market frictions, namely recruiting costs decrease as the number of workers looking for a job increases. It such a framework, multiple equilibria and "low skill-low human capital" 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. Finally a preliminary, suggestive evidence is shown, pointing out of a possible working feedback effect between labor supply and labor demand in Italy: between 2004 and 2014 in regions where the number of graduates increased relatively faster, the share of skilled jobs grew more intensively.

In the 90's Acemoglu [1] and Redding [8] 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 [6] - starting a new rich branch of literature [2],[13],[3], [12], [10], [11]. On the empirical side, many authors investigated complementarities between innovation and human capital at a micro level ([9]), employing reduced form econometric techniques; to the best of my knowledge no evidence of a "low skills-low human capita" traps has been made yet at a macroeconomic level. The remainder of the paper is organized as follows. In section 2) the theoretical model is built and solved while in section 3) an empirical test of the main theoretical prediction is performed. Finally section 4) is reserved to conclusions. Technical Appendix follows.

2 The Model

We use a static one-period model à la Redding [8] in which workers invest in human capital and firms pick the optimal combination of high and low-skill jobs. In economic literature the term *skilled work* is sometimes ambivalent. It can refer to either occupation or worker's characteristics, describing the complexity of the tasks involved or the ability of the worker performing them. In this paper, to avoid ambiguity, the term skill refers exclusively to job characteristics, while the terms *educated* or *qualified* is applied to discuss individual ability, knowledge and competences. The two choices display strategic complementarities: on the one hand scarcity of qualified workers might weaken firms incentive to create high-skill jobs, on the other hand low availability of the latter reduces economic return of human capital.

2.1 Firms

An homogeneous good is produced by a n measure of firms using a CES production function $F(s,u) = [\theta s^\rho + u^\rho]^{\frac{1}{\rho}}$ that combines high-skill jobs s, involving complex tasks and requiring sophisticated competences, and low-skill jobs u, involving simple task that can be carried out without any advanced knowledge. The variable s can be interpreted as a measure of firm's skill intensity. The parameter θ captures the relative high-to-low skill jobs productivity. Firms pay a fixed cost k to enter the market with unitary capacity bounding the maximum number of workers able to operate in its plant: $s + u \leq 1$. Finally, since the recruiting process is costly, to fill a single vacancy for a j-type job ($j = S, U$) firms pay, beside the nominal wage w_j, a cost μ_j. Firm will then maximize:

$$\Pi^*(s) = max_s F(s, 1-s) - w_S - w_U(1-s) - \mu_S s - \mu_u(1-s) \quad (1)$$

where, exploiting the capacity constraint $u = 1 - s$, the profit is expressed as a function of only s, .

2.2 Workers

The economy is populated by a unitary measure of workers. At the beginning each worker decides whether to invest in human capital and acquire high level competences ($i = H$) or not ($i = L$). The labor market is structured as in the classical model: job offers accrue to an unemployed workers with probability λ_i, while employed workers receives a wage w_i. For simplicity we assume linear utility function $U = A_i c$ where c is the consumption and A_i controls the individual utility of acquiring skills, encompassing both non-monetary benefit (social status, personal satisfaction) and cost (effort, foregone wages). The utility parameters are randomly distributed with cumulative function $G(A_H)$ and A_L normalized to 1. Since consumption will be equal to labour income expected utility for a i-type worker can be expressed by:

$$V_i = E(U_i) = A_i \left[\lambda_i w_i + (1 - \lambda_i)0\right] = A_i \ \lambda_i w_i \tag{2}$$

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

$$\max_{H,L}\{V_H, V_L\} = \max_{H,L}\{A_H \ \lambda_H w_H, \, \lambda_L w_L\}, \tag{3}$$

2.3 Wage Setting and Labor Market frictions

For the sake of simplicity we assume that only educated worker can perform high-skill occupations, while simple task are reserved to low educated workers. A more complex model, where the correspondence between workers' education and job skills is not exclusive would deliver the same, basic theoretical implications. Under a standard assumption of continuous negotiation between firms and workers wages are proportional to marginal productivity:

$$w_H = w_S = \alpha F_s; \ w_L = w_U = \alpha F_u \tag{4}$$

where α represents workers' bargaining power. As discussed earlier we want this model to capture the strategic complementarities between demand and supply of human capital, through frictions in the labor market. As in the standard matching function we assume that recruiting cost is a decreasing convex function of the relevant market tightness defined as the ration between demand and supply for a given task. With some abuse of nation, denoting by H ($L = 1 - H$) the measure of educated workers:

$$\mu_S = \mu \left(\frac{S}{H} \right)^{\beta}, \mu_U = \mu \left(\frac{U}{L} \right)^{\beta} \tag{5}$$

where $\beta > 0$ is a measure of market frictions and $S = ns$ and $U = n(1-s)$ are the relative demand for high and low skill jobs. The larger is the number of educated workers, the smaller would be firms' cost to recruit them and, therefore, greater the incentive to post a vacancy for a high-skill job.

2.4 Equilibrium

2.4.1 Labor Demand

We solve the equilibrium backwards, starting with firms' hiring problem. First order condition from firm's problem 1 yield:

$$(F_s - F_u) = (w_S - w_U) + (\mu_S - \mu_U) \tag{6}$$

Vacancy costs μ_S, μ_U depends on aggregate labor demand and are therefore taken as given by firms. Nevertheless, plugging conditions 5 in 6 we obtain the following equilibrium condition defining optimal skill intensity s:

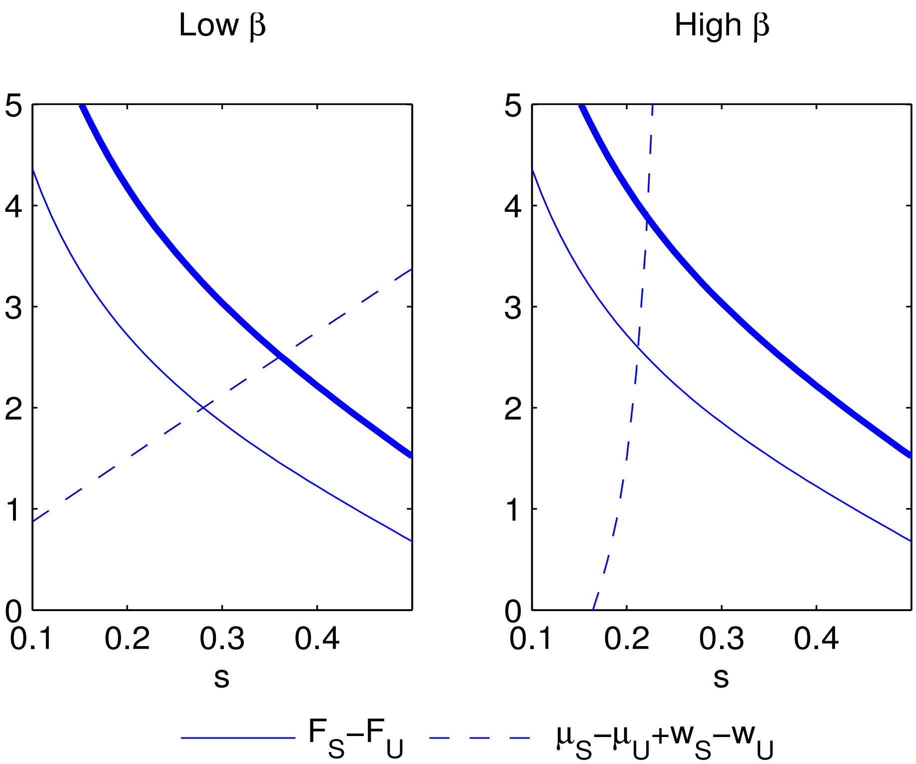
$$[F_s(s, 1-s) - F_u(s, 1-s)] = w_S - w_U + \mu \left[\left(\frac{sn}{H} \right)^{\beta} - \left(\frac{(1-s)n}{1-H} \right)^{\beta} \right] \tag{7}$$

Equation 7 represent the key relation of the model: it implicitly defines skill intensity (in this case entirely determined by the complex task share) s as a function of labor supply composition and number of firms, namely $s(H, n)$.

Lemma 1. *There is an unique $s(H, n) \in (0, 1)$ satisfying equation 7.*

The proof of the previous lemma is in the Appendix, but the intuition is straightforward. The LHS and the RHS of the equation represent respectively the marginal benefit and the marginal cost of replacing a low-skill job with a high-skill one. The marginal benefit is given by the marginal gain in output and is therefore non-increasing in complex task share: it goes to $+\infty$ to $+\infty$ as $s \to 0$ and $s \to 1$, respectively. The marginal cost, on the other hand, is an increasing function of s, ranging from $-\infty$ to $+\infty$ as s goes from 0 to 1: stronger demand for high educated workers, generated by a more intense use of complex task, would rise the relevant recruiting cost. Therefore a single equilibrium value for s is determined.

Figure 1: Labour Demand and Productivity Shocks



Source: Authors' simulations

The next two lemmas completely characterize the optimal policy s and the profit function Π.

Lemma 2. *Optimal skill intensity s is an increasing function of the relative suppply of educated workers H such thah $s(0,n) = 0$ and $s(1,n) = 1$. Moreover if high-skill jobs are relatively better paid than low-skill ones, that is an empirical regularity, skill intensity is a decreasing function of all factors inflating the recruiting cost: matching functions paramters μ and β and number of firms n. The profit function $\Pi(s(H,n))$ inherits automatically the same properties.*

$$\frac{\partial s(H,n)}{\partial H} > 0, \frac{\partial s(H,n)}{\partial \mu} < 0, \frac{\partial s(H,n)}{\partial \beta} < 0, \frac{\partial s(H,n)}{\partial n} < 0 \tag{8}$$

$$\frac{\partial \Pi(H,n)}{\partial H} > 0, \frac{\partial \Pi(H,n)}{\partial \mu} < 0, \frac{\partial \Pi(H,n)}{\partial \beta} < 0, \frac{\partial \Pi(H,n)}{\partial n} < 0 \tag{9}$$

Properties 8 and 9 come from the *strategic* complementarities discussed earlier: a firm will find it convenient to post a larger number of vacancies for skilled jobs if the relative number of workers is higher. A larger supply of educated workers reduces the relative recruiting cost, shifting the marginal cost curve - the RHS of the equation - down and to the right. Similarly, a larger number of firms, would tighten the market for high level jobs, shifting the marginal cost curve low and to the left. In both cases, the equilibrium skill intensity s^* increases.

It's worth discussing an important implication of equation 7. The slope of its RHS, measuring the marginal benefit curve depends on the matching function elasticity to market tightness, namely β. This implies that in *frictional* markets, characterized by higher values of β, labor demand is less elastic to demand shocks (productivity shocks making high-skill jobs relatively more productive, i.e an increase of θ) but more responsive to supply shocks (an increase in the share of educated workers generated, for example, by a decrease in the cost of education). Let's consider Figure 1. It represents equation 7 with the marginal benefit and the marginal cost schedule traced by the solid and dotted line, respectively. The overall impact of a productivity shock is much larger in the left panel, where an economy with low labor market frictions is depicted (high β). Viceversa, as shown in Figure 2, in a frictional economy firms' choices are more strictly bounded by labour scarcity through market tightness, and therefore supply shocks can significantly enhance the relative demand.

Finally the number of firms n is pinned down by the assumption of free entry, that requires that expected profit equates the entry cost:

$$\Pi^*(H, n) = k \tag{10}$$

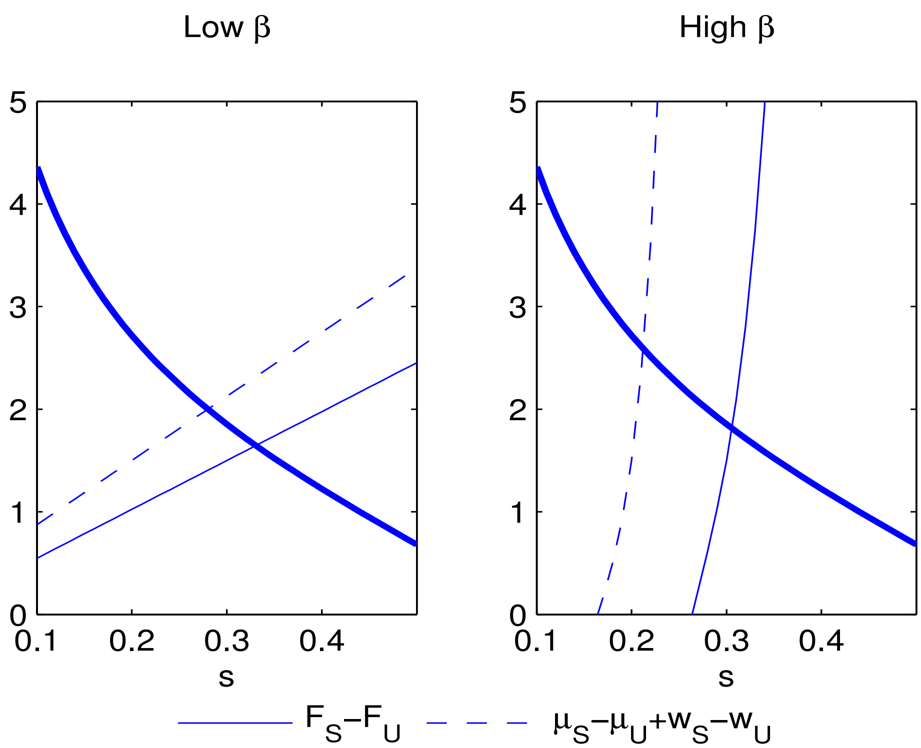
We can now fully characterize firms' optimal policy function:

Definition 3. *Labor demand skill intensity* $s^*(H)$ *is a continuous function* $H^* : [0, 1] \to [0, 1]$ *such that:*

1 $s^*(H) = s(H, n * (H))$ *where* $s(H, n)$ *is a implicitly defined by 7;*

2 $n^*(H)$ *solves .*

Figure 2: Labour Demand and Supply Shocks



Source: Authors' simulations

2.4.2 Labor Supply

Plugging the probability of being employed $\frac{S}{H}$ and $\frac{n-S}{1-H}$ for educated and on educated worker, expected utilities 2 can be reformulated as:

$$V_H = A_H \frac{w_s S}{\gamma H} \tag{11}$$

$$V_L = \frac{w_u U}{\gamma L} \tag{12}$$

$$\tag{13}$$

This allows us to completely describe worker's optimal policy by defining a threshold utility $A_S^* = \frac{V_H}{V_L}$ such that an agent will decide to invest in human capital if and only if $A > A_H^*$. The shares of high educated workers will be:

$$H = 1 - G\left(A_S^*\right) = 1 - G\left(\frac{V_H}{V_L}\right) = 1 - L \tag{14}$$

where $1 - G(A_H^*)$ is the share of agents successfully engaging in human capital accumulation. By plugging 11 and 12 we obtain

$$H = 1 - G\left(\frac{sF_S(s, 1-s)}{H} \frac{1-H}{(1-s)F_u(s, 1-s)}\right) \tag{15}$$

$$H = H^*\left(\frac{sF_S(s, 1-s)}{(1-s)F_u(s, 1-s)}\right) \tag{16}$$

that implicitly defines labor supply share H as a function of skill intensity s. In particular human capital decision is driven exclusively by the ratio between income share for high and low-skill jobs.

Definition 4. *Labor supply function $H^*(s)$ is a continuous function $H^* : [0,1] \to [0,1]$ such that for every value of skilled labor demand s, $H^*(s)$ solves 15*

We can now describe a competitive equilibrium as a a skill labor demand and supply share $\bar{s} = \bar{H}$ such that

1. Given skilled labor supply $\bar{H}$, $\bar{s} = s^*(H)$ solves firm's problem;

2. Given skilled labor demand $\bar{s}$, $\bar{H} = H^*(s)$ solves worker's problem.

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

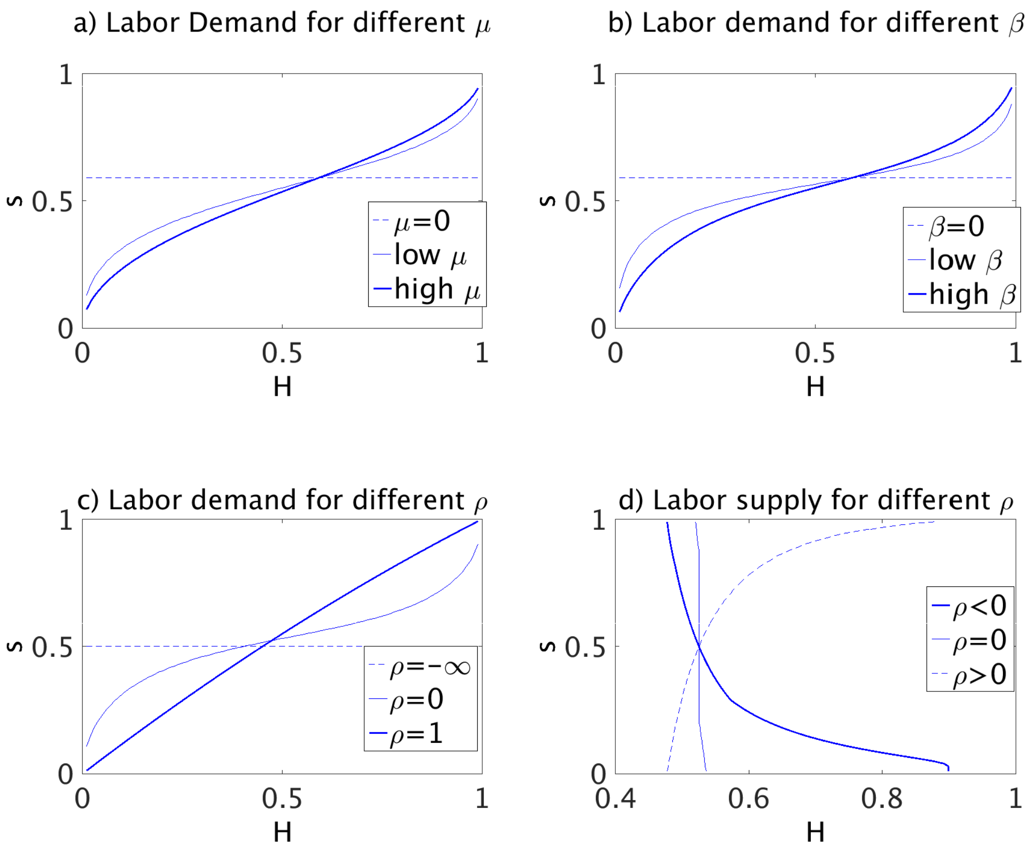
Theorem 1. *Labor demand $s^*(H)$ is an increasing function of H such that $s^*(0) = 0$ and $s^*(1) = 1$. Moreover if in equilibrium $w_S > w_U$:*

$$\frac{\partial \bar{s}}{\partial \mu} < 0, \frac{\partial \bar{s}}{\partial \beta}, \frac{\partial \bar{s}}{\partial \rho} < 0 \tag{17}$$

Theorem 1 is a direct corollary of previous lemmas and is depicted in figure 3 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 s^* would be independent of labor supply H.

Finally labor demand is more elastic to labor supply whenever skilled and unskilled labor are more substitutable: labor demand would accommodate the relative supply and, upon a relative scarcity of educated workers, firms would limit their posting of high-skill jobs. Viceversa when the two inputs are complementary firms can freely adjust the employment composition. Therefore s wouldn't decrease even if educated workers are relatively scarce.

Figure 3: Comparative Statics



Source: Authors' simulations

Theorem 2. *Labor supply H^* is function of skill intensity s. 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 ($\rho < 0$).*

The incentive to acquire human capital depends exclusively on the ratio between the income shares for skilled and unskilled work. In a CES function, if the two inputs are complementary

($\rho < 0$) the relative income share of an input is decreasing in its relative use, since its marginal productivity drops faster. Viceversa, if the two inputs are substitutable (i.e production function is linear *enough*,the relative income share of an input increases with its use, since its productivity is constant. In our case, if high and low skills jobs are complementary, an higher demand for high educated would reduce its income share. Similarly, if the two types of jobs display some degree of substitutability, a larger use of high skill jobs services will rise their overall income shares and therefore workers' incentive to acquire human capital. 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 Suggestive evidence

While a careful structural estimation of the model is beyond the scope of this paper, this section contains a test of the main prediction of the model using italian data. Specifically, space-time variations are exploited to verify if, at regional level, an increase in the share of graduate in the active population shifts employment composition towards more skilled jobs. A simplified version of equation 6 is estimated, expressing the share oh high-skilled jobs to be a function of the skill wage premium, and the relative share of skilled worker. The baseline equation is

$$\mathrm{s}_{j,t} = \alpha + \beta w_{j,t} + \gamma H_{j,t} + \epsilon_{j,y} \tag{18}$$

where, for a give region j and time t, $s_{j,t}, w_{j,t}$ are the employment share and the relative wage of high-skill jobs, while $H_{j,t}$ represents the percentage of the active population holding a tertiary degree.

3.1 Data

We use micro data from the EU-SILC, the Community Statistics on Income and Living Conditions, conducted by the Statistics Offices of the European countries to monitor changes in income and living conditions over time[1]. The survey collects information relating to a broad range of issues in

[1]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.

relation to income and living conditions. Using nine waves, from 2005 to 2013, we can compute for each year, and each region, our variables of interest. Skills acquisition is identified with college graduation so that $H_{j,t}$ will be the percentage of the active population - in working age (from 15 to 64 years old) and either employed or looking for a job - holding at least a tertiary degree (a 5 or higher level degree in the ISCED classification). In order to compute the share of high-skill occupations, we refer to the International Standard Occupational Classification [5], defining $s_{j,t}$ as skilled the occupation ranked 4 or higher. Hourly wage are characterized for dependent workers, dividing the monthly earnings by the average monthly working hours and $w_{j,t}$ is the ration between the hourly wages for high and low-skill occupations. Basic Statistics are shown in Table 1.

Total employment is evenly split between high and low-skill occupations (column 1) but amongst the former the share of of graduates is almost twice as high (column 2) than in the total sample. Overall almost nine out of ten graduate workers have an high skill job. Not surprisingly high skill jobs pay a much higher wage (column 3), and a higher premium to workers with tertiary education (column 4). Italy display a significant heterogeneity across region,as shown in Table 2. Northern regions are characterized, on average, by larger share of both graduates in the labor force, and a high skill jobs. The latter are also awarded a larger premium than in the South. Overall theoretical prediction seem to hold: labor demand for high-skill occupations seems to be positively correlated with the average level of schooling, and negatively correlated with the relative wage.

Table 1: Summary Statistics

ISCO	Occupation	Empl. Share	% Graduate	Wage	College premium
1	Legislators,an	6.48	15.62	64.26	78.16
2	Professionals	11.96	69.03	26.72	70.12
3	Technicians	19.02	21.45	11.57	53.49
4	Clerks	12.39	12.81	12.37	47.42
	High Skill	**45.85**	**29.11**	**21.91**	**56.44**
5	Service workers	12.58	5.85	14.81	39.11
6	Agric. & Fish	2.47	3.21	86.69	34.01
7	Crafting	16.97	2.24	15.06	40.04
8	Plant operators	8.44	2.27	11.08	42.51
9	Elementary occupations	9.70	3.39	3.41	35.51
	Low Skill	**54.15**	**3.45**	**15.70**	**39.18**
	Total	**100.00**	**15.08**	**18.52**	**47.78**

Source: Authors' computations from EU-SILC data (2005-2013

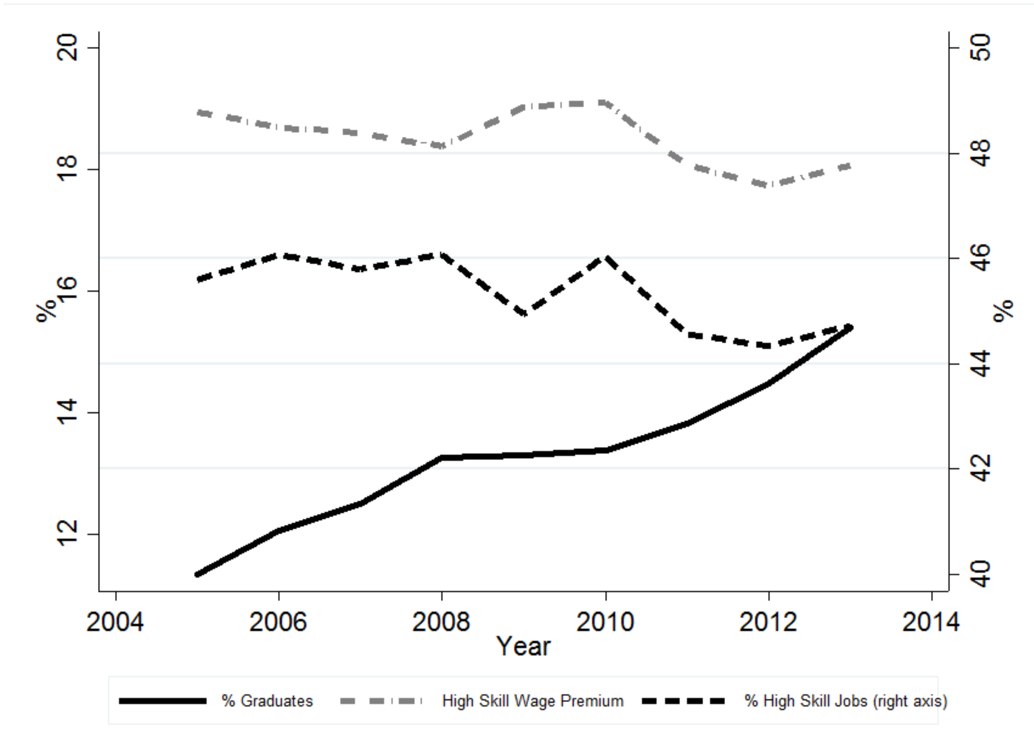
Table 2: Regional Statistics

Region	Graduate % Labor Force	High Skill % Employment	Skill Wage Premium
Valle d'Aosta	12.83	45.77	40.69
Piemonte	13.52	47.62	41.00
Lombardia	14.31	50.03	39.77
North-West	**13.86**	**48.70**	**40.0**
Trento	12.35	48.26	41.87
Bolzano	13.45	43.13	42.00
Veneto	11.32	43.28	35.79
Friuli-Venezia-Giulia	15.38	46.09	36.44
Nord-Est	**12.23**	**44.09**	**36.78**
Liguria	14.85	49.29	38.74
Emilia-Romagna	15.79	46.80	37.48
Toscana	13.91	45.05	38.11
Umbria	14.23	41.71	41.81
Marche	13.19	41.46	40.71
Lazio	17.76	52.00	48.99
Center	**15.65**	**47.49**	**41.93**
Abruzzo	15.54	40.65	39.63
Molise	13.69	38.57	40.40
Campania	10.95	41.83	50.04
Puglia	10.59	37.40	57.66
Basilicata	12.34	41.24	46.38
Calabria	13.17	41.03	58.70
Sicilia	10.28	42.64	57.81
Sardegna	11.26	40.35	48.33
South	**11.32**	**40.74**	**53.19**
Total	**13.29**	**45.35**	**44.85**

Source: Authors' computations from EU-SILC data (2005-2013)

Looking at the dynamics (Fig. 3.1), it can be observed that the share of high skill jobs (dotted line) stayed constant untill 2008, and then decreased during the Great Recession. The relative wage premium (grey line) observed a similar pattern, signaling a worsening of the demand. Viceversa, labor supply of graduates share, represented by the black solid line, kept on increasing, following a long term trend.

Figure 4: Italy, 2005-2013



Source: EU-SILC data (2005-2013)

Finally, figure 3.1 plots yearly changes in the regional share of high skill jobs versus the yearly change in the regional labour force share of graduates: the unconditional correlation is 0.44.

3.2 Estimation method

A simple OLS estimator of equation 18 is likely to yield inconsistent estimates of the effect of a large labour supply of graduates on the share of high skill occupation for several reasons. First a reverse causality problem might arise. If in a given region firms endogenously adopt high skill technologies,

Figure 5: Skill Jobs and Graduates

Source: EU-SILC data (2005-2013)

requiring a greater level of knowledge, workers might decide to increase their educational attainment, and highly educated workers would be less prone to leave the labor market. Graduates worker will also tend to move in region characterized by a larger demand for high skill occupations. In both cases the correlation between our variables would reflect a causality effect of the demand on the supply. Moreover, the other explanatory variable, the relative wage is endogenously determined. Technological differences will likely have a positive effect on both quantity and prices, rising both the demand and the wage of high skill jobs.

In order to overcome these problems, a Two-Stage-Least-Squares (2SLS) strategy exploiting two different instruments is implemented. To control for exogenous variation of labor supply, I use the share of graduates in the population aged 40 and over. Since both regional and time effect are considered, such an instrument is valid as long as labor demand doesn't immediately affect education and mobility decisions of such population. Focusing only on mature workers, who have in general already completed their studies, and are less prone to move, these problems should be minimized. A second instrument, controlling for exogenous wage variation is needed. Italy is characterized by an highly centralized bargaining system, where industry-specific minimum wages are set at national level. Mimnimum wages are likely to be binding for low-skill jobs, thus compressing the skill premium. In order to generate regional variation, a standard "shift-share" procedure is performed: regional specific minimum wages are predicted on the basis of the employment shares by sector in 1995. Specifically, for each region j, the wage premium is instrumented by:

$$c_{j,t} = \sum_k q_{k,j,1995} mw_{k,t} \tag{19}$$

where $q_{k,j,1995}$ is the employment share of industry k in region j in 1995, and $mw_{k,t}$ is the minimum wage set by national contract in time t for sector k.

3.3 Results

Results are displayed in Table Results. OLS estimates are shown in column (1): both variables seem to have the sign predicted by the theory. Higher skill intensity is associated with a lower skill wage premium and with relative abundance of graduates workers. When time and region fixed effects are introduced (columns (2) and (3)) the correlation with labour supply remains positive and significant, while the coefficient of relative wages switch signs and loses significance. Finally columns (4) and (5) display results from IV regression, when only $H_{j,t}$ or both explanatory variables are instrumented. A shown in Table 4 the first stage yields the expected results: both instruments are robust predictors of the reference variables, with the correct signs. In particular higher minimum wages are associated with lower skill premium wage. Again, regions with a larger supply of graduates display a more intense us of high skill occupations, while the impact of relative wage is negligible. Also IV coefficients describe the same correlation: firms seems to react to a locally larger supply of educated workers by increasing their labour demand skill intensity, that is assigning a larger share of workers to high skill jobs.

4 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

Table 3: Results

	(1)	(2)	(3)	(4)	(5)
% Graduates,Labor force	0.596***	0.343*	0.529***	0.613**	0.814*
	(0.125)	(0.139)	(0.146)	(0.227)	(0.404)
High skill job Wage Premium	-0.033**	0.022	0.015	0.015	-0.140
	(0.012)	(0.012)	(0.012)	(0.012)	(0.096)
Constant	0.459***	0.344***	0.332***	0.317***	0.613**
	(0.028)	(0.039)	(0.038)	(0.049)	(0.199)
Region Fixed Effects	No	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	Yes	Yes	Yes
R-squared	0.174	0.676	0.710	0.709	0.177
Number of Obs.	126	126	126	126	126

Heteroskedasticity-robust standard errors clustered at the region and year level.

Table 4: First Stage

Instrumented variable	% Graduates Labor force	High skill job Wage Premium
% Graduates,Pop¿40	0.75***	1.02
F-Statistics on the excluded instrument	69.4	1.96
Minimum wage	1.18	33.32***
F-Statistics on the excluded instrument	1.69	8.54

Heteroskedasticity-robust standard errors clustered at the region and year level.

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.

The main theoretical prediction is empirically verified: at regional level, higher educational attainment is correlated with a a composition of employment more skewed towards high-skill jobs. Results seems to suggest an high elasticity of skilled labor demand to human capital supply. In the model such elasticity is exogenous, but it might reflect policies or other institutions affecting the matching mechanism between labor demand and supply. For instance in Italy public employment services are considered to be highly ineffective and informal network connections prevail both in job search and job hiring([4], [7]). 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.

Technical Appendix

Lemma 1

There is a unique $s \in (0,1)$ such that

$$T(s) = (1-\alpha)[F_s(s,1-s) - F_u(s,1-s)] - \mu\left[\left(\frac{sn}{H}\right)^{\beta} - \left(\frac{(1-s)n}{1-H}\right)^{\beta}\right] = 0$$

Proof. Existence follows from the continuous function theorem and the standard properties of the production function:

$$\lim_{s\to 0} T(s) = \lim_{s\to 0}(1-\alpha)[F_s(s,1-s) - F_u(s,1-s)] + \mu\left(\tfrac{n}{1-H}\right)^{\beta} = +\infty$$
$$\lim_{s\to 1} T(s) = \lim_{s\to 0}(1-\alpha)[F_s(s,1-s) - F_u(s,1-s)] - \mu\left(\tfrac{n}{H}\right)^{\beta} = -\infty$$

Uniquness requires that $T'(s) < 0, \forall s \in (0,1)$.

$$\text{T'(s)=(1-}\alpha\text{)}[F_{s,s} - 2F_{s,u} + F_{u,u}] - \mu\beta\left[\tfrac{1}{s}\left(\tfrac{sn}{H}\right)^{\beta} + \tfrac{1}{1-s}\left(\tfrac{(1-s)n}{(1-s)(1-H)}\right)^{\beta}\right] < 0$$

where $[F_{s,s} - 2F_{s,u} + F_{u,u}] < 0$ comes from concavity of the CES function. □

Lemma 2

Let $s(H,n)$ the unique value such that

$$T(s|H,n) = (1-\alpha)[F_s(s,1-s) - F_u(s,1-s)] - \mu\left[\left(\frac{sn}{H}\right)^{\beta} - \left(\frac{(1-s)n}{1-H}\right)^{\beta}\right] = 0$$

and

$$\Pi(s(H,n)) = (1-\alpha)F(s(H,n),(1-s(H,n)) - \mu\left[s\left(\tfrac{s(H,n)n}{H}\right)^{\beta} + (1-s(H,n))\left(\tfrac{(1-s(H,n))n}{1-H}\right)^{\beta}\right]$$

Then,

$$s(0,n) = 0; s(1,n) = 1 \forall n > 0$$

$$\frac{\partial s(H,n)}{\partial H} > 0; \frac{\partial s(H,n)}{\partial n} < 0;$$
$$\frac{\partial \Pi(s(H,n))}{\partial H} > 0; \frac{\partial \Pi(s(H,n))}{\partial n} < 0;$$

Proof. It's easy to verify that $\forall \epsilon > 0$ $\exists X_\epsilon, d_\epsilon > 0$ such that:

1 $T(\epsilon|H,n) < -d_\epsilon$ $\forall H \in (0, X_\epsilon)$

2 $T(1-\epsilon|H,n) > d_\epsilon$ $\forall H \in (1-X_\epsilon, 1)$

there fore $s(0,n) = 0$ and $s(1,n) = 1$ Then, let's notice that for a given parameter x

$$\frac{\partial s}{\partial x} = \frac{\frac{\partial T}{\partial x}}{\frac{\partial T}{\partial s}}$$

Since $\frac{\partial T}{\partial s} > 0$ it's sufficient to study the sign of $\frac{\partial T}{\partial x}$

$$\frac{\partial T}{\partial H} = \mu\beta \left[H \left(\frac{sn}{H} \right)^{\beta} + (1-H) \left(\frac{(1-s)n}{1-H} \right)^{\beta} \right] > 0$$

$$\frac{\partial T}{\partial \mu} = - \left[\left(\frac{sn}{H} \right)^{\beta} - \left(\frac{(1-s)n}{1-H} \right)^{\beta} \right] = - \frac{\mu_S - \mu_U}{\mu} < 0$$

$$\frac{\partial T}{\partial n} = \frac{\mu\beta}{n} \left[\left(\frac{sn}{H} \right)^{\beta} - \left(\frac{(1-s)n}{1-H} \right)^{\beta} \right] = - \frac{\beta}{n} \left(\mu_S - \mu_U \right) < 0$$

$$\frac{\partial T}{\partial \beta} = \mu \left[\left(\frac{sn}{H} \right)^{\beta} \ln \left(\frac{sn}{H} \right) - \left(\frac{(1-s)n}{1-H} \right)^{\beta} \ln \left(\frac{(1-s)n}{1-H} \right) \right] = - \frac{1}{\beta} \left(\mu_S \ln \mu_s - \mu_U \ln \mu_U \right) < 0$$

where the last three inequalities come from the assumption that $\mu_S - \mu_U = (1-\alpha)\left[F_s - F_u\right] > 0$. First notice that, by the envelope theorem, profit function depends on H,n,μ and β only through their direct impact on the recruiting cost. Therefore for any parameter $x = H, n, \beta, \mu$

$$\frac{\partial \Pi}{\partial x} = s \frac{\partial \left(\mu_S - \mu_U \right)}{\partial x} = s \frac{\partial T}{\partial x}$$

□

Bibliography

[1] Daron Acemoglu et al. Labour market imperfrections and thick market externalities from innovation. Technical report, Centre for Economic Performance, LSE, 1994.

[2] Keith Blackburn, Victor TY Hung, and Alberto F Pozzolo. Research, development and human capital accumulation. *Journal of Macroeconomics*, 22(2):189–206, 2000.

[3] Alberto Bucci. R&d, imperfect competition and growth with human capital accumulation. *Scottish Journal of Political Economy*, 50(4):417–439, 2003.

[4] Federico Cingano and Alfonso Rosolia. People i know: job search and social networks. *Journal of Labor Economics*, 30(2):291–332, 2012.

[5] ILO. International standard classification of occupations isco-08, 1990.

[6] Richard R Nelson and Edmund S Phelps. Investment in humans, technological diffusion, and economic growth. *The American economic review*, 56(1/2):69–75, 1966.

[7] Michele Pellizzari. Do friends and relatives really help in getting a good job? *Industrial & Labor Relations Review*, 63(3):494–510, 2010.

[8] Stephen Redding. The low-skill, low-quality trap: Strategic complementarities between human capital and r & d. *The Economic Journal*, pages 458–470, 1996.

[9] Fabiano Schivardi and Roberto Torrini. Structural change and human capital in the italian productive system. *Giornale degli Economisti e Annali di Economia*, pages 119–167, 2010.

[10] Sergio Scicchitano. Complementarity between heterogeneous human capital and r&d: can job-training avoid low development traps? *Empirica*, 37(4):361–380, 2010.

[11] Manfred Stadler. Engines of growth: Education and innovation. *Review of Economics*, 63(2):113–124, 2012.

[12] Frederic Tournemaine and Pongsak Luangaram. R&d, human capital, fertility, and growth. *Journal of Population Economics*, 25(3):923–953, 2012.

[13] Jinli Zeng. Reexamining the interaction between innovation and capital accumulation. *Journal of Macroeconomics*, 25(4):541–560, 2003.