Competence-based Compatibility between Jobs and University Curricula

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Summary. In this paper, we put forward a mathematical and statistical model for measuring the "compatibility" between jobs and university curricula based on professional competences. Our model aims at comparing work requirements and the professional counterparts achievable at school. Even if the basic concepts might be valid for the analysis of outer educational realms, the model is devoted to the analysis of highly qualified jobs, and in specific those "from technical to managerial positions" that may be taught at university. Our model is general enough, too, to frame various studies on the job market and clarify the terminological, conceptual and operational entities of occupations.
Keywords: Competences; Labour market; Jobs; Professional profile; University curricula; Formative profiles; Degree Programmes; Compatibility analysis.

1. Work activities, jobs and university curricula

The professional competences required in global-market activities change rapidly. The changes concern the technical refinement of occupations, i.e. the ability of workers in relating with customers, dealers and colleagues, communicating internally and externally with their company, working in a team, solving problems and organising their own job and that of others.

The term *competences* encompasses the knowledge, skills and attitudes required to applicants for work. This topic is dealt with in Section 2. In the following, without loss of generality, we assume that school is where the competences, as part of a person's personality causally related to superior job performances (Spencer & Spencer, 1993), are grounded.
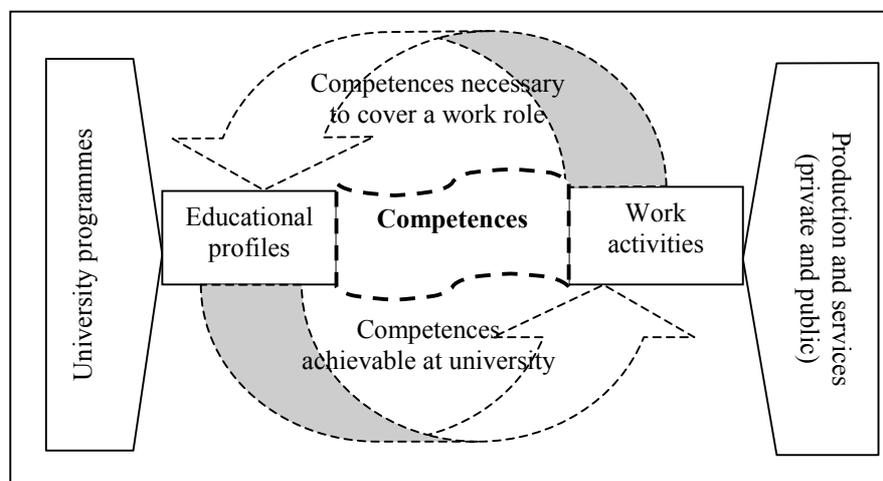

Figure 1. Type of relationships hypothesised between work activities and educational profiles in a "competence-based" society

Our relational model between work activities and competences stems from the hypothesis that the (bi-directional) links between the sites of production-reproduction of knowledge, whose edge is university, and those of economic production, represented by private companies, public bodies and professional offices[2], are knowledge and skills an educated person has to possess to cover a work role. The basic hypothesis of these links, represented in Figure 1, is a "competence-based" social system.

We can describe the links between job demand and offer in mathematical terms and quantify it by focusing upon the pertinent social segment. In particular, each work activity requires competences peculiar to the size and activity of the concerned company and its economic sector. The possibility to quantify the relationships represented in Figure 1 could allow us to predict and harmonise the needs and actions of labour and education universes.

From now on, we will use the terms "educational profile", or "formative profile", to indicate the competences achievable at a study programme. A formative profile is a direct output of a university programme, even if a study programme may generate more than one profile and, on the contrary, different programmes may generate the same essential profile. Sometimes, we will name "curriculum" the formative path a student can go through during his/her university studies.

The terms "professional tasks" and "activities" denote the work roles in companies. The terms "job", "occupation" and "professional profile" are the

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2   From now on, dealing with competences, we will not distinct between the private and
     public sectors of economy.

work roles a person, through his/her interrelated competences and culture, can realise.

In the following, we discuss:

- o *a relational model between work activity and professional competences* (Section 2); the model is specified in statistical and mathematical terms to make the relationships between entities clear,
- o *criteria for identifying the current and possible work activities in the economic sectors we are concerned with, and the competences associated to the identified activities.* The criteria are extrapolated from the current literature (Section 3) and direct data collection (Section 4).

In Section 5 we summarise our analyses and suggest issues for further research.

2. A relational model between work roles and competences

Professional competences are composed of knowledge, skills and attitudes appropriate for working in a productive environment. Knowledge is the set of principles and information usable at work. Skills are the sound aptitudes that enable a person to realise a work activity and may be either job-specific or cross-occupational (Befani, 2004; Silvestri *et al.*, 2005). Attitudes relate to workers' positive relationships with the productive structure, the people working with them, and their own professional tasks.

Competences are the results of a complex personal elaboration of the educational and experiential inputs (Keagan, 2002). This process implies a continuous matching with individual values, beliefs and aims. That is why we can define the competences the professional personality, or the professional style of a person.

Cross-occupational skills and personal attitudes may give a worker five types of know-how: *(i)* facing the complexity and picking up from a situation what is new; *(ii)* focusing on situations and behaving consistently; *(iii)* selecting, with reference to values, the most correct, appropriate, desirable behaviour; *(iv)* perceiving other people's competences; *(v)* abstracting over the contingent situation and imagining alternative scenarios. This know-how has no relationship with job-specific knowledge.

The job-specific competences differ according to job. They are composed of knowledge and skills specific of a certain job. Some technical competences are basic, and, at the hiring stage, it is taken for granted that graduates who apply for certain jobs possess these general competences. For technical and managerial positions cross-occupation competences are the fluency in English, spoken and written, and the ability to use the main computer functions and to correctly use the national language (for details, see Section 4). The 'a priori'

relevance attributed to these skills does not imply all graduates at work (Fab-bris & Visentin, 2005) use them.

From a mathematical viewpoint, the relationship between work activities and competences may be expressed with the following data matrices:

- o competence-by-job matrix (Section 2.1),
- o competence-by-educational profile matrix (Section 2.2),
- o job-by economic sector matrix (Section 2.3),
- o curriculum-by-university matrix (Section 2.4),
- o job-by-educational profile compatibility matrix (Section 2.5).

2.1. The competence-by-job matrix

A matrix of competence-by-job is a rectangular ($A \times K$) matrix, where A is the number of jobs identified within S economic sectors we are concerned with and K is the number of job-related competences:

$$_s\mathbf{Z} = \left\{ _s z_{ak} \right\} \quad (s = 1, ..., S; \ a = 1, ..., A; \ k = 1, ..., K),$$

where the element $_s z_{akv}$ is the amount of competences of k-th type necessary to realise a-th activity.

The expanded form of matrix $_s\mathbf{Z}$ is represented in Figure 2. Each row-vector represents the variety of competences used for a-th activity and each column the jobs for which k-th competence may be used. The relevance of a compe-tence to an occupation may be estimated with Delphi-like methods (Ford, 1975).

The mean of the elements of a column vector

$$_s\bar{z}_k = \sum_{a}^{A} {}_s z_{ak} / A = \mathbf{1'}_s \mathbf{Z} / A \quad (s = 1, ..., S; \ k = 1, ..., K),$$

where $\mathbf{1'}$ is a vector of A ones, estimate the average level of k-th competence utilisation in occupations of sector s.
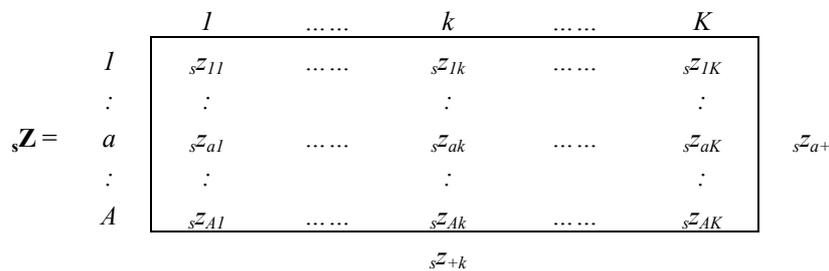

Figure 2. Matrix of competences needed to realise work activities in the economic sector s (s=1,…, S)

The sum by row, weighted to account for the possible non-independence of competences relevant to *a*-th job (see Section 2.5), represent the average use of competences to realise that job:

$$_s z_{a+} = {_s}\mathbf{Z}\,\mathbf{w}_a = \sum_k^K {_s}z_{ak}\,w_{ak} \quad (s = 1, ..., S;\ a = 1, ..., A),$$

where $\mathbf{w}_a$ is a vector of K weights that vary between 0 and 1 and sum 1.

2.2. The competence-by-educational profile matrix

The competences associated to C University curricula are ordered in a $(C \times K)$ matrix

$$_u\mathbf{Z} = \left\{ {_u}z_{ck} \right\} \quad (u = 1, ..., U;\ c = 1, ..., C;\ k = 1, ..., K),$$

whose generic element $_u z_{ck}$ represents the amount of competences associated to *k*-th profile achievable by attending programmes at university u (u=1, …, U).

The expanded form of matrix $_u\mathbf{Z}$ is represented in Figure 3. A row-vector represents the competences associated to *c*-th curriculum (c=1, …, C) and a column-vector the set of programmes where *k*-th competence is modelled. The column mean

$$_u\bar{z}_k = \sum_c^C {_u}z_{ck} / C = \mathbf{1'}\,{_u}\mathbf{Z}/C \quad (u = 1, ..., U;\ k = 1, ..., K),$$

where **1'** is of order C, is the average level of *k*-th competence achievable at *u*-th university programmes.

Analogously, the weighted mean by row is an estimate of the level of competences achievable by attending programme *c* (c=1, …, C):

$$_u z_{c+} = {_u}\mathbf{Z}\,\mathbf{w}_c = \sum_k^K {_u}z_{ck}\,w_{ck} \quad (u = 1, ..., U;\ c = 1, ..., C),$$

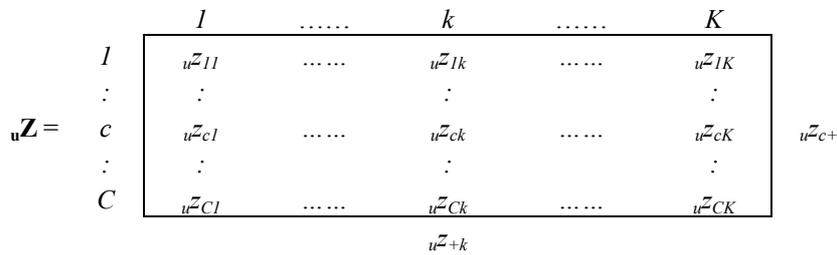where $\mathbf{w}_c$ is a column vector of K non-negative weights whose sum is one.

Figure 3. Matrix of competences achievable at study programme *u* (u=1, .., *U*)

2.3. The job-by-economic sector matrix

The job by economic sector matrix is of order ($S \times A^*$), where S is the number of sectors and A^* that of occupations of s-th sector

$$\mathbf{X} = \{x_{sa}\} \quad (s = 1, ..., S; a = 1, ..., A)$$

where the generic element x_{as} is a 0-1 indicator of the absence-presence of a-th occupation in s-th sector. Zero denotes the absence of a-th occupation, one its presence[3]. The expanded form of matrix $\mathbf{X}$ is presented in Figure 4. The ones of a row of the matrix represent the work activities of s-th sector (s=1, …, S) and the ones of a column the sectors where a-th job is required.

Figure 4. Matrix of jobs by economic sector

2.4. The curriculum-by-university matrix

The matrix of curriculum-by-university is of ($U \times C$) order, where U is the number of universities and C that of different curricula:

$$\mathbf{Y} = \{y_{ujc}\} \quad (u = 1, ..., U; c = 1, ..., C)$$

where y_{uc} is the 0-1 indicator of the c-th formative profile stemming from the homonymous programme at u-th university.

The expanded form is presented in Figure 5.

Figure 5. Matrix of curricula by university

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[3] Matrix **X** could be a *relevance* matrix of jobs to sectors, too, and its elements assume values between zero and one. In the following, we will assume, without loss in generality, that matrix elements are zeroes and ones.

2.5. The compatibility matrix

The relationship between educational profiles and occupations may be organised in a ($A \times C$) matrix of "compatibilities":

$$\mathbf{P} = \{p_{ac}\} \quad (a = 1, ..., A; c = 1, ..., C),$$

whose element p_{ac} is the amount of competences shared by c-th educational profile and a-th occupation. The values of matrix **P** vary between zero and one, zero indicating the absolute independence of occupation and educational profile and one being its maximum. The expanded form is presented in Figure 6.

Figure 6. Matrix of compatibilities between formative profiles and occupations

The compatibility is an appropriate function of $_u\mathbf{Z}$ and $_s\mathbf{Z}$. If we assume competences are independent to each other, in both matrices, compatibility p_{ac} between a-th activity and c-th curriculum may be quantified as follows:

$$p_{ac}^I = \sum_k^K \min(_uz_{ck};\, _sz_{ak})w_k \quad (a = 1, ..., A;\ c = 1, ..., C),$$

where w_k is a non negative weight associated to k-th competence ($\Sigma_k\, w_k = 1$). Such compatibility varies between 0, if no overlap exists between a-th activity and c-th curriculum, and 1, if the use of competence is systematic and continuous.

If we assume that competences correlate either with an activity, or with an educational profile, we could transform columns of matrices $_u\mathbf{Z}$ and $_s\mathbf{Z}$ into their independent linear components. A possibility is to define a ($AC \times K$) matrix **X** whose rows are the logical product of rows of the two **Z** matrices and columns are the competences. The generic element of matrix **X** may be estimated as the minimum value of k-th competence proper to both educational and professional profiles:

$$x_{ik} = \min(z_{ak};\, z_{ck}) \quad (i = 1, ..., AC; k = 1, ..., K).$$

Another measure, p_{ac}^{II}, of compatibility between c-th educational and a.-th professional profiles may be the sum of the r factorial scores f_{ij} weighted with their eigenvalues:

$$p_{ac}^{II} = \sum_{j}^{r} f_{ij} \sqrt{\lambda_j} \quad (i = 1, ..., ac, ..., AC),$$

r being the *rank(X)* and λ_j the generic eigenvalue of the variance-covariance **S** matrix whose columns sum zero:

$$\mathbf{S} = \mathbf{X'X} / AC = \left\{ s_{ij} = \sum_{i}^{AC} x_{ik} \, x_{ih} / CA \right\}.$$

3.   Compatibility estimation

To define the relationships between work activities and educational profiles it is necessary:

- *to represent the functional structure of companies of each economic sector*. The identification of functional areas that discriminate some types of companies, and in particular companies by size, will give us hints for understanding the specificity of competences of a given occupation;

- *to identify work activities of all functional areas of companies of a given economic sector*. We are concerned with managerial, technical and other white-collar activities, to which general clerical positions are added[4]. These work positions are those that a graduate may aspire to and, actually, are covered by graduates. To define work activities, entrepreneurs, managers and other top people in companies, and entrepreneurial associations are to be interviewed. Operatively, it is necessary to define a dictionary of activities of the examined economic sectors. We can start from the last Ateco classification (ISTAT, 2002) and add the new findings in classification research, such as the OECD (2001) classification developed after PISA project, CITP-88 international classification of jobs by ILO-BIT, ISTAT's in progress classification of jobs, ROME (1982, 1999) system developed by ANPE - *Agence Nationale française Pour l'Emploi*, the Italian Ministry of Labour-ISFOL series of publications on jobs typical of an economic sector or a functional area within companies (ISFOL, 1999; www.isfol.it/orientaonline), the repertory of jobs of Padua University (Fabbris, 2000, 2005) and other repertories fostered for guidance, statistical, or simply rational, purposes;

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[4]   Despite clerk, as a professional position, is generic in principle, it is often required in practice that clerical workers possess qualified competences. This is why clerk is considered as a position relevant even for graduates. Several graduates accept clerical positions while looking for first employment (Cappa & Fabbris, 2004). Blue collar positions are, instead, absent on graduates' expectations, even if they should be considered merely for first employment.

- *to identify professional competences inherent to work activities*. Competences can be ascertained according to research experience or expert evaluation. Type and intensity of competences may be correlated to structural features (economic sector, size) of companies and functional areas within them. An important issue is to realise if, in a given work environment, competences are specialised forms of a broader category, or are simply different. For this, we need a 'dictionary of competences' of each examined economic sector. The basic grid edited by the University of Padua for its repertory of jobs, the Spencer & Spencer (1993) list will be the bases to be enriched with outer experiences;

- *to define target competences of each university curriculum*. The terminology of competences must be that in use at work. We will try to harmonise the possibly different terminology of competences as defined at the labour and educational levels (see González & Wagenaar, 2005). Either competences may be achieved from the stated curriculum, or interviewing graduates about their work activities. Competences and jobs associated with a university curriculum may depend on the university that offers it, i.e. programme contents and teaching methodology of different universities may differ substantially. Nevertheless, for the sake of generality, programmes with the same name will be considered equivalent;

- *to define a one-to-one correspondence between competences qualifying work activities and university programmes*. To define the correspondence, a common terminology is to be used. We should use the terminology used in the job market;

- *to measure compatibility between work activities and programme aims*. To be able and associate a number to compatibility, we assume it is possible to quantify both the relationships between the activity and competences, and that between the curriculum aims and competences. A one-to-one correspondence between a formative profile and a job exists just for the regulated professions and some other specialised activities. Either the correspondence between non-regulated professions becomes to blur as the company size lowers[5] or its activities are new and unconventional. In micro and small companies, graduates are hired to realise work activities, some of which are consequent to his/her degree, while others may be more or less qualified.

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[5] Del Favero & Fabbris (2002) found that 36% of Padua graduates work in micro and small companies (up to 19 employees). This implies that several graduates may cover rather heterogeneous professional roles.

4.   Criteria for data collection on occupations

We assume that the employers, managers and experts in charge of personnel hiring within companies possess realistic information on work roles. They are informed about the company's professional needs regarding both the number of people recently hired and the company's future needs of jobs and competence.

The data may be collected face-to-face with a partially structured question-naire administered by skilled interviewers. Normally, the data collection is re-alised on the company's premises.

A CATI – *Computer Assisted Telephone Interviewing* may be realised if ei-ther the companies of the analysed economic sector are heterogeneous, or a lar-ger sample is required, or a face-to-face survey is not practicable. A CATI sur-vey is less expensive and organisationally easier than a face-to-face interview.

The collection of data on professional roles of handicrafts and regulated professions may be realised with focus groups, where a limited number of people (8 to 12) are interviewed together by the researcher him/herself. Focus group interaction makes it easier to define roles and competences than inde-pendent interviewing.

A questionnaire should be designed to collect the following areas of con-tent:

- o   Size, age, legal, organisational and network structures, and outsourc-ing activities of the company.
- o   Indicators of company development related to certification, informa-tion system, plants renewal, e-business, and so on.
- o   Functional organisation of company (areas with a person in charge of that function)
- o   Number of employee by professional position and company's func-tional areas. The seasonal and foreign people hiring, the frequency of parental aid and the annual frequency of internships.
- o   Turnover and new occupation forecast two-three[6] years apart.
- o   Definition of technical, intermediate and managerial positions exist-ing within the company, or to be covered with future recruitment, by functional areas.
- o   Basic, cross-occupational and job-specific competences of profes-sional roles, possibly by functional areas.

Basic competences may be surveyed with reference to the following re-quirements:

- -   the level of spoken and written English. It is convenient to inquire about the knowledge of other foreign languages, even if the other than English knowledge is to be considered a job-specific skill;

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[6]   It could be possible to enquire the entrepreneurs/managers and foresee their needs five years onward. Several research experiences indicate that this is really a problematic task.

- the level of computer skill. The question should be asked in a non trivial way, given that no technician can work without knowing Office package, nor can managers manifest the snobbish attitude not to use PCs. In general, we can distinguish between the abilities of using highly specific packages and that of producing computer programmes.

Cross-occupation competences are peculiar from the data collection viewpoint, since they are not taught as such at school despite their professional relevance. These competences – to be collected in relation with work effectiveness[7] and not personal effectiveness – are the capacities:

- to work in team,
- to communicate with customers and tradesmen,
- to organise his/her own and other people's work,
- to conceive and manage research and work projects,
- to write and present reports and management indicators.

The job-specific competences differ according to job. Hence, it should be decided beforehand if the survey should care about it. In general, entrepreneurs and managers leave them implicit into the occupation labels perceived as suitable for a work position. Besides, there are questions about competences used on (almost) a daily basis and others on peculiar and very qualifying professional activities. Whenever the information about job-specific competences is collected, it may be processed by means of text analysis and enters the dictionary of competences.

The attitudes that deserve to be collected are the professionally distinctive ones. We can ask about the availability to work in uncomfortable conditions, such as, working in open air, underground or in closed environment, travelling frequently or for long periods. With reference to a job, these attitudes could be thought as technical requirements.

5. Conclusive considerations

Our model aimed to quantify the compatibilities between educational and professional profiles. Compatibilities are a paradigm to qualify curricula and jobs in terms of competences, too.

Our model takes it for granted that university programmes can be compared with work needs. We doubt work needs are a parameter for quality of competences acquired at university, because otherwise cultural, non-professional, competences risk to be considered second category. We aim to define how it is

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[7] Competences oriented to personal effectiveness are: the possession of formal languages, mental flexibility, leadership, self consciousness, decisional character, ability to face the unexpected, analytic and synthetic abilities, risk propensity, autonomy of judgement, emotional self-control, professional engagement, faithfulness, creativity and other competences ideal for work and life.

possible to assess relationships between the two kinds of profile whenever the decision to start this link would be taken.

The critical point of our model is the possibility to quantify the competences required for working purposes. Even the possible quantification of relationships between educational and professional profiles would be meaningless if not framed within a design concerned with the estimate of short-mean term work possibilities for the considered economic sectors.

The estimate of work chances are an aim of Excelsior informative system (www.excelsior.unioncamere.it) and Istat's surveys (Decennial population and economic activities censuses, quarterly labour force survey, European panel survey on families).

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