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Abstract and Paper

***A gap in competencies or in capabilities?: the role of regional universities  
in developing scientific and technological skills in Campania*****Maria Del Sorbo**

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[G.N.Von-Tunzelmann@sussex.ac.uk](mailto:G.N.Von-Tunzelmann@sussex.ac.uk)**Abstract:**

The paper assesses the role of universities in resolving the STEM (Science, Technology, Engineering and Mathematics) skills gap in the Campania region of Southern Italy. The results are shown to hinge on a doubled supply/demand model, involving a first upstream stage (logically if not chronologically) of derived demands for and supplies of STEM-based skill development within universities, and a second downstream stage of the usage of these skills in industrial firms. The main objective of this work is to re-examine the role of conventional ‘knowledge capital’ arguments for the role of universities in development processes in catching-up regions of the EU – i.e. human capital and R&D capital, or what will be identified here as ‘competencies’ – as against what we refer to as ‘capabilities’ arguments, reflected here in better ways in which universities might adapt to the actual needs of industry for highly skilled workers and research outcomes. The results suggest that the STEM skills gap is not clearly a deficiency just in capabilities, but more so in the links between capabilities and competencies. Moreover, the STEM universities are trying to feed the interaction with industry, however it is still left mostly to the

personal relationships of the professors or their administrative counterparts, e.g. head of the T&T office, and/or to placement.

**Key words:** *Derived demand and supply, STEM subjects, Mezzogiorno region, skills gap, competencies and capabilities.*

## **Introduction**

Much has been heard in recent months and recent years about the so-called ‘knowledge triangle’, of education, research and innovation, as it has also been of the ‘Triple Helix’, of universities, government and industry. As tends to be the way in matching up function based systems with agent based ones, the two though ostensibly concerned with similar fields map only quite imperfectly into one another – here the function of research is for instance carried out by all three types of agents in significant quantities. This in turn implies, through its rejection of a schema of complete specialization of the kind attempted under the Former Soviet Union (FSU), considerable scope for both complementarity but also for some elements of competition around the margin. There is also some evidence that the system thrives when working with a moderate degree of competitive behaviour, such as that exhibited for instance in the widely admired German mixed system for technology transfer (built around the Fraunhofer institutes but with overlapping albeit non-identical roles for the ‘competitors’ like the Steinbeis or the AN Institutes (Harding, 2002). Equally there is some damning evidence to condemn the (over-)specialized system of the FSU in missing its real objective of achieving a vibrant, innovative society and economy through excessively focusing on the supposed benefits of not just specialization but of non-competition and massification (von Tunzelmann, 1995). Although competition is supposed to attain high levels and to reduce or even eliminate ‘waste’, in a more dynamic environment innovation can be boosted by having a certain amount of slack and partial duplication to work with (e.g. Penrose, 1959). This is for more reasons than simply the matter of freeing resources, since it raises ontological issues surrounding the structuring of knowledge, and of how different agents playing different roles can view the same bit of ‘information’ in quite different ways – what we shall be referring to later in the paper as asymmetries of knowledge.<sup>1</sup> Thus, within a university research system, somebody trained exclusively in chemistry might see or read a paper

<sup>1</sup> This contrasts with the widely known situation of ‘asymmetries of information’, in which different agents, precisely because of their differences of roles, do not have access to the same bits of information.

in biochemistry rather differently from someone else from a background exclusively in biology, and so on.

The main objective of the present paper is to assess the role of conventional ‘knowledge capital’ arguments for the role of universities in development processes in catching-up regions in the EU – i.e. human capital and R&D capital, or what are going to be identified here as ‘competencies’ – as against what we refer to as ‘capabilities’ arguments, reflected here in better ways in which universities might adapt to the actual needs of industry for highly skilled workers and research outcomes. Our prior view before testing these hypotheses, using a mixture of quantitative and qualitative evidence, was that the university system in such regions might be able to adjust its course and research provision more satisfactorily, so as to meet the industrial demands, especially in relation to areas of science and technology. Our posterior view, on the basis of the interviews conducted so far, is however quite different and distinctly more ambivalent – the evidence we are obtaining indicates that many of the key individuals share these more outgoing views of what universities ought to be providing; this makes us more optimistic about having to do less ourselves to persuade them that this approach is preferable to an ‘us alone’ stance, but more pessimistic about the possibilities for radically rethinking the current policy stance and hoping for a great gain in effectiveness as a result.

The paper takes a critical look at approaches to differences in regional economic performance, whether in static terms (e.g. per capita income levels) or dynamic terms (e.g. rates of economic growth), which explain such differences by means of ‘human capital’ and ‘R&D capital’ (‘technology’). This does not mean that we repudiate any causative mechanism at work here, and still less that we reject any correlation between human capital or technology measures and income levels or growth rates, but that we contend that the causal influences need to be interpreted much more carefully than is commonly maintained. More specifically, we would cast doubt on what could be described as a ‘mechanistic’ (as opposed to a more ‘organic’<sup>2</sup>) view of the role often implicitly granted to knowledge capital of ‘the more, the merrier’; in other words that development is a matter of investing to accumulate larger stocks of human or technological capital. More precisely, we see the regional economic differences as being driven more by differences in human and technological ‘capabilities’ rather than in human and technological ‘competencies’ – where drawing such distinctions is obviously critical to the argument (see von

<sup>2</sup> To adopt here the language and meaning of Burns and Stalker (1961).

Tunzelmann and Wang, 2007; Iammarino et al., 2008; von Tunzelmann, 2009a). On the other hand, it may be necessary – although not sufficient – to invest initially (and to reinvest subsequently) in acquiring those ‘competencies’ in order to kick-start the development process; in other words, building the educational edge of the ‘knowledge triangle’ ahead of demand.

The Supply-Supply/Demand-Demand (SS/DD) model, proposed in a previous work see Del Sorbo (2010), is based on a bilateral knowledge flow between universities, firms and students. In this paper the supply side: university is taken into account.

The university operates on several scales of activity. Its capacity to provide more qualified skills for industry needs an integrated approach that combines firstly the understanding of different disciplines in order to gain new knowledge, and secondly the ability to feed the relationship between the educational and business worlds at a local, regional and national level (European Union, 2006; Perry B. & May T., 2007).

To attain this aim the mobility of individual workers is a key driver to create bonds between the triple helix actors and to create the externalities in labour markets, as argued by Marshall (De Laurentis C., 2006). The need for regional intelligence<sup>3</sup> to understand the local socio-economic context, local needs, linked conditions, policy learning and the capacity of strategic thinking is crucial in this context (Komninos, 2004).

The “intensity of local academic knowledge transfers is strongly and positively correlated with spatial concentration of economic activities. A major policy consequence of this finding is that strengthening universities in order to advance local economies can be a good option for a relatively well developed metropolitan area but not necessarily for a lagging high technology region.”, (Varga A., 1997). STEM skills are crucial *knowledge workers* because of their strong capacity to adapt to new conditions.

Although lots of research efforts have considered knowledge workers in Science and Technology and R&D from both the demand and supply side (Mogu rou P. & Di Pietrogiacomo M. P., 2007), at regional level the empirical evidence is still rather scanty.

<sup>3</sup> Regional intelligence: “distributed information systems localized over a region allowing continuous updates and learning on technologies, competitors, markets, and the environment.”

In this work we deal with the university as a provider of courses to students of the STEM subjects. The demand from prospective students for places on the courses offered will depend on: i) the desire of students to undertake courses in these subjects (which will depend on their *perceptions* of course attractiveness (‘sexiness’), course difficulty, subsequent job availability, etc.); ii) student abilities to fund their courses (including ‘opportunity costs’ of foregone earnings, state subsidies, etc.); and iii) the course fees. These propositions should guarantee the conventional downward-sloping demand curve, showing that increased fees (for instance) reduce the number of students willing to study for a course.

However, the courses that a university is actually able to offer in order to satisfy the demands of students is also dependent on the availability of resources that the university actually possesses. This will depend on its capacity to offer high-quality courses that become crucial in the STEM fields. The supply curve of university courses should take on the usual upward-sloping shape, reflecting the high marginal costs of acquiring and utilizing resources to maintain and upgrade standards of course provision in the areas concerned as student numbers increase.

In universities there would seem to be an under-production in terms of STEM subjects, as it seems there is an inadequate availability of Science and Technology resources for industry. The internal question for universities is whether this is due to a deficit in student demand for places or a deficit in university STEM courses, or maybe both.

The demand from students and the supply of courses may be seen in terms of disciplines, i.e. each of the STEM subjects. For this reason the relevant data coming from universities and associated statistical agencies is highly discipline-based. However, are the students well qualified or not? Will they find suitable jobs allocated to them in the labour market? To answer these issues we must look at the demand side of industry (DTI Department of Trade and Industry Office of Science and Technology, 2003). A shortfall of students or a lack of STEM courses may be causes of an under-production of STEM resources, and an investigation into this could form a useful contribution to the result of this research.

## 1. Competencies vs. capabilities for development

### 1.1. Capabilities and Actors

To many scholars, the distinction between ‘competencies’ and ‘capabilities’ is such a fine one that they do not find any difficulty with conflating the two, pausing only to distinguish among more broadly defined concepts (e.g. referring regularly to ‘technological capabilities’ or ‘dynamic capabilities’ rather than to ‘technological competencies’ or ‘dynamic competencies’, or equivalently to ‘core competencies’ rather than ‘core capabilities’ – and even this, more by way of verbal routines and thus for ease of communication than for any deeper logical reason). To such authors the distinctions involved may be purely semantic,<sup>4</sup> and if so they are right to avoid wasting any more of their time (or their readers’) on fine-tuning the dictionary, in our view. Several of such a group use one or other term to represent both (and other terms as well).<sup>5</sup>

On the other hand a number of scholars have believed that there is more to the differences than just semantics; that the distinctions in terms of real applicability are substantial, both analytically and empirically; and that drawing such distinctions can help in many recognisable ways towards understanding the sources of differentiation and even of success and failure at all levels, from the micro level of individual organizations, through meso levels of individual industries and localities, up to macro levels of individual countries and whole continents.

This paper leans towards the latter view, though it quickly runs into the problem that there has been no consensus in the subject or its surrounding literatures about how to go about drawing a relevant set of distinctions, much less about what any consistent set of distinctions consists of. Such debates have been going on for about two decades now; hence there is a lot of terrain to cover.

As our guiding influence on the nature of capabilities, we build on the work of Amartya Sen (1985, 1999), as one of the world’s deepest thinkers on the matter of defining ‘capabilities’. Sen’s formal structure does not go beyond what we would describe as ‘consumer capabilities’. In

<sup>4</sup> e.g. statements such as “... resources, core competencies, capabilities or whatever we decide to call these knowledge assets ...” (Foss, 1996: 18). Throughout this paper we will not try to differentiate between “competency/ies” and “competence/s”.

<sup>5</sup> e.g. Teece et al. (1997: 510), in their seminal paper on dynamic capabilities, use that term to cover both capabilities and competences. An even more encompassing use of ‘competencies’ to cover both resources and capabilities appears in Lado and Wilson (1994).

this exposition, we will launch straight into the equivalent for ‘producer capabilities’.

First, it is important to understand what is meant here by the consumer, producer and supplier, to take the three categories that are of concern to us. The main point to stress is that these categories throughout the present paper refer to *actors*, not to *agents*. That is, they refer to individuals and their organizations who play parts that may take on all of these roles at more or less the same time. So for instance, while we are personally engaged in the act of producing this paper, we are being supplied with (and hence we consume) the inputs that are both technological artifacts (like the computers and peripherals or the word-processing and powerpoint software packages which we are using to present the results), and bodies of knowledge represented by the journal articles and books that we consulted and sometimes cite in the paper. In turn we hope to supply you – the quasi-mythical ‘dear reader’ – with the fruits of our thinking, which you as the potential consumer of our products (this paper and presentation) are of course free to accept or reject on the basis of its arguments as you prefer. Your choices in this respect should depend on your own knowledge base of ‘competing products’, as well as the perceived inherent quality of this product. This roughly simultaneous set of acting roles that we play in the course of writing the present paper is duplicated many times over in more complex organizations. By contrast, each type of organization will have a fixed role judged as an agent, be it as a university or university department, manufacturing firm, bank, government research team, or whatever.

With the principle in mind that we are discussing producers as actors rather than as agents, we can analyse producer capabilities of STEM departments (Science, Technology, Engineering and Mathematics or Medicine) in universities by setting out the successive steps necessary to map *productive resources* into *rewards* for those producers.<sup>6</sup> To do so, we can define the outcomes for universities in terms of nested vectors, differentiated in the first place by the specific *characteristics* of the subject matter. Most universities nowadays would define their principal products as the outcomes of processes relating to the production of teaching, research, and ‘third-stream’ consultancy or similar projects. Next, *functionings* (in Sen’s terminology) represent how well an individual producer’s needs are met by the particular resource bundle with its set of characteristics. The bundle of functionings for the individual producer constitutes its

<sup>6</sup> The following formal analysis is extracted from a published paper (von Tunzelmann and Wang, 2007), with some significant new additions as well as many deletions.

production *capabilities* (again using Sen's own language). Finally, the rewards ('*profitability*') are determined by the capability set and the associated functionings.

This approach to production matches the heterogeneity of the resource inputs and their characteristics against the heterogeneity of producers and their needs for such inputs (their 'production possibility set', in orthodox economists' language), in the same way as Sen's capabilities approach to consumption allows matching the heterogeneity of product characteristics existing in markets to the heterogeneity of consumers and their demands (in effect, a 'consumption possibility set'). The rewards ('profits' or 'earnings') of producers reflect the ability to conform their resources to their own needs, and linked with that, to conform their product ranges to (heterogeneous) consumer needs. Clearly the levels of rewards normally influence the longer-term dynamics of growth of the producers. However in the case of universities, the not-for-profit nature of publicly funded organizations requires some rethinking of the rewards on offer, as clearly brought out in the literature on the so-called 'new economics of science' (Dasgupta & David, 1994). In their view, the rewards in academia lie in 'prizes' rather than 'profits' in the usual sense, and these prizes (honours, professorial posts, etc.) depend on priority in open publication instead of commercial secrecy.<sup>7</sup> This however may be clearer in 'basic' rather than 'applied' sciences.









The whole variety of resource and product transformations utilised by universities and other organizations is itself largely the result of production processes of one kind or another, and the analysis can, if need be, be pursued further in a somewhat repetitive, recursive fashion. Aside from this last twist of additional complexity, the structure so far as it relates to university STEM departments can be represented as Figure 1, showing the 3 nested levels of the Sen approach in the rows together with the 3 kinds of actors in the columns. The figure supposes that some distinctions can be drawn between 'basic' (the S of STEM subjects, plus M where M=mathematics) and 'applied' sciences (the TE subjects). Not shown are columns further to the left or right, e.g. the 'product possibilities' and 'consumption capabilities' of final users/consumers to the right of the industrial users.

<sup>7</sup> The current vogue for 'open innovation', alongside the 'open-source' movement in software and other industries, might be regarded as partial incursions of academic values into the business world, albeit often advocated for good commercial reasons of promoting interactivity (see below).



The diagonal single-headed arrows represent supply factors (S), emanating in each case from the capabilities of the actor located next upstream. The vertical, upward-pointing arrows show the demand factors (D), obtained from the capabilities of the actors operating on that level; however it is only when we move outside academia into the business arena that fully-functioning market prices and associated mechanisms begin to be established, and hence the demands for applied research (technology) can be thought of as ‘derived demands’ linking backwards from the sales of final goods and services, shown by the horizontal, left-pointing arrows in the figure (DD). Moreover, and especially the case in situations such as those depicted here where freely determined market price structures do not prevail, and indeed would be difficult to implement adequately on grounds of Kenneth Arrow’s ‘paradox of information’ (Arrow, 1962a), there may exist direct interchanges of knowledge based on paired capabilities of actors, i.e. ‘knowledge exchange’ or less accurately ‘knowledge transfer’ as shown by the horizontal, double-headed arrows in the capabilities row (KE). Finally, the disputed area of interaction between the teaching and research functions is shown by the U-shaped double-headed arrows (which could also show up in other columns in a variety of ways, e.g. between industrial firms and their own R&D).

**Figure 1: The capabilities schema for universities**

	<i>Supplier</i> <i>(of basic research)</i>	<i>Producer</i> <i>(of teaching, applied research)</i>	<i>Industrial User</i>
<b>Characteristics</b> 	 <b>Science possibilities</b>   	<b>Technological / pedagogical possibilities</b>	<b>Production possibilities</b>
<b>Capabilities</b> 	 <b>Scientific capabilities</b> 	<b>Technological / pedagogical capabilities</b>	<b>Production capabilities</b>
<b>Rewards</b>	<b>Prizes</b>	<b>Earnings (IPRs)</b>	<b>Profits</b>

In the figure, the production possibilities come from the intersection of the supply of

technological capabilities and the demand from producers' capabilities, and so on. But, as we argue was the case in postwar UK in von Tunzelmann (2009), any breakdown in the system at these rather rarefied levels may have been the result of 'network failure' of the KE arrow kind rather than straightforward market failure of the D–S type.

To summarise, the model of production we are taking on board here replaces the demand–supply duality of the traditional 'classical' type<sup>8</sup> with a threefold classification of demand–production–supply. Each producer, whether it be of science (universities), technologies (laboratories), products (firms), capital (banks), and so on, is looking both ways – upstream to the supply of its inputs and downstream to the demand for its outputs. The contributions of the actors/agents come on three levels: the characteristics of the product (etc.) they are dealing with, the capabilities proper showing how they function in this context, and the rewards they earn from being so engaged.

## 1.2. Interactive and dynamic capabilities

Malerba (1992) argued, partly through a literature search and partly through an empirical analysis of American manufacturing firms, that learning came about in a variety of ways and often required the commitment of substantial resources and capabilities by the firm. Learning can be linked to different but specifiable sources of knowledge, which may be internal to the firm (e.g. generated via production activities) or external (e.g. transferred from supplier firms, user firms or general advances in science and technology). Malerba proposed a taxonomy of learning processes that can be restyled here as in Table 1:

**Table 1: Taxonomy of learning mechanisms**

<i>Source:</i>	<i>Internal</i>	<i>External</i>
From production	Learning by doing	Learning by spillovers
From consumption	Learning by using	Learning by interacting
From 'search' (supply)	Learning by training / R&D	Learning by education / S&T

*Source: after Malerba (1992) with own elaborations*

<sup>8</sup> von Tunzelmann (1995), ch. 2.

The rows of this table roughly equate to the threefold structure provided by the columns of Figure 1 above, although here adopted from a quite different literature. For universities, and reading across each row in turn, we find production activities themselves (i.e. teaching and research) generating learning, both learning-by-doing of the classic Arrow kind (internal) and learning from the production activities of collaborator or competitor departments elsewhere (external); consumption activities giving rise to ‘learning by using’ of what is supplied (internal) and learning by actually interacting with suppliers or users (external);<sup>9</sup> together with more formal ‘search’ procedures associated with such suppliers of technologies and skills, namely R&D and training (internal) and science and technology (S&T) systems plus education systems in general (external). To be sure, some of these divisions are somewhat more arbitrary in a university context than in Malerba’s situation of manufacturing firms.

Up to this point we have not attached any special time flag to the capabilities involved. The likely reality is however Schumpeter’s depiction (1934) of ‘dynamic competition’, in which it is not just a question of fluctuating prices but of ever-changing technologies, resources, products, market structures and so forth. Dynamic capabilities therefore require the gearing of both static and interactive capabilities to the context of dynamic competition.

One can think of dynamic capabilities as relating to time in two ways. The first is as real-time responses on the part of the producers, that could be validated by intelligent appraisal, intuition or good guesswork (say) on their part, but most likely success will call for interaction of some kind – i.e. interactive knowledge flows and ‘learning by interacting’ in the broad sense of Lundvall (1992) – with consumers and/or suppliers. Hence we can in principle contrast ‘interactive capabilities’ and ‘dynamic capabilities’, though in practice both will often go together as ‘dynamic interactive capabilities’, and for further discussion in this paper we will define ‘dynamic capabilities’ as both real-time and interactive. There is thus great pressure to do things fast, and preferably ahead of time. Although such pressures may seem weaker in academia than in business, the previously mentioned priority system for publication in order to win the prizes demonstrates that the scientific world is far from immune, as do the patent races beloved by industrial economists in the world of technology.

<sup>9</sup> The category of ‘learning by interacting’ from upstream suppliers or downstream users was developed by Lundvall (1992).

Such images of real-time pressures have to be put alongside the argument that dynamic capabilities are shaped by the internal co-evolution of learning mechanisms developed from operating routines (Zollo and Winter, 2002). The second type of dynamic capabilities is thus also time-dependent, but here depending on historical time rather than ‘real time’. This view allows the incorporation of cyclical behaviour and time-lags into a dynamically evolving system. It permits the inclusion of long-term (historical) scale and scope economies arising out of cumulative learning, and issues surrounding path-dependency and ‘past-dependency’. Much of this work is at an early stage of development, picking up on the cue from the paper by Teece et al. (1997) and its reference to ‘paths’.<sup>10</sup> A significant contribution here is that of Helfat and Peteraf (2003) on ‘capability lifecycles’, where instead of a final stage of decline as in product lifecycle approaches, the authors posit no fewer than 6 possible outcomes (retirement, retrenchment, replication, renewal, redeployment or recombination). The actual selection made depends partly on circumstances, e.g. regulatory changes, and partly on abilities to re-grow; hence one way or another on capabilities. Through such capability lifecycles and selection points, the authors claim they can identify some of the sources of heterogeneity across the range of producers, and thus of their capabilities (see also Hoopes and Madsen, 2008). Such perspectives are readily applicable to the birth, death and rebirth (or regeneration) of university departments.

### **1.3. Competencies versus Capabilities**

We turn now to the contentious issue of the distinction (if any) between ‘competencies’ on the one side and ‘capabilities’ on the other. Of the many contrasts we will be drawing between them in this paper, the most fundamental concerns our interpretation of competencies as relating to enhanced resources, while capabilities are linked to enhanced functions. Much also rests on where exactly the ‘enhancement’ takes place; in particular, whether the learning processes that generate such enhancements are internal or external to the producer in question. In this manner the provision of more – and maybe better – graduates to the local labour market is a consequence of the capabilities of the locality’s university departments, and not of the industrial firms that draw upon that graduate labour market – for them the graduates they employ represent a

<sup>10</sup> Eisenhardt and Martin (2000: 1107) thus define dynamic capabilities as “the *antecedent* organizational and strategic routines by which managers alter their resource base ...” (our italics). However they also contrast “moderately dynamic” with “high-velocity” landscapes, without making it clear whether the rapid changes are taking place in markets or technologies (or both).

competency, at least until the employing firm is able to reskill them in its own ways. At such a point, though not before, the ‘functionings’ of the firm’s R&D department (etc.) improve and its capabilities can be said to rise.

Figure 2 shows dyadic network relations as they pertain to ‘resources’, converging on a particular University *x* in the format of in-degree network centrality as reflecting its demands for (enhanced) resources, and in reverse fanning out from the university in question as the resources of graduate students, applied research, etc. that it feeds back to many of the groups of its own suppliers, now of course acting as its users (e.g. supplying schools with trained teachers). Non-enhanced resources are not displayed (e.g. unskilled labour from households, basic raw materials from farms or mines, etc.), yet the picture is already quite complicated. Each group or type of enhanced resource comes primarily from a different type of organization (e.g. managerial labour from business schools, research labour from (other) universities, and so forth). Each group is represented by a ‘box’ of inputs as rows and of outputs as columns – in other words a fairly conventional input–output matrix, with the same rows and columns for the higher education sector always highlighted.

**Figure 2: Resource networks and sources of added value, for competencies**

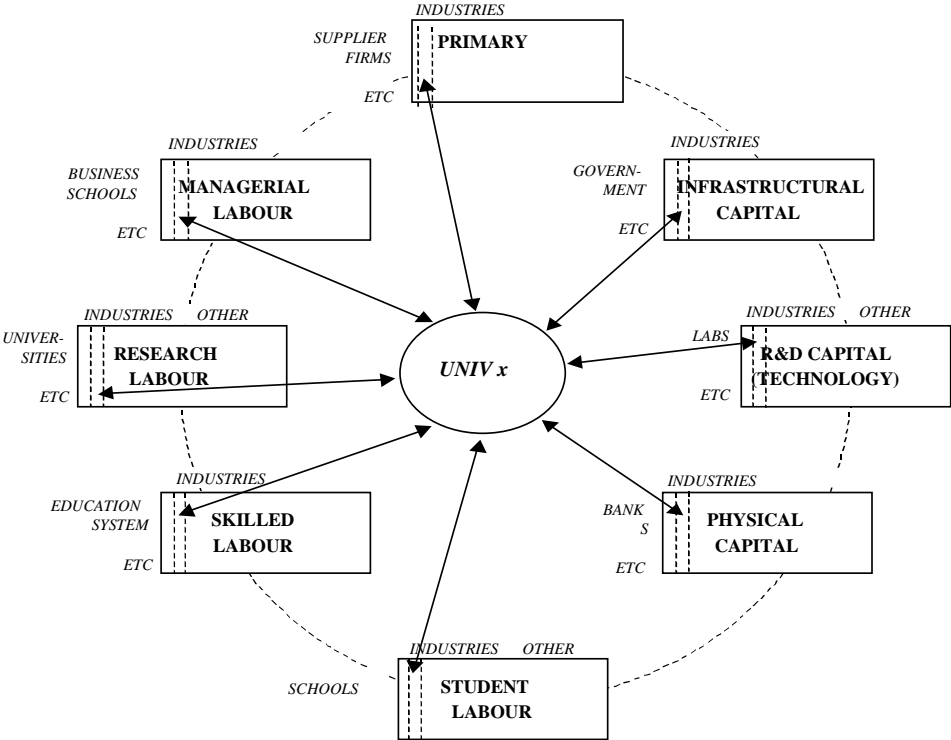


Figure 2 as the guideline to ‘competencies’ assumes the enhancements take place outside the university of our concern, which rather inadvertently adheres to the notion of the producer as a ‘black box’. This assumption is countered when we look to the ‘capabilities’ and their own enhancement through gaining functionality, as in Figure 3. Such gains are not limited to the products function but can occur anywhere in the micro (or macro) system.

**Figure 3: Functional structures within organizations, plus macro links, for capabilities**

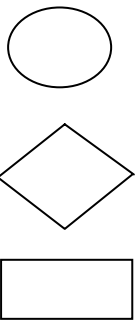
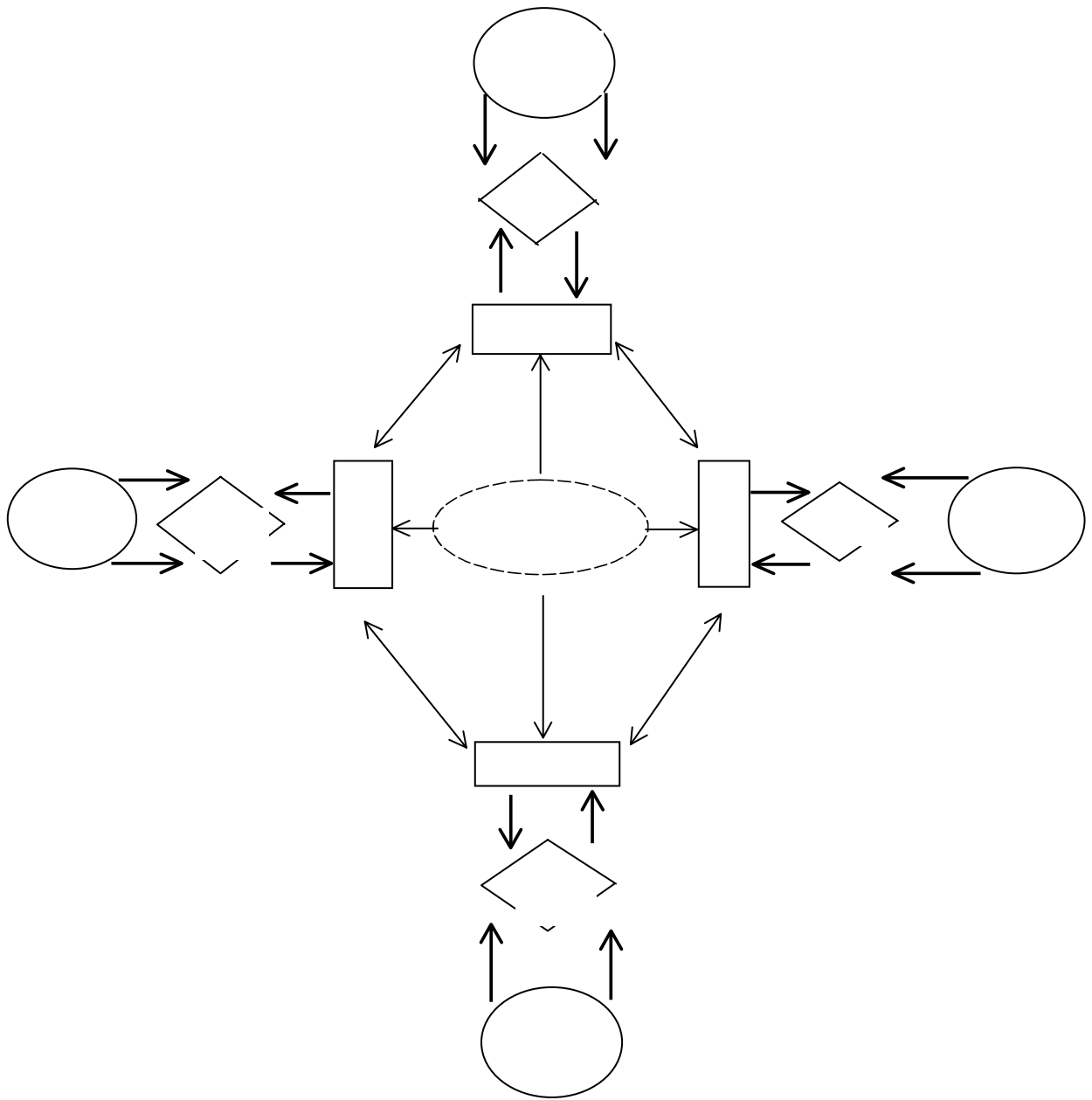


Table 2 summarises, albeit rather baldly and bluntly, our suggestions for distinguishing competencies from capabilities. Set out in this way they appear to be more oppositional than overlapping, more like antitheses than acting as synonyms or even complements. This appearance is of course the fault of a method of selective sampling, biased heavily towards finding contrasts rather than similarities. In reality there are many shades of grey between the black of one category and the white of the corresponding entry in the other category. Moreover there is the suggestion that follows from the comments at the end of the preceding section of a life-cycle pattern of transformation of one into the other, and to an extent back again.

**Table 2: Characteristics of competencies versus capabilities**

	<b>Competencies</b>	<b>Capabilities</b>
1. Function	Enhancements to ‘resources’	Enhancements to ‘services’
2. Stocks	Human and R&D capital stocks	Knowledge stocks
3. Chain position	Inputs related	Outputs related
4. Product area	Specific, focused	General, adaptable
5. Supply–demand	Supply driven	Demand and supply driven
6. Stage	Potential	Realised
7. Development	Acquired and hired	Accumulated within
8. Learning	Learning by searching	Learning by doing
9. Asymmetries	Asymmetries of information	Asymmetries of knowledge
10. Skills	Generic, transferable	Specific, non-transferable
11. Breadth	Relatedly Simple	Relatedly Complex
12. Depth	Cognitively Complex	Cognitively Simple
13. Reasoning	Logic	Nous
14. Time location	A priori	A posteriori
15. Appropriation	Appropriate	Appropriable
16. Spread	Diffusion by information	Diffusion by demonstration

*Source: Author, from multiple secondary sources (see text in von Tunzelmann, 2009c).*

The distinctions in the first half of the table can be deemed ‘essential’, with the first six being regarded as ‘static’, while the rows 7 and 8 relate more to dynamic competencies and capabilities. It will be observed that the term ‘dynamics’ even in this context is not reserved just for



capabilities. The remaining rows, from 9 onwards (in a list that it would not be difficult to extend further) can be thought of as ‘associated attributes’, implying that these play a supportive rather than a key definitional role, and indeed the later entries in this table become quite vague and impressionistic. Certainly where there is any conflict between the essentials and the associated attributes, it would be more prudent to rely on the former for classification purposes, even though the extra ‘colour’ imparted by the latter may continue to complicate the story.

Clearly we have only limited space here to justify and to expand upon the categories thus set out. The interested reader can refer to the forthcoming paper (von Tunzelmann, 2009c) that takes these items as points of reference for a more detailed elaboration. And so far we have followed conventional economic wisdom in seeing the two as a matter of choice between them – of allocation decisions of an either/or kind. Instead the tenor of this paper is that there is not really much of a choice in practical situations, except perhaps right at the margin, since both are essential albeit in their different ways. Over the longer term, competencies can be transformed into enhanced capabilities, while additional capabilities also ‘feed back’ into more and deeper needs for strengthening or extending the range of competencies, but these involve complex learning procedures (e.g. ‘learning to learn’)<sup>11</sup> that in our view lie at the heart of successful regional development processes.

## **2. Regional and other capabilities**

Up to this point we have had little to say about the actual content of either competencies or capabilities. However this has required a degree of finessing such practical matters, on which we ought now to ‘come clean’. In view of the subject matter of this conference, the question of regional topics is of particular concern. As observed in Iammarino et al. (2008), aspects that can be regarded as ‘exogenous’ to the individual micro unit such as firms and thus falling into the realm of ‘competencies’ for that micro level of analysis, can become ‘endogenous’ and therefore ‘capabilities’ at the macro level of the region/country more generally. This of course is because of the heterogeneity of micro units found at the regional level. In the field of university–industry contributions to local development this is transparently clear: while regional universities may

<sup>11</sup> The notion of ‘double-loop learning’ put forward by Argyris and Schön (1978) also arises at this point.

continue to tap into national or international sources for their academic staff, the flow of their graduates into business is likely to be predominantly intra-regional.<sup>12</sup> From the point of view of *regional development*, the decision here may rest importantly on the effectiveness of usage of the input characteristics in producing the range of industrial output. Thus the UK had a long-held reputation for being good at science but poor at carrying those scientific advances through into industrial innovation, and therefore a rather broken ‘innovation system’ despite its successful ‘science system’ (von Tunzelmann, 2009b). In a more extreme vein, we were struck, in the course of past work on Eastern Europe, by the evident disparities between competencies and capabilities in the transition era of such countries in the 1990s – for instance, by PhD graduates in Moscow who found driving taxis a more lucrative source of employment in these years than, say, research in higher mathematics. In other words, the efficacy of a ‘system’ – and thus the measure of its capabilities – depends on the demands placed on that system as well as what it is supplied with (Table 2, row 5).

As argued at much greater length in von Tunzelmann (2009a), the regeneration of old industrial districts involves a blending between older and newer patterns of adjustment – bridging between the traditional strengths and the new requirements in order not to lose the region’s sources of comparative or absolute advantage in a wider world of dynamic competition *à la mode Schumpeterienne*. In that paper we focused in functional terms on the blending of products (the mix of high-tech and low-tech products), processes and policies (including corporate strategies). Here we might wish to add in the remaining functions of technology (S&T system) and – in the light of recent events – administration including finance. The objective is to secure for the region’s continued industrial development what we term an ‘appropriate’ set of competencies in Table 2 (row 15).

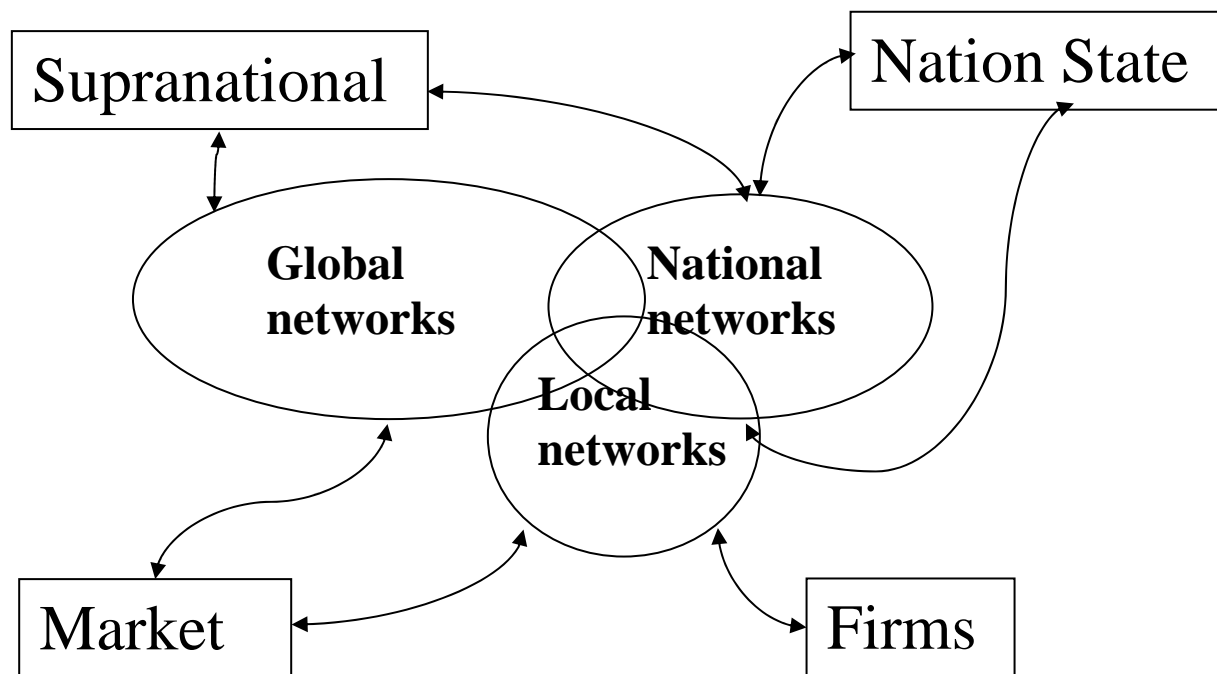
In Figure 2 we chart a third level of network structures, that in reality is interwoven with the two preceding types of networking, namely the resource basis in Figure 2 and the functional basis of Figure 3. Complexity is revealed here in the form of the multiple overlaying types of territory, which give rise to issues surrounding ‘multi-level governance’ as various local, regional, national and supranational levels compete and maybe sometimes collaborate in their

<sup>12</sup> The comparison between Campania and Scotland originally promised for this presentation considers the data relating to this point.

interests of exercising authority.<sup>13</sup>

The diagram portrays the conventional modes of governance (i.e. markets and hierarchies, with the latter here divided into corporate hierarchies (firms), supranational political hierarchies (like the EU's Structural Funds), and national/regional political hierarchies), meeting in an overlapping framework of networks (as the third mode of governance), defined here in spatial terms.

**Figure 4: Spatial structures of governance and their interactions**



Our reasoning in regard to explaining regional differences is based partly on such theoretical analysis, but to a much greater extent on empirical studies, both in other contexts and in the region singled out for study here. The findings of an earlier study of Campania by one of the present authors are very pertinent (Del Sorbo, 2009).

<sup>13</sup> In addition, the picture could easily be complicated further by introducing all sorts of 'local' levels, from the parish up to broad regional levels.

### **3. Research Methodology**

Employing the Qualitative Comparative Analysis, we attempt to answer to the research questions: 'Minding the STEM gap in the Campania region is a matter of competencies or capabilities? What is the role of the universities?', also testing the following hypotheses:

Hp 1 (main): STEM Skills are shaped by U/I type interactions. Unilateral relationships are associated with the building of competencies, while bilateral relationships are associated with the building of capabilities.

Hp a): the Campania region minds the STEM gap due to the presence of competencies or/and capabilities. The university has a specific role in this, particularly when interacting with local industry.

#### **3.1. Data Collection**

The data were collected throughout twenty-four *in depth face to face* interviews see Del Sorbo (2010). They were conducted at universities (the five STEM universities) from June 2009 to October 2009.

The respondents were officers in charge of admissions, technology transfer and placement, and/or career advisors, plus the heads of the Engineering and/or Science faculties (and where available, both of them).

The regional universities involved were the Parthenope University of Naples, the University of Naples 'Federico II', the University of Salerno, the Second University of Naples, and the University of Sannio. The interview for universities' officers focused on: recruiting students - and in what numbers - and the importance of employability (admissions officers); recruiting graduates and how firms recruit STEM graduates through the university placement offices (placement officers and/or career advisers); the degree to which the university interacts with firms; training in skills and how the university builds up these skills, and the promotion of STEM courses (heads of STEM departments/schools); and finally the universities' relationships with industry (innovation and technology transfer officers).

The data were analysed through the Qualitative Comparative Analysis (Ragin, 1987) employing the Tool for small *n* analysis, Tosmana, (Cronqvist, 2007).

### **3.2. QCA**

The QCA unveils the complex causing conditions of the skills (mis)match. It is a strategy combining qualitative or case-oriented, and the quantitative or variable oriented approaches. In this research it has been used the two versions, the original Boolean approach, which nowadays adds 'crisp set' (cs) as a prefix (csQCA), indicating the use of dichotomous variable (Rihoux & Lobe, 2009, pp. 222-242). The improved version called 'fuzzy sets' (fsQCA) was built up in the 1990's, which enhances the restriction of dichotomous independent variables to multiple values (Drass, Meyer, & Ragin, 1984; Kogut & Ragin, 2004; Ragin, 1987).

This case oriented approach allows examinations of single cases in their wholeness and not as an assembly of components; thereby allows discovering and understanding the typical patterns of case studies and their (dis) similarities as its truth table can break down their complexity (Cargal, 2005; Ragin, 1987; Ragin, et al., 1984).

#### **3.2.1. Strengths and limitations of QCA**

The strength of QCA lies on the use of a systematic comparison of a small number of cases shaped on the base of the development of explanatory models. Several disciplines apply it: policy analysis, political science, sociology, organisational studies and other fields. John Gerring states that 'QCA is one of the few genuine methodological innovations of the last few decades'. Also, it recognises the presence and/or absence of a set of causal conditions generating a significant outcome at social and scientific level allowing comparisons between similarities and dissimilarities of 'a limited set of comparable cases'. Thus, it can be seen a powerful tool able to recognise different patterns leading to an outcome useful for supporting policy advise and 'for post experimentation/policy manipulation' (Marx, 2006, pp. 2, 16).

Further, Kogut and Fiss implement it, therefore reading them may be very useful for additional explanations and understanding (Fiss, 2008; Kogut, Ragin, & MacDuffie, 2004; Kogut B. & Ragin C., 2004; Lieberson, 2004, pp. 13-14; Ragin, 2000, 2007).

There are several critiques on QCA, in particular to the models it can generate. Firstly, according to Lieberson QCA does not allow to discriminate between real and random data, therefore it would create a model with or without real data (random data). Secondly, he argues ‘there is an upper-limit to the number of variables’ (Marx, 2006, pp. 1-3). Marx shows however, employing a methodological experiment that QCA distinguishes in fact between reality and randomness only ‘under certain conditions namely when the proportion of variables on cases goes below a certain threshold, which differs as a function of the combination of variables on cases’ (Caren & Panofsky, 2005; Cortina, 1993). Moreover, other limitations are linked to the dichotomisation, which if on one side breaks down the complexity of the cases, on the other side, from an econometric point of view it ‘sacrifices’ information regarding interactive, marginal and dynamic (temporal dimension) effects (Marx, 2006, p. 1).

However, the limitations of the QCA are based on the Boolean algebra causing a problem of uniqueness and on which the literature needs to catch up (Aristotle, 350 B.C./2007).

### **3.2.2. Implementing QCA**

At the end of implementing the QCA it is crucial to consider and understand the causal relation existing between a specific set of causal conditions and its outcome. Thus, it is helpful considering its definition: the relationship linking two events, where the former termed *cause* A generates the latter termed *effect* B (Järvinen, Lamberg, Murmann, & Ojala, 2009). The causal condition may be:

1. Necessary if: when Y occurs then X occurs necessarily, therefore if X is missing then Y does not occur; however if X occurs, Y can be missing; hence the existence of Y depends on the existence of X but it is not truth vice-versa. Thus, an outcome Y is a subset of the causal condition X if  $X \geq Y$  clutches for the fuzzy-membership scores of conditions X and Y for all cases’ (Katz, Vom Hau, & Mahoney, 2005).

2. Sufficient if: X implies Y: if X exists then Y exists; therefore if Y does not exist then X does not occur; however if X does not exist, Y can exist. The existence of Y can occur even without X. Thus, the causal condition is a subset of the outcome. Explicitly, X is a sufficient cause for Y, if  $X \leq Y$  clutches for all cases.

QCA allows identifying different sets of causal conditions leading to an outcome; in addition, its results may be statistically significant even with small samples being the hypotheses (necessary and sufficient condition) bivariate in nature, not only with large sample according to the regression analysis.

Ragin developed two algorithms to perform the fuzzy-set qualitative comparative analysis respectively in 2000, and in 2007: the ‘inclusion algorithm’ then applied by several scholars such as: Katz et al. (2005), Kogut, MacDuffie & Ragin (2004), Pajunen (2008); and the ‘truth table algorithm’ whose the same author recognises its superiority compared with the first algorithm, and consequently it had been preferred (Järvinen et al., 2009; Ragin, 1987, pp. 98-102; Smith, 1982).

The first step in the method is developing the truth table assigning a specific value per each condition (variable) according to the coding process the researcher follows. Secondly, the results given by the truth table allow to assess whether a set of causal conditions is significant or not for the outcome. If it is significant, it is possible to identify whether it is a necessary or/and a sufficient condition for the final outcome. Thirdly, as Ragin (2007) suggests, it is important selecting a threshold recognising which configurations record significant empirical evidence from those that do not.

Fourthly, once having investigated on the combination of causal conditions associated with a positive outcome, it is interesting and less time consuming implementing the De Morgan’s law to assess the set of causal conditions related to a negative outcome, rather than start again from the beginning and building up and minimising a new truth table (Cronqvist, 2009). The data collected for conducting this piece of research have been examined following respectively, the mvQCA (variation of the fuzzy-set) and crisp-set (using thresholds) analyses using the Tool for small  $n$  cases software: Tosmana created by Cronqvist (2007).

### **3.3. Data Analysis**

The interview guideline prepared for the university is articulated in four parts. The first part regards the role of the respondent at the university, followed by a set of questions regarding the weight given to employability by the students when they enrol. The second part is concerned

with how the firms recruit graduates through the placement office of the university, and what influences emerge from interacting with the firms. Thirdly, we got an idea of the kind of STEM skills the University builds up through its education: generic and/or specific; and the promotion of STEM courses. The fourth part focuses on the university-industry relationship.

The data on the university's side was collected by interviewing different respondents, and asking each of them a specific set of questions. The first part regards the recruitment of students: how much weight is given to the employability of STEM students by admission officers? The second part concerns the recruitment of graduates: how do firms recruit STEM graduates through the university placement office? If there is any influence due to the interactions with firms, how does this work? (This part was directed at the placement officers and/or career advisers of STEM departments and schools). The third part concerns training in skills: how does the university build STEM skills, if they promote them? The fourth part concerns the relationships with industry by the innovation and technology transfer officers.

### **3.3.1. mvQCA**

It follows the results obtained using the Tosmana software running a multivariate analysis within a Qualitative Comparative Analysis: mvQCA. Following the operationalisation described in the paragraph 2.3 (see Table 2: Characteristics of competencies versus capabilities) , the analysis has been conducted considering as independent variables all the characteristics of competencies and capabilities organised in three groups: 1) essential static characteristics: function, stocks, chain position, product area, supply and demand, and stage; 2) essential dynamic characteristics: development and learning; and 3) the associated attributes: asymmetries, skills, breath, depth, reasoning, time location, appropriation and spread.

First it is necessary to recognise the presence or absence of competencies or/and capabilities by identifying their essential characteristics and associated attributes.

The following procedure is quite mechanic as it repeats the same pattern per each characteristic, essential and not essential, from number 1 to number 16. Each characteristic has a dual aspect, as shown in generating competencies and/or capabilities. For instance, taking the first characteristic,



function explains enhancement of resources, then it indicates the presence of competencies; whereas if function explains enhancement of services, it indicates the presence of capabilities. The order in which they are explained is significant as the first aspect will always refer to the competencies, the second to the capabilities produced.

### **3.4. Operationalizing QCA**

The coding of the data is based on a termed competencies and capabilities matrix. The matrix is populated with values from 0 to 3 to classify the presence and/or absence of competence and capabilities attributes (independent variables). The absence of both is equal to 0; the presence of competencies and absence of capabilities is equal to 1; the presence of capabilities and the absence of competencies is equal to 2; finally the presence of both is equal to 3. The dependent variable takes a value of 0 or 1, where 0 represents the absence of both competencies and capabilities, and 1 implies their presence. The mvQCA provided the combinations of the various independent variables causing the skills gap (dependent variable) to widen (value=0) or to narrow (value=1).

The analysis compares the competency and capability attributes of six associations. The attributes include the following characteristics: *function*, *stocks*, *chain position*, *product area*, *supply–demand*, *stage*, *development*, *learning*, *asymmetries*, and *skills*. Each characteristic or attribute is assigned a different notation, as shown in the table below, according to whether it is a competence or a capability (J. Järvinen, J. A. Lamberg, J. P. Murmann, & J. Ojala, 2009).

A pre-analysis has been used to identify the presence or absence of capabilities and/or competencies based on a preliminary assessment of the interview information. The intention was to give robust significance to the analysis, so that the findings are initially provided by the data interpretation of the researcher and are then validated by the software mentioned above.

Such pre-analysis has been required to identify the presence or absence of capabilities or/and competencies based on the reading, comprehension and ‘classification’ of the answers given. In fact this took the form of selecting key words and highlighting in red and blues those referring respectively to the presence of competencies and capabilities, and in violet those referring to the

presence of both. On the other hand, the colours orange, green and yellow referred to, respectively, the absence of competencies, capabilities and both.

Fuzzy-set analysis and Crisp-set analysis then followed this pre-analysis.

Table 4 explains which code is assigned to each characteristic according to the presence (or not) of competencies and/or of capabilities. Code 0 indicates the absence of competencies and capabilities; code 1 indicates the presence of only competencies; code 2 indicates the presence of capabilities and, finally code 3 indicates the presence of both.

**Table 3: Competencies and Capabilities (CC) Matrix**

Matrix CC		Comp	
		0	1
Cap	0	0	1
	1	2	3

**Table 4: Competencies and capabilities truth table STEM Universities in Campania, Qualitative Comparative Analysis (QCA)**

University/Competence s versus Capabilities	<i>Parthenope</i>				
	<i>University</i>	<i>Unina</i>	<i>SUN</i>	<i>Unisa</i>	<i>Unisannio</i>
1.Function	3	3	2	3	2
2.Stocks	3	3	3	3	3
3.Chain position	1	1	2	2	1
4.Product area	1	1	2	2	1
5.Supply/demand	2	1	2	1	2
6.Stage	3	2	1	3	1
7.Development	1	3	2	3	2
8.Learning	1	3	3	3	3
9.Asymmetries	1	1	3	3	3
10.Skills	3	3	3	3	3
11.Breadth	2	2	1	2	1
12.Depth	1	1	1	1	1
13.Reasoning	2	2	3	2	2
14.Time location	3	3	2	2	2
15.Appropriation	3	3	2	2	2
16.Spread	3	3	3	3	3
<i>CC Results before</i>					
<i>Tosmana</i>	4	3	2	3	2
<i>CCGap*</i>	1	1	1	1	1
<i>CCGap2**</i>	1	1	0	1	0

\* dichotomised variable assuming a value equal to 0 if CC result is <2, and equal to 1 if CC result is >=2

\*\*dichotomised variable assuming a value equal to 0 if CC result is <=2 and equal to 1 if >2

Further investigation then attempted to identify the presence (or not) of a gap in competencies and/or capabilities, by employing a dichotomised dependent variable termed CCgap, assuming a value of 0 or 1 according to the presence of competencies and capabilities that was measured by four dependent sub-variables: 1) the weight given to employability by STEM students, the weight of the University placement office in recruiting STEM graduates, and the level of generic/specific skills provided by the university; 2) the weight of influence the firms had in designing the study paths; 3) promotion of STEM degrees paths; and 4) the development level of the relationship with firms, whose value is equal to 0 if they are decreasing/stable and equal to 1 if they are increasing. If the sum of values of these variables is less than 2 then the CCgap variable assumes a value of 0 ('not minding the gap'); if it is more than 2 then the CCgap variable assumes a value equal to 1 ('minding the gap'). In the following analysis, the following abbreviations will be used:

- Comp=competencies
- Cap=capabilities
- CC=competencies+capabilities.

The following sections present the results of the Qualitative Comparative Analysis for the five universities mentioned. The characteristics analysed are the static essential characteristics leading to an outcome that is equal to 1. As all the universities had this characteristic; we will not attempt to analyse the 'turning tables' where the outcome is equal to 0, as none of them would have such a finding. This will instead be carried out by a second analysis where a different and more stringent threshold is employed to dichotomise the competencies and capabilities gap (Ccgap2) and therefore produce different outcomes.

#### **3.4.1. Fuzzy-set analysis and results**

The CC gap variable has been dichotomised; an outcome equal to 1 shows the presence of competencies and capabilities, and indicates that universities are 'minding the gap'. On the other hand, 'turning the table' by implementing De Morgan's law leads us to identify the causal conditions of outcomes equal to 0, which indicates the absence of competencies and/or capabilities in universities, and shows that they are 'not minding the gap'.

The analysis proceeds now by looking at the universities. The coding rules used for the firms are also respected for the universities.

The Universities analysed are the five that provide STEM subjects in the Campania region: the Parthenope University (UniParthenope), the University of Naples ‘Federico II’ (Unina), the University of Salerno (Unisa), the Second University of Naples (SUN) and the University of Sannio (Unisannio).

Table 5 illustrates results regarding the essential, (i.e. static and dynamic and the associated) attributes of competencies and capabilities with outcome equal to 1.

Each university achieve an outcome equal to 1 with a different set of causal conditions; see truth table. The significant variable determining such outcome is ‘function’ (if 2: cap enhancement of services or if 3: CC enhancement of resources and services). Thus, universities employ the characteristic ‘function’ to build up the CC tending consequentially to ‘minding the gap’. The same results are gathered by only the static characteristics, thus those dynamics are not significant.

As according to the fuzzy-set analysis all the universities mind the gap, thus we do not ‘turn the table’ to see what happens, as applying the De Morgan Law, none of them ‘not minding the gap’.

**Table 5: STEM Campania Universities Essential characteristics and associated attributes, Results – outcome 1**

```

Tosmana Report

Settings:
  Minimizing Value 1 C
  including         R

Variable Settings:

Name      Thresholds
1. Function --
2. Stocks --
3. Chain position --
4. Product area --
5. Supply/demand --
6. Stage --
7. Development --
8. Learning --
9. Asymmetries --
10. Skills --
11. Breadth --
12. Depth --
13. Reasoning --
14. Time location --
15. Appropriation --
16. Spread --
CCGap    1.95

Truth Table:

v1: 1. Function      v2: 2. Stocks
v3: 3. Chain position v4: 4. Product area
v5: 5. Supply/demand v6: 6. Stage
v7: 7. Development  v8: 8. Learning
v9: 9. Asymmetries  v10: 10. Skills
v11: 11. Breadth    v12: 12. Depth
v13: 13. Reasoning  v14: 14. Time location
v15: 15. Appropriation v16: 16. Spread

O:      CCGap      id:  University/Competences versus Capabilities

id Parth. Unina  SUN  Unisa Unisannio
v1  3      3      2      3      2
v2  3      3      3      3      3
v3  1      1      2      2      1
v4  1      1      2      2      1
v5  2      1      2      1      2
v6  3      2      1      3      1
v7  1      3      2      3      2
v8  1      3      3      3      3
v9  1      1      3      3      3
v10 3      3      3      3      3
v11 2      2      1      2      1
v12 1      1      1      1      1
v13 2      2      3      2      2
v14 3      3      2      2      2
v15 3      3      2      2      2
v16 3      3      3      3      3
O   1      1      1      1      1

Result: (all)
      1. Function(2,3)
      (Parthenope+Unina +SUN+Unisa+Unisannio)

Created with Tosmana Version 1.301

```

### 3.4.2. Crisp-set analysis and results

The analysis now proceeds by adding the same thresholds (1.95) for significant variables while ignoring those that are non-significant<sup>14</sup>; the former variables influence the outcome, the latter do not. Consequently, when the variable was coded 0, indicating the absence of CC, or 1, indicating the presence of only competencies, its re-code would be 0. Where the variable was coded 2, indicating the presence of capabilities, or 3, indicating the presence of both, then it is re-coded as 1. The reason for this is an attempt to make a more robust analysis that employs stricter values for the significant variables, and identifies immediately whether the presence of capabilities ‘minds the gap’. Using the threshold we are able to distinguish clearly between an outcome related to competencies and an outcome related to capabilities.

To this end, a different outcome is also employed: CCgap2 dichotomic dependent variable assume, which takes a value of 0 if the sum of the values of the four dependent sub-variables are 0 to 2 (these four sub-variables are: the weight given to employability by STEM students, plus the weight of the university placement office in the recruiting of STEM graduates and generic/specific skills provided by the university; the weight of the influence of the firms in designing study paths; the promotion of STEM degrees paths; and finally the development level of the relationship with firms). It will take a value of 1 if the sum of the sub-variables is 3 or 4. Therefore, if the CCgap2 is 0 then firms are not ‘minding the gap’, while a value of 1 means that they are ‘minding the gap’.

According to table 7, the significant variables determining an outcome equal to 1 are *stage* and *breadth*, which are both in themselves equal to 1. The former explains the presence of realized capabilities or both potential competencies and realized capabilities<sup>15</sup>. The latter indicates the presence of relatedly complex capabilities<sup>16</sup>. The results leading to an outcome of 1 were present

<sup>14</sup> The non-significant variables are those recording the same value, equal to 1, for all the universities, such as: *stock*, *skills*, *depth*, and *spread*.

<sup>15</sup> The value of *stage* 1 was equal to 2: realized capabilities; and equal to 3: potential competencies and realized capabilities before the dichotomisation, see table--.

<sup>16</sup> Its value was equal to 2 before the dichotomisation (presence of relatedly complex capabilities).

in the following universities: Parthenope, Naples and Salerno, who are all *minding the gap* (see the truth table, table 7).

By ‘turning the table’, we are able to confirm and complete the results, see table 8. The truth table shows the results achieved when we analyse the essential (i.e. static and dynamic) characteristics and the associated attributes with an outcome of 0.

The significant variables that determine this are the same as above: *stage* and *breadth*. However, both assume a value equal to 0 and are present in the University of Naples (SUN) and the University of Sannio (Unisannio). *Stage* being equal to 0 explains the presence of potential competencies for both that generate an outcome of 0, which means that they are *not minding the gap*. Additionally, the variable *breadth* is also equal to 0, suggesting the presence of relatedly simplex competencies<sup>17</sup>.

**Table 6: STEM Campania Universities Essential characteristics and associated attributes Results – outcome 1 (thresholds)**

Tosmana Report		O:	CCGap2*	id:	University/Competences versus Capabilities
Settings:	Minimizing Value 1 C				
	including R				
Variable Settings:		id	Parthenope	Unina	SUN
Name	Thresholds				Unisa Unisannio
1. Function	1.95	v1	1	1	1
2. Stocks	1.95	v2	1	1	1
3. Chain position	1.95	v3	0	0	1
4. Product area	1.95	v4	0	0	1
5. Supply/demand	1.95	v5	1	0	1
6. Stage	1.95	v6	1	1	0
7. Development	1.95	v7	0	1	1
8. Learning	1.95	v8	0	1	1
9. Asymmetries	1.95	v9	0	0	1
10. Skills	1.95	v10	1	1	1
11. Breadth	1.95	v11	1	1	0
12. Depth	1.95	v12	0	0	0
13. Reasoning	1.95	v13	1	1	1
14. Time location	1.95	v14	1	1	1
15. Appropriation	1.95	v15	1	1	1
16. Spread	1.95	v16	1	1	1
CCGap	1.95	O	1	1	0
Truth Table:		Result: (all)			
v1: 1. Function	v2: 2. Stocks	6. STAGE			
v3: 3. Chain position	v4: 4. Product area	(Parthenope+Unina +Unisa)			
v5: 5. Supply/demand	v6: 6. Stage	11. BREADTH			
v7: 7. Development	v8: 8. Learning	(Parthenope+Unina +Unisa)			
v9: 9. Asymmetries	v10: 10. Skills				
v11: 11. Breadth	v12: 12. Depth				
v13: 13. Reasoning	v14: 14. Time location				
v15: 15. Appropriation	v16: 16. Spread				
		Created with Tosmana Version 1.301			

<sup>17</sup> *Stage* and *breadth* were both equal to 1, explaining respectively the presence of potential competencies and of relatedly simplex competencies in the previous analysis without the thresholds.

**Table 7: STEM Campania Universities Essential characteristics and associated attributes Results – outcome 0 (thresholds)**

```

Tosmana Report
|
Settings:
  Minimizing Value 0 C -
  Including          R

Variable Settings:

Name      Thresholds
1. Function      1.95
2. Stocks        1.95
3. Chain position 1.95
4. Product area  1.95
5. Supply/demand 1.95
6. Stage         1.95
7. Development   1.95
8. Learning      1.95
9. Asymmetries  1.95
10. Skills       1.95
11. Breadth     1.95
12. Depth       1.95
13. Reasoning   1.95
14. Time location 1.95
15. Appropriation 1.95
16. Spread      1.95
CCGap          1.95

Truth Table:

v1:  1. Function      v2:  2. Stocks
v3:  3. Chain position v4:  4. Product area
v5:  5. Supply/demand v6:  6. Stage
v7:  7. Development   v8:  8. Learning
v9:  9. Asymmetries   v10: 10. Skills
v11: 11. Breadth      v12: 12. Depth
v13: 13. Reasoning    v14: 14. Time location
v15: 15. Appropriation v16: 16. Spread

O:  CCGap2*  id:  University/Competences versus Capabilities
id  Parthenope Unina  SUN  Unisa  Unisannio
v1  1  1  1  1  1
v2  1  1  1  1  1
v3  0  0  1  1  0
v4  0  0  1  1  0
v5  1  0  1  0  1
v6  1  1  0  1  0
v7  0  1  1  1  1
v8  0  1  1  1  1
v9  0  0  1  1  1
v10 1  1  1  1  1
v11 1  1  0  1  0
v12 0  0  0  0  0
v13 1  1  1  1  1
v14 1  1  1  1  1
v15 1  1  1  1  1
v16 1  1  1  1  1
O   1  1  0  1  0

Result: (all)

6. Stage(0)
(SUN+Unisannio)

11. Breadth(0)
(SUN+Unisannio)

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### 3.5. Summary of Results

According to the fuzzy-set analysis a key significant variable is *function*. Taking a value equal to 2 (indicating the presence of capabilities characterised by the enhancements of services), is the necessary condition to gather an outcome equal to 1; furthermore, the same applies for a *function* with a value equal to 3 (indicating the presence of both competencies characterised by enhancements of resources and capabilities in the enhancement of services), respectively a necessary and sufficient condition to gain such a result. These findings are achieved by all the universities under investigation: the Parthenope University, the University of Naples (Unina), the University of Salerno (Unisa), the Second University of Naples (SUN) and the University of Sannio (Unisannio). Therefore, apparently according to these initial results STEM universities tend to ‘mind’ the competencies and capabilities gap in the Campania region (see the competence and capabilities truth table in Table 5).

The second, stricter, crisp-set analysis shows that in Campania there are three Universities (Parthenope, Naples and Salerno) ‘minding the gap’, and the most significant variables among all these characteristics and associated attributes are *stage* with a value of 1 and *breadth* with a

value of 1, which determine an eventual outcome of 1. The former explains the presence of realized capabilities, or both potential competencies and realized capabilities<sup>18</sup>, whilst the latter, being equal to 1, similarly indicates the presence of relatedly complex capabilities<sup>19</sup>. These results leading to an outcome of 1 are present in Parthenope, Naples and Salerno universities, all of which are therefore *minding the gap* (see the truth table, Table 6).

By ‘turning the table’, we get the causal configurations for essential characteristics and the associated attributes of an outcome of 0. We noticed the same significant variables determining an outcome of 1, i.e. *stage* and *breadth*, but both this time with a value equal to 0 at the Second University of Naples (SUN) and the University of Sannio (Unisannio). *Stage* equalling 0 explains the presence of potential competencies for both that generate an outcome of 0, meaning that they are *not minding the gap*. Additionally, the variable *breadth* is also equal to 0, which explains the presence of relatedly simplex competencies<sup>20</sup>.

### 3.6. Discussion

The following tables summarize the results achieved in the previous empirical analysis. The universities ‘minding the gap’ all achieve this, according to fuzzy-set analysis, due to the causal condition *function* that when its value is 2 explains the presence of capabilities; it is also sufficient when it is equal to 3. However, according to the stricter crisp-set analysis the University Parthenope, the University of Naples and the University of Salerno also ‘mind the gap’ due to the causal conditions *stage* and *breadth* both being equal to 1. Here, a realized *stage* is a necessary condition, and a potential and realized *stage* is a sufficient condition (see chapters three and five). There are different patterns to reach a positive outcome, and the determining variables are the same for each university (see Table 3.6. and Table 3.6.1).

#### Table 3.6. Universities minding the gap

<sup>18</sup>Before the dichotomisation the value of *stage* was equal to 2 for Parthenope: realized capabilities; and equal to 3 for Unina and Unisa: potential competencies and realized capabilities before the dichotomisation, see table--.

<sup>19</sup>Its value was equal to 2 for the three universities before the dichotomisation presence of relatedly complex capabilities.

<sup>20</sup>*Stage* and *breadth* were both equal to 1, explaining respectively the presence of potential competencies and of relatedly simplex competencies in the fuzzy-set without the thresholds.



Universities	Analysis	Causal conditions	Outcome
Parthenope, Unina, Unisa, SUN, UniSannio	Fuzzy-set	1.Function [2, 3]	1
Parthenope, Unina, Unisa	Crisp-set	6.Stage (1) or 11.breath (1)	1

**Table 3.6.1 Universities not minding the gap**

Universities	Analysis	Causal conditions	Outcome
None	Fuzzy-set	1.Function [0, 0]	0
SUN, UniSannio	Crisp-set	6.Stage (0) and 11.breath (0)	0

‘Turning the table’ and applying De Morgan’s Law, the results are confirmed, as according to the fuzzy-set analysis there is not a single university ‘not minding the gap’.

According to the crisp-set analysis, the universities not minding the gap are the Second University of Naples and the University of Sannio. In both cases the variables determining these outcome are *function* (in the former case) and *stage* and *breadth* (in the latter case). The presence of only competencies is not a necessary, nor a sufficient condition for generating a positive outcome. There are several key points that we should pay attention to at this stage. Crucially we need to compare the results and outcomes gathered for both sides using the stricter crisp-set analysis and the less-straightened fuzzy-set analysis.

Firstly, on the university side the determinant variables *stage* and *breadth* capture competencies and capabilities, a necessary and sufficient condition for ‘minding the gap’.

On the other hand, the results regarding the universities lead us to a different approach. *Stage* and *breadth* are both sufficient conditions leading the universities towards a ‘minding the gap’ outcome. However, whilst *stage* is regarded an essential characteristic, *breadth* is not. In fact, *breadth*, as presented in von Tunzelmann’s table, is an associated attribute. If we consider its meaningful impact on generating a positive ‘minding the gap’ outcome, however, it is possible to make a case for the ‘promotion’ of *breadth* from the ranks of the associated attributes into the ranks of the essential characteristics. This depends on context, of course, but the context in this work is Campania, a region that needs to ‘mind the gap’ and raise up the innovation indicator tables illustrated in the contextual chapter (chapter three). Therefore maybe the repositioning of *breadth* is auspicious for a more precise picture of the characteristics that build up competencies

and capabilities at a regional level. Of course more empirical exploration is needed to confirm or refute those results, but that would involve further research at a later date.

The STEM skills gap is not clearly a deficiency just in capabilities, but more so in the links between capabilities and competencies. The SSDD model shows how the University's attempt to adapt to the industry needs varies according to the way they combine competencies and capabilities, as well as to their characteristics. Also they can take advantage exploiting the firms' needs to receiving funding rather than facilitate their innovative growth.

Furthermore, a stable institutionalized relationship with an efficient communication flows between the associations, firms and universities seem to be required so that the reciprocal roles and duties are well defined. This means, especially in terms of STEM graduates placement that firms require dedicated professionals dealing with the demand and supply of STEM graduates. This may be due to the need of combining competencies and capabilities accordingly to the specific needs of the lag regions, working on its strengths, such as agro-food, Information and Communication Technology (ICT), engineering and aerospace industries, rather than its weaknesses.

Enhancing the potential stage of competencies with a realised stage of capabilities, such as assuring a roll for the bio-technologist degree profile; and enhancing the relatedly simplex competencies with a relatedly complex capabilities, such as employing the appropriate mix of competencies and capabilities tending to mind the gap by, for instance, mapping the regional needs in term of Science and Technology.

To conclude, it seems there are several issues needing to be addressed by the policy makers at regional and national level. In particular, within those matters it requires to be cited the need of stable, reliable and efficient public institutions as there is some evidence regarding Northern Italian regions (Emilia Romagna, Toscana, Lombardia) whose economy 'has been positively affected by efficient political institutions that have been built up civic traditions', which are also related to 'the historical evolution of the regional dimension' (Becker, 1964; Del Monte & Papagni, 2007).

Stepping back to the theoretical background, we have said that on one side the human capital theory is among the theories linking the knowledge and the skills possessed by individuals with successful results in their job-life, particularly stressing the job productivity and the reward systems which should rely on the skills of individual, such as talents, education and degree of expertise (Lambert, 2003, p. 114); the job competition model explains the differences in salary and job success levels argued by Thurow.

Both theories deem the individual requirements, the job and the working environment. Moreover, Sattinger argues that the job typology depends on typology of *skills and capability*. As all those theories valorise the quality of the skills and competencies required by the labour market a SS-DD model seems to fit in this theoretical picture, which also fits within the new economic growth theories involving directly the government policies and, indirectly institutional policies related to skills acquisition are relevant to reduce the skills gap. Likewise, Lambert suggests the roles of university and industry, the former defining the ‘research innovative and competitive skills’ and the latter employing ‘the innovative ideas of the university and its network in a productive way’. This reciprocal flowing of knowledge and information may be efficient whether channelled through stable interactions as the ‘business can raise the skills levels of their workforce and learn about the latest academic ideas, while universities may keep profitable returns from their courses’ (Isaksen, 2006; Tidd, Bessant, & Pavitt, 2005) Nevertheless those stable interactions require a reliable institutional frame where there is a specific definition of the roles of university and industry; a precise identification and analysis of the regional needs and opportunities, within those, the STEM skills are both: the former as required by the Lisbon Strategy (S&T students); the latter as they (S&T graduates) may be employed in the regional economy otherwise the lag will become always more accentuated.

#### **4. Conclusions**

The aim of this research was to show how regional universities adapt to the actual needs of industry for highly skilled workers and research outcomes, and to consider whether this could be done better in Campania. The results show that STEM universities are trying to attain better interactions with industry, but that it is still left mostly to the personal relationships of the professors (e.g. the dean of the department or head of the T&T office and/or placement).

The universities argue that they provide both generic and specific skills, as they are part of the education and training offered to students by the Science and Technology faculties. However, there may be room for improvement as regular interactions and dedicated human and economic resources are needed in all universities; at the moment the former are sporadic and the latter scanty. Additionally, there is almost no trace of bi-directional knowledge flows from business to university and vice versa, as there is a relationship based on demand, which most universities know they need to get funding.

According to the results achieved, it can be stated that the STEM skills gap in Campania demonstrates a deficiency in competencies and capabilities. For that reason more work is needed on both, especially with positive action directed to U-I collaboration where projects are implemented as well as planned.

In fact the universities ‘minding the gap’ are those showing a *stage* as potential and realized (or only realized) competencies and capabilities. Additionally, the universities ‘minding the gap’ are those with *breadth*, explaining the presence of relatedly complex capabilities. These universities have a more developed relationship with firms, demonstrating that bilateral relationships are associated with the building of capabilities. The universities ‘not minding the gap’ are those associated with unilateral relationships whose *stage* and *breadth* are related to the presence of competencies alone. Thus, a more intense activity of interaction between universities and businesses is not only auspicious, but also beneficial to minding the regional skills gap. The university may improve its educational role through enhancing its relationship with firms to offer skills closer to those required by the business.

Apparently, considering whether universities should provide general and more transferable skills or instead more specific and industrial skills might help to solve the skills gap, because the findings could be generated by a lack of matching up of the firms’ requirements by the university system, which may in turn be due to a lack of communication between them.

The results show that firms seek specific/vocational skills to be exploitative in the short-medium term, and generic/transferable skills to be explorative in the long-term.

This research has led to several contributions. The first type of contribution is the empirical application of von Tunzelmann's framework on competencies versus capabilities. The distinction is relevant because it identifies a major reason why existing models of economic growth so often fail to predict models accurately, when rooted in supply-led situations of throwing more money (R&D) or brainpower (human resources) at the problem.

The second type of contribution is methodological, in adopting a two-level model of supply and demand. Firstly, there is the supply–demand situation in both universities and firms. Universities supply suitable courses in order to meet the demands of students. Similarly, firms match the supply of graduates from universities who seek employment with their own demands for skilled workers. Secondly, there is the more orthodox demand–supply situation. In order to meet the market demand, universities supply the prospective employees and advanced skills needed by firms. The situation as regards R&D provided by universities to local firms can be approached analogously. In order to meet the demand for science and technology, universities supply R&D activities outcomes needed by firms.

The third type of contribution is the analytical approach. This work represents the first attempt to implement QCA developed by Ragin (based upon Boolean theory) with the help of Tosmana software developed by Cronqvist (2007), in the topic of regional studies focusing on competence and capabilities building.

Fourthly and finally, this work has attempted to provide a little theoretical contribution through the reallocation of '*breadth*', termed an associated attribute of competence and capabilities by von Tunzelmann. The proposal is, after the evidence specific to Campania is this work, to reposition it as an essential characteristic. More generally, the proposal is to take a more flexible approach towards the identification of several types of characteristics. i.e. essential, non-essential and associated attributes of competencies and capabilities. In this way each region under investigation may find its own way in building competencies and capabilities that need their ad hoc institutional design using the appropriate regional policies.

#### **4.1. Policy implications**

While universities' aims are public in nature, and therefore not designed to maximize their profit, on the other hand the need to engage more in training and in consultancy work seems to offer a good opportunity for the university system to penetrate deeper into the labour market and, at the same time, to find other ways to get funding. The universities, in consent with industry and government, should open dialogues to support the decision-making processes.

The benchmarking of innovative performances among the several regions could be considered as a means to improve practice in the European and national contexts. Other possible and desirable interventions are: technical and financial private-public support; intra- and inter-university mobility for researchers, PhD students and knowledge workers; and incentive systems to guarantee not only mobility, but the possibility of returning to their own countries and regions.

The Campania region, in particular its University should build degree paths that carefully consider the kind of skills required by local and regional firms. The idea is to enhance regional growth and attempt to keep the best graduates by employing them properly. This does not mean closing the regional system and stopping the flow of graduates and know-how between the south and north of Italy; on the contrary it means investing in human capital to employ in the region in order to build-up an eventual bi-directional flow of graduates and know-how, know-why and know-what, so that the region of Campania may benefit from higher innovative skills to sink into their industrial system (Becker, 1964).

Likewise, the University should invest more in attracting students from outside the region, because it seems that it has reached its limit in attracting good local students. To achieve this the university needs to be competitive both scientifically and territorially. Moreover, although the universities understand regional needs, a regulation implementing a dedicated role to the biotechnologist profile should also be considered to ensure future recognition by the firms' associations.

Additionally, an orientating communication plan for potential students, mostly high-school students, should be prepared showing the statistical evidence of career opportunities related to degree paths, taking into account the personal aspirations, talents and attitudes of the pupils.

These kinds of interventions require efficient institutions and dedicated human and economic resources. In particular, STEM universities not minding the skills gap should pass from the potential to the realized stage of competencies and capabilities or widen the number of activities they share with firms. This matter raises the whole issue concerning the development of capabilities, not just of competencies.

A direct implication of this dichotomy is that competencies are generally nurtured outside the immediate boundaries of the organization in question, whereas capabilities are overwhelmingly built up within it, although this building-up process will usually depend in part on competencies that will have been acquired or hired from other organizations.

Thus a pharmaceuticals company hiring recent graduates from a local university chemistry department saw increases in its competency level through augmenting its base of ‘enhanced resources’. It did so by drawing on the capabilities of the local university to provide ‘products’ (students with chemistry degrees) and through enhancing its *functions* (of the types they already possessed), of packaging, storing, delivering and transferring knowledge.

In this picture the geographical, political and socio-economic context needs to be considered in the course of distinguishing such competency and capability developments. An important reason for this is that knowledge – as distinct from information – is usually very ‘sticky’ in nature.

To go into greater detail, we should also emphasize the role of conventional ‘knowledge capital’ arguments for the position of universities in development processes in ‘catching-up’ regions of the EU – i.e. inadequate levels of human capital and R&D capital, or what are identified here as deficiencies in competencies supplied to firms – as against what we refer to as ‘capabilities’ arguments, reflected here in better (different) ways in which universities might adapt to the actual needs of industry for highly skilled workers and research outcomes (Iammarino, Padilla, & von Tunzelmann, 2008; von Tunzelmann, 2009; von Tunzelmann & Wang, 2007).

More precisely, we see the regional economic differences as being driven by a misalignment of human and technological capabilities with human and technological competencies – where drawing such distinctions is obviously critical to the argument (see (Foundation Innovation Alliance, 2004). Competencies and capabilities are different according to this view – which

contradicts the great majority of management literature – but it is from the interaction between them that the dynamics of the system evolve.

Future research might have as its objective a deeper and more analytical vision of the innovative capacity in the Campania region to support a balanced and sustainable decision-making process.

## 5. Further research

A wider research (Del Sorbo M., 2010) leading to this work, includes also the role of firms' associations on the current dilemma: '*Does the STEM skills gap in Campania reflect a deficiency in competencies or capabilities? And, if so what?*'

Also, the firms' side will be analysed in a following paper. The interviewees were the firms' associations officers, interviewed about their role in the region in generating innovation processes and growth; their perception about the U-I linkages and what they in fact do about it, i.e. how they relate with universities; further, what are the placement mechanisms for STEM graduates/skills; the type and sector of the firms actively involved in recruitment of STEM graduates; and lastly, whether disembodied flows of knowledge are important in their relationships with universities (e.g. published research, project contracts, joint workshops, etc.) and how they work.

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