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Introducing Academic Skills in Know-how-based Firms: Innovative Potential or Non-complementarity?

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Abstract:
This paper contributes with two new findings to the literature on how universities contribute to industrial development. First, it argues and substantiates quantitatively through logistic regression models that introduction of academically skilled graduates in small, know-how-based firms can be instrumental in spurring innovation and upgrading changes in the firms. Second, it argues and substantiates quantitatively that it is not just graduates with technical and natural scientific qualifications that can contribute positively. Graduates with other academic qualifications also hold potential for innovation and upgrading changes in the firms, especially when it comes to major organisational changes. Qua these findings the paper contributes to the literature in two ways. It is a contribution to and substantiation of the 'broader' view arguing that universities contribute to industrial development with more than directly applicable information and technologies. And, academically skilled graduates are not only relevant in technological R&D departments of science-based firms.

Key words: Science; Academic research; Skilled graduates; Innovation; Technological change; Organisational change

Jel codes: D83; I23; J24; O31; O33

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1. Introduction

It is widely accepted that innovations, their diffusion, technological and organisational changes are important sources of economic growth (Fagerberg 1994; Freeman 1994; Edquist 1997; Fagerberg and Verspagen 2002; Fagerberg et al. 2005). This consensus generally substantiates a large and growing literature on innovations, technological and organisational changes in the economic system, and more specifically it substantiates a literature that examines the roles of universities, science, and research in relation to innovation, industrial development, and economic growth. But how, then, do universities, science, and research contribute to innovation and economic development?

One traditional and influential conceptualisation is the view that universities, science, and research produce new information and technologies that are *directly* transferable to and applicable in industry. This view appears, for example, in the 'market failure' rationale for public funding of basic research in universities. According to this rationale, basic research produce new information and technologies with public good properties, and these public good properties reduce the motivation for private funding and provide the raison d'être for some public funding of basic research (Nelson 1959; Arrow 1962). Being interested in the social rate of return from academic research, Mansfield (1991) provides measures on how academic research through informative findings has benefited innovating firms and industrial development. Besides, the view that universities, science, and research produce new information and technologies that are *directly* transferable to and applicable in industry is also pronounced in the large and growing literatures on patents, licenses, and technology transfers from universities to industry, even though these latter literatures are different in dealing with limitations in the public good dimensions of university research.

Censuring the traditional view, other scholarly contributions have established that any conceptualisation perceiving universities merely as producers of information and technologies *directly* transferable to and applicable in industry is a mistaken, too narrow approach that does not capture the full spectrum of contributions from universities, science, and research to industrial development (Gibbons and Johnston 1974; Pavitt 1991; Brooks 1994; Rosenberg and Nelson 1994; Klevorick et al. 1995; Salter and Martin 2001; Mowery and Sampat 2005). In stead we should apply a broader approach, widening the narrow focus with *crucially important, if less direct*, contributions from universities to industry such as education, training, and the large share of basic research and science that is not directly relevant to industry. Concurring the broader approach, Salter and Martin (2001), Klevorick et al. (1995), and Pavitt (1991) are three contributions that are clear in emphasising the education and training process of graduates as the potentially most important contribution from universities to industry and industrial development.

However, even though the broader approach is arguably a more complete, and therefore potentially better, conceptualisation of the roles universities play in the economic system, it does suffer from at least one fundamental problem. It is inherently more difficult to coherently measure, count, and thus substantiate quantitatively the whole spectrum of less direct contributions from universities, science, and research to industry. And, how is it at all possible to quantify the complex and partly individualised processes of research-based higher education, not to mention how (some of) these processes continue into benefiting industry? This 'quantification problem' of the broader approach seems to give some credit to the narrow, more directly measurable approach, especially in a policy context of "intensified demands from governments to raise the (measurable) economic returns to their substantial investments in academic research and education" (Mowery and Sampat 2005: 233).

The broader approach is not, however, without relevant empirical indicators and quantitative measures. Nelson and Rosenberg (1993) observe that university trained scientists and engineers are crucially important staff in R&D departments of science-based firms, and empirical contributions based on the Yale survey have also been instrumental in substantiating a broader view on how universities, science, and research contribute to industry and industrial development (see e.g. Klevorick et al. 1995).

This paper will contribute conceptually as well as empirically to the broader view of how universities do, and may, benefit industry and industrial development. Acknowledging that the education and training process in which science (some of it recent research) and scientific methods is taught to and embodied in graduate students is likely the most important contribution from universities to industry, the paper will extend the literature in two dimensions. First, it will argue and substantiate quantitatively that introduction of academically skilled graduates in small firms based on practical know-how may be instrumental in upgrading and improving innovation performance of these firms. This finding extends the insight that university educated graduates are crucially important labour in R&D departments of science-based firms. Second, the paper will demonstrate that a view focusing on how graduates with technical and natural scientific qualifications contribute to technological and industrial development is too narrow. Graduates with other qualifications, e.g. from the social sciences, are also found to be important in contributing to industrial development, especially when it comes to the organisational changes that are arguably also an important dimension of industrial development.

The paper is structured as follows: Section two discusses and conceptualises how introduction of skilled graduates may contribute to innovations in, and technological and organisational upgrades of small, know-how-based firms. This discussion leads to hypotheses for quantitative, empirical analysis. Section three presents the data, measures, models, and results of the empirical analysis. Section four formulates the conclusions and discusses policy implications.

2. Introducing academic skills in small, know-how-based firms

As mentioned, existing literature has established that highly educated employees with academic qualifications are highly important, if not necessary, human resources in R&D departments of science-based firms whose technological and economic development is dependent on science and scientific progress (see e.g. Nelson and Rosenberg 1993; Klevorick et al. 1995). This role of skilled graduates, primarily graduates with technical and scientific qualifications, is naturally a highly important way in which research-based training of graduate students contributes to industrial development. If you are to understand, combine, develop, and exploit scientific and technological pieces of knowledge in new and creative ways in a R&D lab, then you will benefit from an academic qualification and scientific competences.

But, skilled graduates may also hold other, less obvious, potential for non-science-based industrial development. Illustrating with the case of Denmark, the Danish economy (and others with it) is substantially characterised by many small, low-tech firms that have *no* employees with an academic qualification, but still these firms face a transformation pressure for implementing innovations and upgrading changes (Gjerding et al. 1997; Christensen et al. 1999; Lundvall 2002a; Nielsen 2007). This empirical context has motivated an interest in whether introduction of academically skilled graduates in small, know-how-based firms may be instrumental in spurring innovation and upgrading changes in the firms. Given the stated interest it is not, however, obvious whether introduction of highly educated labour and academic skills can contribute positively to these firms. In principle, such labour may be irrelevant, non-complementary, or even detrimental to firms based on practical knowledge bases, but it may also embody positive potential vis-à-vis innovation and upgrading changes – technological and/or organisational – in the firms. We cannot determine this a priori.

Interestingly, tentative Danish policy reports have empirically indicated that introduction of academically skilled graduates in small, know-how-based firms seem to be instrumental in upgrading and improving innovation performance of the firms. One, quantitative based policy report (Rambøll-Management et al. 2004b) finds a statistically significant indication that recruitment of a first highly educated employee in a small firm positively affects the likelihood of product/service innovation. This finding is substantiated by, and complementary to, other findings from eight case studies stated in a qualitative based report (Rambøll-Management et al. 2004a). General experiences from the case-studies thus indicate that introduction of highly educated labour have tended to be instrumental in upgrading the firms through innovation and changes, and this has improved the performance of the firms. More specifically, a small firm (25 employees) within electronic products has experienced that the introduction of a computer scientist has improved the firm's capacity of product innovation, as well as it has been instrumental in upgrading ICT and quality systems of the firm (Rambøll-Management et al. 2004a: 8-9).

If these indicative empirical results are merely partly trustworthy, then they may reveal a glimpse of an important contribution from Danish universities to Danish industry. At least they give empirical grounds for considering the potential that *introduction* of skilled graduates may hold untapped benefits vis-à-vis innovation and upgrading changes in know-how-based firms. But, are there any conceptual, analytical reasons to expect that academically skilled graduates may contribute positively to practical, know-how-based firms? And how, if at all, do the empirical indications relate to the innovation literature, that does not hold specific contributions on these matters? These are important questions to study before seeking further empirical results on the relationship, and to provide a structured answer to the questions, we shall establish and start from the following two analytical definitions:

- *Academically skilled graduates or simply highly educated labour* have formally qualified as such (i.e. earned these credentials) by having participated in and passed through the institutional and organisational setting of research-based higher education. Qua this, graduates have participated in an education and training process in which science, some of it recent research, and scientific methods are passed on to and, at least partly, embodied into graduate students. The result is arguably highly educated labour which can be assumed to have enhanced its knowledge within a given field of study, as well as its general academic skills such as perception, analytical, and systematisation skills to a relatively advanced level when compared with other groups of labour.
- *Know-how-based firms* are firms that are predominantly based on practical knowledge bases, i.e. firms that are not substantially based on scientific knowledge. Relatedly, it is less likely that highly educated labour will constitute a substantial part of the workforce. In fact, at the margin, firms based on practical knowledge will have no highly educated labour employed.

Starting from these definitions, introduction of academically skilled graduates can be seen as an enlargement, as well as a diversification of the knowledge base and the qualification structure in know-how-based firms. This enlargement and diversification may arguably hold innovative potentials. Kogut and Zander (1992) establish a model in which recruitment of "new people" is seen as one form of "external learning" at the firm level. Together with the current knowledge structure of the firm, internal learning processes within the firm, and other types of external learning, such recruitments contributes to "combinative capabilities" of the firm and these capabilities are related to "organizing and technological opportunities" and thus "market opportunities" of the firm (Kogut and Zander 1992: 385).

This view is in keeping with March (1991) arguing that recruiting new employees with "untypical skills" will introduce diversity in a firm's knowledge structure, and this diversity is important for "exploration", "learning", and "innovation". Interpreting a modelling result indicating that introduction of new recruits contributes positively to organisational knowledge, March states that the positive effect from new recruitment "does not come from the superior knowledge of the average new recruit. Recruits are, on average, less knowledgeable than the individuals they replace. The gains come from their diversity … Old-timers, on average, know more, but what they know is redundant with knowledge already reflected in the [knowledge] code. They are less likely to contribute new knowledge on the margin. Novices know less on average, but what they know is less redundant with the [knowledge] code and occasionally better, thus more likely to contribute to improving the code".

This view that a diverse knowledge structure, a diversity of skills, and a diversity of thinking can be seen as a prerequisite as well as a stimulating setting for generating new ideas, new learning, new knowledge, and innovation in individual firms is, again, in keeping with Cohen and Levinthal (1990: 133) recalling that "Utterback (1971) … noted that diversity in the work setting "stimulates the generation of new ideas"". Cohen and Levinthal also suggest that high reliance on learning by doing, which may characterise firms based on practical knowledge and practical routines, does "not contribute to the diversity that is critical to learning about or creating something that is relatively new … the focus on one class of activity entailed by learning by doing may effectively diminish the diversity of background that an individual or organization may have at one time possessed and, consequently, undercut organizational … innovative performance" (Cohen and Levinthal 1990: 134). Elsewhere, they mention that "dynamically self-reinforcing behaviour … may lead to the neglect of new technological developments" (Cohen and Levinthal 1990: 138).

Basically, too much homogeneity may be viewed as a damper on innovation and firm level changes, at least some diversity shall prevail for innovation and changes to take place, and one way to add extra knowledge and diversity to know-how-based firms is to introduce academically skilled labour. On the other hand, there are no a priori guarantee that the knowledge added and the skills diversity will contribute relevantly and positively to innovation and upgrading changes in small know-how-based firms. But, in fact, there are general analytical reasons to expect that introduction of skilled graduates may spur interactive creativity, innovations, and upgrading developments in small firms. Because, as analytically defined, highly educated individuals, qua their educational background, are expected to embody: (1) academic skills, as well as (2) specialised academic knowledge within their field of study to a comparatively advanced level (i.e. when compared to other types of labour), and these two dimensions substantiate the following reasoning:

First, unleashing graduates' relative well-developed academic skills such as perception, analytical, and systematisation skills in a context of practical knowledge and/or practice-based routines may arguably bring in new perspectives and spur fundamental, thought-provoking questions such as: Why do you do X that way? Would it not be more rational to do X this way? Have you considered that technology Y may be helpful in Z way? Have you considered that with U changes, product V may sell at market W? Expecting such questions is not only generally in keeping with March (1991), Kogut and Zander (1992), and Cohen and Levinthal (1990) as referred to above, it is also in keeping with Lundvall (2002b) assuming that highly educated labour, or at least "well-educated graduates", are endowed with "critical minds and good learning skills … skills in systematic problem solving".

Of course, a certain degree of the questions and suggestions posed by newly introduced graduates may, very likely, be characterised as 'practical ignorant' (a degree that should be inversely proportional to practical experience) and, relatedly, there may be very sensible arguments for doing things in a certain practical, and/or routine, way. But, this does not exclude that another degree of the questions and suggestions based on relatively well-developed perceptive, analytical, and systematization skills will be well-founded, worth a second thought, and potentially enhance perceived technological, organisational, and market opportunities. And, if so, the academic skills of highly educated labour can be said to interact creatively with the existing practical knowledge of the small know-how-based firm. Such creative interaction can, again, spur innovation, upgrading change, and development of new routines within the firms.[1]

Second, in addition to a general academic skills contribution, the more specific knowledge gained through higher education shall also be considered. In this respect we shall, of course, expect that an engineer with a certain educational specialisation will be especially competent in suggesting implementations of relevant technologies he or she knows of, that a business economist educated in organisation of business will be relative competent in suggesting new ways of organising, that a business economists educated

[1] It is important to emphasise that the conceptual analysis is not meant to downgrade the relevance of existing know-how and skills in the firms based on practical knowledge bases. The argument perceives introduction of skilled graduates as a supplement with innovative potential, not as introducing a 'better' form of knowledge and skills.

within marketing will be relative competent in suggesting and marketing new products, and so on.

Summing up, from a conceptual and analytical perspective, introducing skilled graduates in small know-how-based firms will enlarge and diversify the existing practical knowledge bases and skills structures of the firms, and this can start interactive creative processes that, again, can spur learning, innovation, and development in the firms. This conceptual and analytical reasoning makes sense of the empirical findings in the aforementioned qualitative and quantitative studies (Rambøll-Management et al. 2004b; Rambøll-Management et al. 2004a), and in combination these sources suggest the following two hypotheses for empirical test:

Hypothesis 1:

Introduction of skilled graduates in a small firm will tend to spur innovation and upgrading change in the firm.

Hypothesis 2:

The specific type of academic qualification of graduates is expected to matter in relation to the specific type of innovation and upgrading change in the firm.

3. Empirical analysis

3.1. The data

The empirical analysis is based on a data source combining longitudinal labour market register data with survey data on aspects such as technological changes, organisational changes, and product innovation. This data source allows us to study how introduction of graduates affects the likelihood of innovation, technological and organisational changes. To appreciate why, the combined data source shall be presented in this section.

The Integrated Database for Labour Market Research, in Danish this abbreviates to IDA, is a comprehensive longitudinal (from 1980 until one year before present time) labour market database held by Statistics Denmark. Covering all Danes, the IDA database holds personal information such as personal ID-number, age, sex, family status, highest completed education, employment relation, occupation, work experience, income, wealth, and unemployment. Focusing here on the highest completed education, each type of education in the formal Danish education system is represented by a code that is constructed in a way that contains information on the level and type of education, and these educational codes are connected to individual Danes through the personal ID-number in a way where it is the highest formal education of the person that is registered and, if relevant, upgraded. That is, a vocationally trained carpenter with no further education will be registered as such, an individual whose highest education is a given line of secondary education will be registered as such, an engineer whose highest education is a M.Sc. in process engineering will be registered as such, an economist whose highest education is a Master of Economics will be registered as such, and so forth.

Importantly, through the personal ID-number and the employment relation, this personal information is combined with information on the employer's establishment which, for example, allow us to determine industrial belonging, and number of employees in and qualification structure of the establishment, not to mention that the longitudinal quality allow us to trace changes herein. Besides, through a firm number this combined information is, again, coupled with the aforementioned innovation survey data (for a documentation of this combination see Reichstein and Vinding 2003).

The survey database is based on a survey carried out by the DISKO project at Aalborg University in 1996. A questionnaire on aspects such as work organisation, major organisational changes, product/service innovation, introduction of new ICT, and introduction of other forms of new technology in 1993-95 was submitted to the management in a sample of 3,993 firms from the private Danish business sector. The sample included all Danish firms with at least 100 full-time employees, as well as a selection among manufacturing firms with at least 20 full-time employees and non-manufacturing firms with at least 10 full-time employees. The survey resulted in 1,900 useful questionnaires and this amounts to a response rate of 47.6%. 1,206 of the useful questionnaires were received from small firms with up to 50 employees, and 694 were received from firms with more than 50 employees. Gjerding et al. (1997) provide a first descriptive analysis of the survey. Besides, the complete DISKO questionnaire, including distributions of answers, is available in English in Reichstein and Vinding (2003).

3.2. Measures and models

Evaluating this combined data source in the light of the research interest in measuring potential impacts on innovation, technological and organisational changes from introducing skilled graduates in small, know-how-based firms, it should be obvious that the data contains relevant potentials. In this section we shall operationalise the data source according to the research interest, and we shall present the models for quantitative analyses.

Small firms are defined as private business firms with 20 to 50 employees, and know-how-based firms are defined as firms that do *not* employ highly educated labour in base year 1990. These selection criteria generate a population of firms, and based on this population we shall apply regression analysis to address whether firms introducing graduates in the period 1991-95 were significantly more likely to be product/service innovative, to implement ICT upgrading changes, to implement other technological changes, or to implement major organisational changes in the period 1993-95 when compared to their counterparts (i.e. firms not introducing highly educated labour in the period 1991-95).

Regarding the four dependent variables, they are all binary variables measuring the following aspects for the period 1993-95: (1) whether a given firm has introduced new products/services when excluding minor improvements of existing products, (2) whether a given firm has carried through major organisational changes, (3) whether a given firm has introduced new ICT to a markedly degree, i.e. to a degree directly affecting 25% or more of the workforce, and (4) whether a given firm has introduced 'other forms of new technology' to a markedly degree, i.e. to a degree directly affecting 25% or more of the workforce.

The main explanatory variable is introduction of graduates in the period 1991-95. A highly educated individual at graduate level is defined as a person who has attained a long-term higher education (a master degree or equivalent) in the formal Danish education system. Besides, our labour market data let us distinguish between different types of long-term higher education. Basically, we shall use the educational data from the labour market register data in two different ways. In a first round of regression models, we shall *not* distinguish between different types of higher education, whereas we in a second round of regression models shall distinguish between: (1) introduction of highly educated labour with a technical or natural scientific academic qualification, and (2) introduction of highly educated labour with ‘another’ academic qualification, e.g. from the social sciences or the humanities.

Two control variables shall also be applied in the regression models. First, innovative opportunities may arguably vary across industries (see e.g. Geroski 1990). Therefore we shall control for industry affiliations based on the following categorisation: Construction; Trade, hotels, and restaurants; Transportation, mail, and telecommunication; Financial, business, and other services; Manufacturing. Second, the principles according to which work is organised in a given *t* may arguably affect innovation performance in the following period *t+1* (Laursen and Foss 2003). Therefore we shall control for whether any given firm in 1993 had implemented many (4-6) or few (0-3) of the following ‘learning organisation’ practices: Interdisciplinary workgroups; Quality circles/groups; Systems for collection of proposals from employees; Planned job rotation; Delegation of responsibility; Integration of functions (e.g. sales, production/service, finance).

Since dependent variables are binary variables, regressions are based on binary logit models in which the dependent logit reflects the log-odds of a dichotomous dependent variable. The first round of regression models, in which we do not distinguish between introducing highly educated labour with different types of academic skills, is characterised by the basic specification:

$$\log[p_i/(1-p_i)] = \alpha + \beta_1 HEL_i + \beta_2 LEAORG_i + \beta_3 INDU_i \qquad (1)$$

where $\log[p_i/(1-p_i)]$ is the log-odds of each of the four dependent variables. This means that we have four models in the first round: (1.a.) Product/service innovation; (1.b.) Implementation of major organisational change; (1.c.) Markedly introduction of new ICT; (1.d.) Markedly introduction of other forms of new technology. HEL expresses whether the firms had introduced highly educated labour at graduate level. LEAORG expresses whether the firms had implemented many or few characteristics of a ‘learning organisation’. Finally, INDU expresses industrial affiliations of the firms.

In the second round of regression models we distinguish between introducing highly educated labour with a technical or natural scientific qualification, and highly educated labour with ‘another’ academic qualification. This round of models is characterised by the basic specification:

$$\log[p_i/(1-p_i)] = \alpha + \beta_1 HELTN_i + \beta_2 HELOTH + \beta_3 LEAORGi + \beta_4 INDU_i \quad (2)$$

where the notation is the same as for the first round of models (1) except that HELTN expresses whether the firms had introduced highly educated labour with a technical or natural scientific qualification, and HELOTH expresses whether the firm had introduced highly educated labour with another academic qualification.

3.3. Descriptive statistics and results

In this section we present descriptive statistics and regression results of the empirical analysis. Starting with the descriptive statistics, the dataset contained 514 firms with 20-50 employees, and 92 or 18% of these firms had highly educated labour at graduate level employed in 1990. That is, 422 or 82% of the small firms did *not* employ this type of highly educated labour in 1990, and it is this latter group of firms that we are interested in. Table 1 reports descriptive statistics on the small firms with no highly educated employees in 1990.

Table 1. Descriptive statistics on firm population, dependent and explanatory variables

Variable	N	Percent
Product/service innovation in the firm	414	100%
- Yes	167	40%
- No	247	60%
Implementation of major organisational change in the firm	418	100%
- Yes	180	43%
- No	238	57%
Markedly introduction of new ICT (25%+)	422	100%
- Yes	106	25%
- No	316	75%
Markedly introduction of other forms of new technology (25%+)	422	100%
- Yes	50	12%
- No	372	88%
Introduction of highly educated labour	422	100%
- Yes	88	21%
- No	334	79%
Introduction of highly educated labour with technical or natural scientific qualification	422	100%
- Yes	46	11%
- No	376	89%
Introduction of highly educated labour with another academic qualification	422	100%
- Yes	54	13%
- No	368	87%
Had implemented many or few elements of a learning organisation	422	100%
- Many (4-6 elements)	119	28%
- Few (0-3 elements)	303	72%
Industry affiliation	419	100%
- Construction	89	21%
- Trade, hotels, restaurants	165	39%
- Transportation, mail, telecomm.	23	6%
- Financial, business, other services	14	3%
- Manufacturing (benchmark)	128	31%

Table 2 and table 3 report results of the regression analysis.

Table 2. Regression results showing the effect of introducing highly educated labour on innovation and firm changes.

	Model 1.a. Dependent variable: Product/service innovation				Model 1.b. Dependent variable: Implementation of major organisational change				Model 1.c. Dependent variable: Markedly introduction of new ICT				Model 1.d. Dependent variable: Markedly introduction of other forms of new technology			
Variables	Coefficient		Standard error	Odds ratio	Coefficient		Standard error	Odds ratio	Coefficient		Standard error	Odds ratio	Coefficient		Standard error	Odds ratio
Intercept	-0.3254	**	0.174		-0.372	**	0.185		-1.019	***	0.193		-1.663	***	0.209	
HEL	0.233	*	0.121	1.592	0.171		0.121	1.408	0.441	***	0.126	2.414	0.358	**	0.155	2.044
LEAORG	0.509	***	0.106	2.770	0.529	***	0.105	2.882	0.369	***	0.115	2.093	0.157		0.148	1.368
INDU																
- Construction	-0.495	**	0.240	0.307	0.035		0.233	0.663	-0.438		0.287	0.663	-0.579	*	0.342	0.466
- Trade, hotels, restau.	0.455	**	0.196	0.795	0.704	***	0.206	1.294	0.777	***	0.220	2.233	-0.237		0.266	0.656
- Transp., mail, telecom.	-0.147		0.367	0.435	-0.234		0.390	0.506	0.344		0.392	1.449	-0.238		0.527	0.656
- Finan., busi., other serv.	-0.498		0.484	0.306	-0.951	*	0.543	0.247	-0.656		0.584	0.533	0.870	*	0.474	1.985
- Manufacturing	Benchmark industry				Benchmark industry				Benchmark industry				Benchmark industry			
Observations	411				415				419				419			
Percentage of concordance	65				61				65				60			
Likelihood ratio	59	***			47	***			47	***			16	**		

***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

Note: There are no signs causing concern for multicollinearity between the independent variables in the models. Tests for multicollinearity have used the predicted probabilities of the dependent variables to construct a weight variable. This weight variable has been applied in weighted least square regressions regressing each explanatory variable on all the other explanatory variables. From here 'tolerances' and 'variance inflation factors' have been computed.

Table 3. Regression results showing the effect of introducing highly educated labour with different types of academic qualifications on innovation and firm changes.

	Model 2.a. Dependent variable: Product/service innovation			Model 2.b. Dependent variable: Implementation of major organisational change			Model 2.c. Dependent variable: Markedly introduction of new ICT			Model 2.d. Dependent variable: Markedly introduction of other forms of new technology		
Variables	Coefficient	Standard error	Odds ratio	Coefficient	Standard error	Odds ratio	Coefficient	Standard error	Odds ratio	Coefficient	Standard error	Odds ratio
Intercept	-0.161	0.219		-0.256	0.228		-0.585 **	0.232		-1.329 ***	0.253	
HELTN	0.035	0.160	1.073	-0.033	0.161	0.935	0.400 **	0.166	2.225	0.343 *	0.187	1.984
HELOTH	0.400 ***	0.149	2.227	0.322 **	0.148	1.906	0.527 ***	0.150	2.867	0.381 **	0.179	2.144
LEAORG	0.519 ***	0.107	2.825	0.538 ***	0.106	2.932	0.384 ***	0.116	2.156	0.168	0.148	1.399
INDU												
- Construction	-0.470 *	0.241	0.309	0.052	0.234	0.661	-0.384	0.289	0.695	-0.542	0.344	0.483
- Trade, hotels, restau.	0.430 **	0.198	0.759	0.682 ***	0.207	1.242	0.765 ***	0.223	2.192	-0.266	0.269	0.636
- Transp., mail, telecom.	-0.172	0.369	0.416	-0.264	0.391	0.482	0.380	0.395	1.491	-0.207	0.529	0.675
- Finan., busi., other serv.	-0.493	0.489	0.302	-0.935 *	0.547	0.247	-0.742	0.591	0.486	0.830 *	0.478	1.904
- Manufacturing	Benchmark industry			Benchmark industry			Benchmark industry			Benchmark industry		
Observations	411			415			419			419		
Percentage of concordance	66			63			66			61		
Likelihood ratio	63 ***			50 ***			56 ***			20 ***		

***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

Note: There are no signs causing concern for multicollinearity between the independent variables in the models. Tests for multicollinearity have used the predicted probabilities of the dependent variables to construct a weight variable. This weight variable has been applied in weighted least square regressions regressing each explanatory variable on all the other explanatory variables. From here 'tolerances' and 'variance inflation factors' have been computed.

The purpose of this paper is to study the relationship between introduction of highly educated labour and innovation, technological and organisational changes in small, know-how-based firms. Table 2 and table 3 report regression results revealing several interesting points.

First, with respect to *product/service innovation*, model 1.a in table 2 reports that introduction of highly educated labour in general (HEL) affects product/service innovation at a 10% (or more precisely at a 5.5%) significance level. Evaluating this result in light of findings from model 2.a in table 3, we see that introduction of highly educated labour with 'another' academic qualification (HELOTH) contributes positively and highly significantly – below a 1% significance level – to product/service innovation. In fact, the odds ratio of 2.227 reports that small firms introducing HELOTH during the period 1991-95 had 123% higher odds for having introduced new products/services during the period 1993-95 when compared to counterparts, i.e. when compared to small, know-how-based firms *not* introducing HELOTH. Introducing highly educated labour with a technical or natural scientific qualification (HELTN) does not, however, seem to significantly affect the likelihood of product/service innovation in a given firm.

As regards *implementation of major organisational changes*, model 1.b in table 2 reports that introduction of highly educated labour in general (HEL) does not seem to significantly affect the likelihood of implementing such organisational changes. However, distinguishing between different types of highly educated labour, model 2.b in table 3 reveals that it is mainly introduction of highly educated labour with a technical, or natural scientific qualification (HELTN) that does not contribute significantly to major organisational changes. Introduction of highly educated labour with 'another' academic qualification (HELOTH) does, in fact, significantly affect the likelihood of implementing major organisational changes at a 5% (or more precisely at a 3%) significance level. The relevant odds ratio reveals that introducing HELOTH increases odds of having implemented major organisational changes with 91% when compared to counterparts.

When it comes to *markedly introduction of new ICT*, i.e. an introduction of ICT that affects at least 25% of the workforce, model 1.c in table 2 reports that such introduction is highly significantly affected – i.e. below a 1% significance level – by whether or not a given firm has introduced highly educated labour (HEL). Distinguishing between different types of highly educated labour, model 2.c in table 3 reports that introduction of highly educated labour with technical or natural scientific qualification (HELTN), as well as introduction of highly educated labour with 'another' academic qualification (HELOTH) seems to have quite significant effects on a markedly introduction of new ICT. Introduction of HELTN thus increases odds of such introduction with 123% at a 5% (or more precisely at a 2%) significance level. Similarly, introduction of HELOTH increases odds of such introduction with 187% at a 1% significance level.

Concerning *markedly introduction of other forms of new technology*, model 1.d in table 2 reports that such introduction is significantly affected below the 5% (or even the 3%) level from having introduced highly educated labour (HEL). Model 2.d in table 3 reveals that introduction of highly educated labour with a technical or natural scientific qualification (HELTN) increases the odds of having markedly introduced other forms of new technology with 98% at a 10% (or more precisely at a 7%) significance level. Similarly, introduction of highly educated labour with 'another' academic qualification (HELOTH) increases odds of such introduction with 114% at a 5% (or precisely at a 4%) significance level.

4. Conclusions

4.1. Findings

Our goal in this paper has been to complement established insight that higher education and academic qualifications are important to science-based innovation with new knowledge regarding the potential that *introduction* of skilled graduates may hold untapped benefits vis-à-vis innovation and upgrading changes in small firms based on more practical knowledge bases. Aiming at this goal, it has been argued that introduction of skilled graduates in small know-how-based firms will, in principle, bring in new perspectives, enlarge, and diversify the existing practical knowledge bases and skills of the firms, and this may start interactive creative processes that, again, can spur learning, innovation, and development in the firms.

The conceptual, analytical part of the paper was inspired from, and complementary to empirical reports containing indications, based on qualitative and quantitative studies, that introduction of academically skilled graduates in small, know-how-based firms is instrumental in upgrading and improving innovation performance of the firms. In this respect the argument of the paper is 'a posteriori' substantiated by previous empirical findings, as well as it provides conceptual, analytical grounding for these tentative empirical findings.

The argument of the paper is furthermore substantiated by it owns quantitative empirical analysis. Thus, based on logistic regression models specified to analyse whether introduction of skilled graduates significantly affects upgrading changes of and innovation performance in small, know-how-based firms, the papers does, indeed, report several significant positive effects. These findings can be seen as a quantitative substantiation of the broader view on how universities, science, and research contribute to industry and industrial innovation. Universities produce information, inventions, patents, and technologies directly transferable to industry, but these constitute only a subgroup of important contributions. The findings in this paper substantiate that the education of skilled graduates is also a significant contribution to industry and industrial development, a contribution that is not encapsulated in a too narrow conceptualisation of universities' contributions to industrial development, or in traditional measures in the adjacent human capital literature.

Besides, the finding that skilled graduates can contribute to upgrading changes of and innovation performance in small, know-how-based firms is different from existing literature establishing their importance in R&D labs of science-based firms. Other than being important to science-based industrial development, formal skills and knowledge embodied in graduates can be complementary to practical knowledge bases, and the combination of these two forms of knowledge can hold innovative potential.

Finally, the different positive effects from different groups of graduates give grounds for not just focusing on highly educated labour with technical and natural scientific qualifications. Findings in the paper suggest that introducing graduates with technical or natural scientific qualifications significantly and positively affects markedly introduction of new ICT and markedly introduction of other forms of new technology in small firms. Finding such positive effects on technological upgrades in the firms is no surprise when considering that the labour introduced embodies a technical or natural scientific qualification. Neither, is it fundamentally surprising that this type of graduates does not spur implementation of major organisational changes. Such changes may, more likely, be directly expected from introducing graduates with other types of expertise (see below). However, it is somewhat surprising that introduction of graduates with a technical or natural scientific qualification does not seem to significantly affect the likelihood of product/service innovation in small firms, especially because more than half of the firms in the study are affiliated to either the manufacturing or construction industry. This aspect calls for further research.

As for graduates with ‘another’ academic qualification, including qualifications stemming from the social sciences and the humanities, findings in the paper indicate that introducing this type of labour is rather active in spurring innovation and upgrading changes in small, know-how-based firms. Introduction of these graduates thus significantly and positively affects product/service innovation, implementation of major organisational changes, markedly introduction of new ICT, and markedly introduction of other forms of new technology. The positive effects on product/service innovation and implementation of organisational changes are not fundamentally surprising considering that they stem from introducing graduates from a group in which at least a high degree of the employees are educated in, and thus expected to take interest in, social structures such as markets and organisations in which human activity, interaction, and/or communication is embedded. Basically privately employed individuals with such educational qualifications may, very likely, put focus on market performance and organisational settings. Besides, putting focus on such market and organisational aspects may also explain why this type of labour seems to be attentive of – or at least significantly affect – markedly introductions of new technologies, both ICT and other forms of technology.

4.2. Policy implications

This set of findings carries policy implications from different points of view. From the general point of view, the finding that introduction of skilled graduates contributes to innovation and upgrading changes in small, know-how-based firms is a finding contributing to the policy position that we shall not be too narrow when evaluating how universities, science, and research do, and may, contribute to industry and industrial development. Perceiving universities merely as producers of information and technologies *directly* transferable to and applicable in industry is a mistaken, too narrow approach being short of the research-based education and training of graduates as the potentially most important contribution from universities to industry and industrial development. This empirically substantiated policy position should be seen as a critically important counterbalance to any excessive focus on ‘optimising’ universities as producers of technical inventions, patents, and technology transfers.

From a more specific point of view, the finding that introduction of skilled graduates seems to be instrumental in upgrading and improving innovation performance of small, know-how-based firms is relevant to consider when assigning special policy attention to this group of firms, a group that is quite substantial in several countries. As for other firms in dynamic competitive environments, these know-how-based firms also face a continuous transformation pressure dictating adaptation, upgrades, and innovation, and findings in the paper propound that introduction of skilled graduates seems to hold positive, untapped potential vis-à-vis innovation and upgrading changes in the firms. This potential should be considered as a possible policy instrument, not as a panacea but as an instrument with a certain potential vis-à-vis certain firms.

From a more specific point of view, it is furthermore relevant to notice that it is not just introduction of graduates with technical and natural scientific qualifications that was found to spur innovation and upgrading changes. In fact, findings in the paper suggest that introduction of graduates with other academic qualifications, e.g. from the social sciences and humanities, is at least as active in spurring innovation and upgrading changes as the technical and natural scientifically trained graduates. Especially if the objective is implementation of major organisational changes or product innovations, findings in the paper suggest introduction of graduates with another academic qualification as a relevant opportunity to consider.

A final policy consideration is that even though this paper has attempted to conceptualise, analyse, and quantify how skilled graduates can benefit industry and industrial development, it is naturally far from finally settling questions on how universities, science, and research contribute to industry and industrial development. More research is needed, and some of it should attempt to enhance our knowledge and improve our policy decisions through quantitative studies, but we may also have to accept that not all important contributions are quantifiable, at least not in the short run. This is a crucial point to remember, otherwise we risk emphasising “the countable rather than the important aspects of university-industry interactions [which] could have unfortunate consequences for innovation policy in the industrial and industrializing world” (Mowery and Sampat 2005: 235). It is critically important that we are careful in not promoting a rash, partly undue, quest for ever increasing degrees of quantification that misses or downgrades the full spectrum of important contributions from the university to industry.

5. References

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