Education and Invention

Preliminary draft and results, please do not quote

Otto Toivanen and Lotta Väänänen[*]

06.10.2009

ABSTRACT

We study the causal effect of university engineering education on invention, using a dataset on U.S. patents' Finnish inventors and using the distance to the nearest university offering engineering education as an instrument. We find a positive significant effect of engineering education on the propensity to patent, and a negative OLS bias. These findings suggest that education is a potent policy tool for enhancing invention, and that inventors are not the typical "high ability" individuals who would with high likelihood seek university (engineering) education.

KEYWORDS: ability bias, citations, education, engineers, growth, innovation, invention, inventors, patents

JEL codes:

---

[*] Toivanen: HECER, PO Box 17, FIN 00014 University of Helsinki, Finland. Email: otto.toivanen@helsinki.fi. Väänänen: University of Mannheim. E-mail: lottavaan@googlemail.com. We would like to thank Julia Lane and Joachim Winter for their comments, as well as the seminar participants at the ASIGO conference in Nurnberg and at the FDPE microeconomics seminar in Helsinki. We thank the Yrjö Jahnsson Foundation for financial support. Väänänen also thanks the FDPE for financial support. The usual caveat applies.

1 Introduction

A cornerstone of much of recent growth theory is that ideas, being non-rival in nature, are a key source of growth (for surveys see e.g. Jones 2005 and Aghion and Howitt 1998, 2009). Furthermore, ideas are produced by human capital. The central consequence of this line of thinking is aptly summarized by Jones (2005, pp. 1107): “The more inventors we have, the more ideas we discover, and the richer we all are”. This immediately leads to the following policy question: (How) can the number of inventors be increased? We seek to contribute to answering this question by studying the causal effect of education on invention. To the best of our knowledge, previous research has not addressed this question,[1] while actual policies – educational investments are typically 3 – 6% of GDP[2] - suggest a strong belief in the existence of such a causal link.

We study the effect of individuals’ education, concentrating on university (master’s level or higher) engineering education, on their inventive productivity, as measured by patents and their quality. We use data on U.S. (USPTO) patents[3] matched to individual level data on (essentially) the whole Finnish working population over the period 1988 – 1996. Previous descriptive analysis with data on individual inventors has shown that inventors tend to be highly educated. Giuri et al. (2007) report that 77% of European inventors in the PatVal survey have a university degree and 26% have a

[1] A literature exists that studies the question of the causal effect of educational investments on growth at the macro level. The current consensus (see recent surveys by Silanesi and van Reenen 2003, Stevens and Weale 2004 and Krueger and Lindahl 2001) seems to be that there is at best weak empirical support for the causal relation between education and growth. In a recent paper, Aghion, Boustan, Hoxby and Vandenbussche (2009), using U.S. state level data, provide evidence of a causal link between education and growth (see also Vandenbussche, Aghion and Meghir 2005).

[2] See e.g. WDI education indicators at http://siteresources.worldbank.org/DATASTATISTICS/Resources/table2_9.pdf , accessed August 28th, 2009.

doctorate. In our data about 35% of the inventors have a master's degree and 14% have a doctorate (see Table 1). In addition, our data shows that the majority of Finnish inventors have an engineering degree (66%), indicating that also the field of education is associated with patented inventions.[4] This observation is interestingly in line with Murphy, Shleifer and Vishny (1991) who report some evidence that countries with a higher proportion of engineering college majors grow faster. While existing evidence thus suggests a significant positive association between individuals' education and their inventiveness, the causality of this link remains unexplored.

We identify the causal effect of university engineering education on the propensity to patent by using geographic and over time variation in the possibility to obtain a university engineering degree. During the 1960s and 1970s, Finnish education policies lead to a large increase and geographic diffusion in the possibility to obtain a university engineering degree. We use these changes as a quasi-natural experiment in the spirit of papers (surveyed e.g. by Card 2001) that use distance to college as an instrument in studying returns to education and of papers (e.g. Meghir and Palme 2005 and Pekkarinen, Uusitalo and Kerr 2006) that use the schooling reform implemented in all Nordic countries in the 60s and 70s to study the effects of education on various outcomes. We link the individuals to the distance to the nearest university offering engineering education, as well as to the number of new engineering students at each of the universities relative to the size of the potential applicant cohort and use these as instrumental variables determining the individuals' schooling choice.

---

[3] Obtained from the NBER patents and citations data file (Hall, Jaffe Trajtenberg 2001).

[4] In the macroeconomic literature on the relationship between education and growth there is some work seeking to differentiate the impact of different levels of education on growth. See e.g. ch13 in Aghion and Howitt (1999).

Using Finnish data seems pertinent to the study of the effect of education on invention for two reasons: First, as documented by e.g. Trajtenberg (2001), Finland is among those nations that have accomplished a transformation from a resource based to an invention based economy. This is reflected in the large increase in patent applications to the USPTO in the past two decades (see Figure 1.). Second, while the increased availability of higher education is a widely spread phenomenon among the developed countries, this development has been particular in Finland in two respects. The first one is the scope of this change – the proportion of a cohort to whom there are higher education study places is among the highest in the world (OECD 2008). The second is that the Finnish enlargement of the higher education sector has had a strong emphasis on increasing the availability of engineering education. During this period, three new universities offering engineering education were established in different regions of Finland. Figure 2. shows the increase in the number of new engineering students at the universities from 1950 to 1981. The figure also shows the share of new university students taking engineering, which was decreasing from 1950 until 1965, when it was 9%, and has been rising back up to 15% in 1981. By way of contrast, in the U.S., the proportion of graduate students studying engineering has been around 5% between 1975 and 2005 (NSF 2006, Table 1). Among OECD countries, Finland stands out as the one with the highest emphasis on engineering: 27% of the Finnish working age population with tertiary education has a degree in engineering whereas the OECD average is 15% (OECD 2008). Given that engineering is the form of higher education that is most directly targeted towards industrial R&D, one could view the Finnish education policy as an experiment whose individual level treatment effect we seek to identify.

Figures 1 and 2 here

The first stage results of our IV-estimations show that the distance to the nearest university offering engineering is a good predictor for an individual's entry into such education.[5] We find that university engineering education has a strong causal effect on individuals' later propensity to patent. The estimated coefficient is 2.5 times the OLS estimate when using the number of patents as the outcome variable. We thus find a strong negative ability bias in the OLS estimations. The potentially counterintuitive direction of the bias suggests that lowering the barriers to university education may be an effective policy tool in attracting to formal (tertiary, engineering) education individuals that otherwise would have chosen something else.[6]

The rest of the paper proceeds as follows. Section 2 describes the data and presents a comparison between inventors and non-inventors, especially in terms of education. We also present the data we use to generate our instrumental variable: the number of new engineering students at each of the universities in 1945-1981. Section 3 presents the empirical framework and discusses the identification strategy. In section 4 we present the results and in section 5 the conclusions.

2 Data and descriptive analysis

2.1 Data

Our data comes from several sources. Information on inventors and USPTO patents

[5] I.e., our instrument is not weak.

[6] That is, we identify the (weighted) local average treatment effect on the "compliers", i.e,, those individuals that were prompted to enter university engineering education by a shift in the instrument we use. See e.g. ch. 25 in Cameron and Trivedi (2005) or section 6.3.2 in Imbens and Wooldridge (2008).

comes from the NBER patents data base described in Hall, Jaffe Trajtenberg (2001). This data is matched to the Finnish Linked Employer-Employee data of Statistics Finland (FLEED). The FLEED is a register-based dataset that contains detailed information on the population of Finnish working-age individuals and on their employers. FLEED is described in Korkeamäki and Kyyrä (2000) and the matching process in Toivanen and Väänänen (2008). Third, we use the Finnish 1970 census to add to our data information on the parents of the individuals in our sample. Finally, we match data on the number of new university students in engineering from 1950 to 1981, obtained from the Finnish Educational Establishment Statistics and obtain a matrix of inter-municipality driving distances from the Finnish Road Administration.

The matching of inventors from the patent data to FLEED proceeded as follows. To identify the individuals from the patent data, the information contained in the patent records (name of individual, municipality in which the individual resided at the time, taking patents with country code FI) was used to search the Finnish Population Information System for individuals that matched these data. In case there was more than one match, we picked the individual whose employer's name in the FLEED matched the patent assignee in the USPTO data. If this process failed to identify a single individual, we excluded such individuals from our data. Out of 8065 inventor-patent records we were able to match 5905, consisting of 3253 individuals.

The Finnish Educational Establishment Statistics are available for each year from 1945 onwards. They contain information on all higher education establishments, including the type of the establishment and fields of education, size (by number of students), and geographical coordinates. We concentrate on engineering education at universities as our inventors are predominantly, if unsurprisingly, engineers with a university degree. For each individual, we take the year of their 18th birthday to represent the relevant year of making the schooling choice, and measure the number of new students that year in each of the establishments relative to the size of the potential applicant cohort. We also measure the distance from each engineering establishment to the individual's birth place.[7] The distances we use are road driving distances from the Finnish Road Administration.

2.2 The sample

To construct our sample, we take a cross-section of individuals in the year 1988, who were born between 1932 and 1963. These individuals make their schooling choices in the years 1950-1981, under the assumption that they do so when they are eighteen years old. In addition to all the individuals identified as inventors in the time period 1988-1996 (2328 inventors), our data includes a random sample of working-aged individuals (non-inventors) from the FLEED. The FLEED data contains the full Finnish working-age population. We take a 5% random sample from the 1988 cross-section for our analysis, after which we keep the observations for individuals born between 1932 and 1963. Our sampling weights are the inverse of the sampling probability (1/0.05), i.e. a weight of 20 for each of the control observations. Thus the sampling procedure we use is "choice-based" sampling, with separate random samples for observations with Y=0 and Y>0.

2.3 Descriptive statistics

Table 1 shows the means, measured in 1988, for the key variables for inventors, i.e., for

[7] Municipality of residence at the time of the schooling choice would be preferred, but is unavailable.

those individuals who were inventors in a patent applied in any of the years 1988-1996, as well as for a random sample of the Finnish working-aged population. Comparing the two shows that inventors are different from the rest in that a) they are more likely to be male (only 7% are female), b) they are highly educated, i.e. much more likely to have completed their high-school diploma and have a university education (a bachelor, master or a doctorate degree), c) they are more likely to have their education in the fields of natural sciences and engineering, d) they are particularly likely to be university educated engineers (33% of inventors, 3% of the random sample).

Table 1 here

In Figure 3 we present histograms of the number of patents per inventor over the period of 1988-1996. The great majority of them (60%) have just one patent over the whole time period, while about 20% have two patents and very few with more than 5 patents.

Figure 3 here

We run OLS regressions with 46 dummies for the level-field combinations of education. As control variables, we include in our estimating equation variables for gender, nationality (Finnish, foreign), language (Finnish, Swedish, other). We find significant and large differences between different fields and levels of education. Figure 1 shows the coefficients on the education dummies from an OLS regression. We see that engineering education has a positive significant coefficient at all levels of education, with the magnitude increasing with the level of education. At the doctorate level, also the coefficients for the fields of natural sciences and health and welfare are large and significant, while also resources and services are positive and significant.

Figure 4 here

2.4 Data on engineering education

In this section we present the data we use to generate our instrumental variable. Figure 4 shows a graph of the number of new engineering students in each of the Finnish universities that offered engineering education during the period 1945-1981. In 1945, there were two universities offering engineering education, both in Southern Finland: the largest one in Helsinki (TKK), and a small Swedish-speaking one in Turku (Åbo Akademi). Together they had a total of just over 400 new students starting that year. In 1959, the University of Oulu in Northern Finland began to offer engineering education, followed by Tampere in Southern Finland in 1965 and Lappeenranta in Eastern Finland in 1969. From the year 1960, there has been rapid growth in the total number of new engineering students at universities, tripling from 600 to 1800 in less than 20 years. While the Helsinki University of Technology has doubled its new students in engineering in the period 1945-1981, the universities in other regions have also grown to a significant size.

Figure 4 here

3 The empirical framework

We estimate the effect of engineering higher education on individuals' inventiveness, as measured by their total patent output (USPTO patents by application date) over the time period of 1988-1996. We use a linear specification and estimate equations of the following form:

(1) $$Y_i = \alpha + \beta X_i + \theta ENG_i + \varepsilon \quad .$$

Y_i is our output measure (sum of patents granted to individual *i*, or citations received by the patents of individual *i*), X_i are control variables describing the individual (gender, cohort dummies, native tongue), ENG_i is an indicator equal to one if the individual has obtained a university engineering degree (master or doctorate) by the year 1988. θ is the key parameter of interest, measuring the (weighted) local average treatment effect (see Imbens and Wooldridge, 2008, section 6.3.2) of engineering education on inventive output, and β is a vector of parameters on the control variables.

The error term in equation (1) may be correlated with the schooling measure and patents due to, for example, omitted variables related to unobserved individual ability, as in estimating the returns to schooling. However, it is not clear ex ante what the direction of the omitted variable bias is, because the unobserved ability affecting the propensity to patent (individual's inventiveness) is not necessarily positively correlated with the ability that is typically thought to increase individual's net benefits from schooling. In other words, individuals with low effort costs of studying could on average be less good at creative thinking that leads to invention, leading to negative correlation and a downward bias in the OLS estimate.

In addition, there may also be an issue of essential heterogeneity or selection on gains, which generates positive correlation between schooling and the error term. If engineering higher education increases the propensity to patent, but mainly for those individuals with the innate inventive ability, then those individuals have a higher additional benefit of schooling in terms of their increased propensity to patent, and are thus more likely to choose such schooling.

We apply instrumental variables for the individuals' schooling choice and identify the (weighted) local average treatment effect (LATE) for those individuals who are affected by the instruments we use. We discuss our identification strategy and our instrumental variables in the next section.

3.1 Identification

We borrow the idea of using (time-varying) geographic variation from the literature that utilizes educational reforms to estimate e.g. the returns to education (Card 2001, Meghir and Palme 2005). The quasi-experiment we use is the growth of the Finnish university level engineering education system that took place in the period 1950-1981. This variation allows us to adopt an instrumental variable approach.

Individuals choose their education by evaluating the costs and benefits of the alternatives. We use instruments generated from exogenous factors that affect the individuals' cost of choosing an engineering education. Using individuals' birth year and place, we determine the distance to and availability of university engineering education. These measures correspond to institutional variations on the supply side of the education system, and are typical of the kind of instrumental variables used in the recent literature studying the effects of schooling choices on labor market outcomes (Card, 2001). We combine distance-based instruments (geographical variation) with cohort-based instruments (over time variation).

Our main instrumental variable is based on distance, which exogenously generates variation in the individuals' mobility costs. Individuals, depending on where they live, face different costs of travelling or moving to a town where engineering education is offered. We use the individual's birth place to measure the distance to the nearest engineering university. This instrument mainly has geographical variation, but there is also some variation over cohorts, as three new universities are founded during the time period. When using a location-based instrument, it is important to control for other factors that are correlated with the location. For example, families living in or near university towns are different to those living in smaller towns and rural areas, and family background can influence both schooling and inventiveness. We control for the level and field of the father's education, measured in the year 1970, the first year for which such data is available.

We also generate an instrumental variable that varies by cohort as well as by location. To measure the difficulty in getting in to study engineering at a university, we take the number of new engineering students in each of the universities in the year when the individual is 18 years old, relative to the size of the potential applicant cohort. The potential applicant cohort is defined as the total number of 18-year olds for whom the given university is the nearest university offering engineering education. Thus, depending on which birth cohort the individual belongs to and where he lives, he faces different application costs. We expect that the more students are taken in, the smaller the difficulty in getting a place, i.e. a reduction in the application cost (and students with lower levels of ability for studying are taken in).

The treatment effect we identify is LATE for individuals affected by the instruments we use. As our instruments generate variation in the costs of choosing university engineering education, the individuals affected by the instrument are those who are at the margin of choosing university engineering education over some other schooling choice. It is important to note that it is unclear what the relevant counterfactual is, i.e. what the individuals would have chosen had they not chosen university engineering education. We can only make a guess that the relevant next best choice for this group is either a lower level engineering degree, or a university degree in some other field.

The LATE we identify is a however a relevant variable from the policy point of view. Viewing our instruments as being generated by variation in government educational policy, we are identifying the effect of this policy, to the extent that the policy can be represented by the location of universities and the number of students in engineering.

4 Results

We estimate the effect of university engineering education on individuals' propensity to patent, measured by the sum of their USPTO patent output over the time period of 1988-1996. We report the results from these estimations in Table 2; the first row shows the results from estimations on a larger sample without controlling for family background and the second row from estimations with father's education included as a control (45 dummies for field-level combinations). This sample is smaller, as father's education is not available for all the individuals. The smaller sample is also somewhat different with regard to the ages of the individuals, as for the older cohorts it is more likely that the father is no longer alive in 1970 (see descriptive statistics for this sample in Table A1 in the Appendix). We first run OLS regressions (column 1) and find that the coefficient for the dummy for an engineering university degree is positive and significant (0.110 with s.e. of 0.007; 0.118 with s.e. of 0.009). As discussed earlier, the endogeneity bias in the OLS estimate may be in either direction.

Table 2 here

In the instrumental variable regressions, we use the distance to the nearest university offering an engineering degree as our instrumental variable affecting schooling choice. The coefficients and standard errors of our instrument in the first stage are presented in column 3. We see that the distance to the nearest engineering university has a significant negative effect on choosing such schooling, as expected. The coefficients on the distance (in 100km) are -0.0016 (with father's education) and -0.0026 (without). Given the average probability of choosing engineering education (0.022), this translates into about a 10% increase in the probability as distance decreases by 100km. We also see that our instrument is strong in both specifications, although somewhat reduced by controlling for father's education (t-value of almost 10 in the regression without father's education, and 2.6 in the regression with). Part of this reduction in the strength of the instrument is also due to the younger sample in the regression with father's education; when we run the specification without controls for father's education on this sample, the t-value of the instrument falls to 6.5.

Column 2 presents the estimation results from the second stage of the IV-estimations, i.e. the patenting equation. The estimated coefficient is 2- 2.5 times the OLS estimate. This result could indicate a negative "ability" bias, i.e. that those who have a high innate ability for invention, have a lower ability for studying at a university. This interpretation is, in a sense, in line with the instruments we use and the treatment we effect identify. Individuals who are induced to take engineering higher education as a result of the proximity of a university (our instrument) are individuals at the margin and thus not those who have the highest studying ability and highest net benefits. The LATE we identify is for the part of the population that is affected by these distance-related mobility costs.

Our results provide a potential explanation for the transformation, noted e.g. by Trajtenberg (2001) and analyzed by Honkapohja, Koskela and Uusitalo (2009), of the Finnish economy from a resource based to an innovation based economy. By increasing the (geographic) availability of university engineering education, Finland enticed young people finishing high school to enter engineering education, making them more likely to invent. The negative ability bias that we report suggests that a feature of the policy was to entice “non-standard” individuals to enter engineering education.

5 Conclusions

Paraphrasing Jones (2005, pp. 1107), can we, through educational investments, increase the number of inventors, and thereby make us all richer? Existing evidence based on macro level studies provides at best weak evidence of a causal effect of education on growth (e.g. Krueger and Lindahl 2001), although Aghion, Boustan, Hoxby and Vandenbussche (2009), using U.S. state level data, find evidence of a positive effect of education on growth. To address the question directly, we study if university engineering education increases individuals’ propensity to patent, using a matched dataset on Finnish inventors of U.S. patents in 1988-1996.

We examine the causal effect of engineering education on invention, and find that it has a large positive impact on individuals’ propensity to patent. We use supply-side instruments - distance to the nearest engineering university as our instrument - generated from the Finnish educational policies of the period 1950-1981, i.e. the years in which the individuals in our sample chose their education. The first stage result that distance negatively affects individuals' choice indicates that the educational policy of increasing the geographic availability of engineering education worked, in the sense that it increased the probability that individuals from the nearby regions would enter university engineering education. We find that there is a strong positive causal effect from obtaining a university engineering degree on the propensity to innovate. Furthermore, we find that the OLS bias is negative, indicating that potential inventors are not the typical "high ability" people who would obtain a university (engineering) education. Our answer to the policy question is thus affirmative: Yes, the number of inventors can be increased through educational policy.

References

Acemoglu, Daron, 2002, Technical Change, Inequality, and the Labor Market, *Journal of Economic Literature*, Vol. 40, Iss. 1, pp. 7-72.

Aghion, Philippe, Leah Platt Boustan, Caroline Hoxby and Jerome Vandenbussche, 2009, The Causal Impact of Eduation on Economic Growth: Evidence from U.S., mimeo, Harvard University.

Aghion, Philippe and Peter Howitt, 1998, *Endogenous Growth Theory*, MIT Press, Cambridge, MA.

Aghion, Philippe and Peter Howitt, 2009, *The Economics of Growth*, MIT Press, Cambridge, MA.

Cameron, Colin and Pravin Trivedi, 2005, *Microeconometrics: Methods and Applications*, Cambridge University Press.

Card, David., 2001, Estimating the Return to Schooling: Progress on Some Persistent Econometric Problems, *Econometrica*, Vol. 69, No. 5. pp. 1127-1160.

Giuri P., Mariani M., Brusoni S., Crespi G., Francoz D., Gambardella A., Garcia-Fontes W., Geuna A.,Gonzales R., Harhoff D., Hoisl K., Lebas C., Luzzi A., Magazzini L., Nesta L., Nomaler Ö., Palomeras N., Patel P., Romanelli M., Verspagen B., 2007, Inventors and Invention Processes in Europe. Results from the PatVal-EU Survey, *Research Policy*, vol. 36, No. 8, 1107-1127.

Hall, Bronwyn, Adam B. Jaffe and Manuel Trajtenberg, 2001, The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools, NBER Working Paper 8498.

Imbens, Guido and Jeffrey Wooldridge, 2008, Recent Developments in the Econometrics of Program Evaluation, NBER working paper 14251.

Jones, Charles, 2005, Growth and Ideas, ch. 16 in Handbook of Economic Growth 1B, Aghion P. and S. *Durlauf (eds.), Elsevier B.V.*

Korkeamäki, Ossi and Tomi Kyyrä, 2000, Integrated Panel of Finnish Companies and Workers, VATT Discussion Paper No. 226.

Krueger, Alan and Mikael Lindahl, 2001, Education for Growth: Why and for Whom?, Journal of Economic Literature, Vol. 39, 1101-1136.

Meghir, Costas and Mårten Palme, 2005, Educational Reform, Ability, and Family Background, *The American Economic Review*, Vol. 95, No 1.

Murphy, Kevin, Andrei Shleifer, and Robert Vishny, 1991, The Allocation of Talent: Implications for Growth, *Quarterly Journal of Economics*, Vol. 106, No. 2, 503-530.

National Science Foundation, 2006, Graduate Students and Postdoctorates in Science and Engineering: Fall 2006, available at http://www.nsf.gov/statistics/nsf08306/pdf/nsf08306.pdf, accessed August 28 2009.

OECD, 2008, Tertiary Education for the Knowledge Society, Vol. 1, Special features: governance, funding, quality.

Pekkarinen, Tuomas, Roope Uusitalo and Sari Kerr, 2009, School tracking and intergenerational income mobility: Evidence from the Finnish comprehensive school reform, *Journal of Public Economics*, forthcoming.

Sianesi , Barbara and John Van Reenen, January 2003, The Returns to Education: Macroeconomics, *Journal of Economic Surveys*, Vol. 17, No. 2, 157-200.

Stevens, Philip and Martin Weale, 2004, Education and Economic Growth, in *The International Handbook on the Economics of Education*, Johnes G. and Johnes J. (eds.), Edward Elgar Publishing.

Toivanen, Otto and Lotta Väänänen, 2008, Returns to Inventors, HECER Discussion Paper No. 237.

Trajtenberg, Manuel, 1990, A Penny for Your Quotes: Patent Citations and the Value of Innovations, *Rand Journal of Economics*, Vol. 21, pp.172-187.

Trajtenberg, Manuel, 2001, Innovation in Israel 1968–1997: a Comparative Analysis Using Patent Data, *Research Policy*, Vol. 30, Iss. 3, pp. 363-389.

Vandenbussche, Jerome, Philippe Aghion, and Costas Meghir, 2005, Growth and the Composition of Human Capital, *Journal of Economic Growth*, vol. 11, No. 2, 97-127.

Table 1. Descriptive statistics for the inventors and for a random sample of the population

	Inventors	Others
No. of observations	2,328	66,530
Level of education		
upper secondary	14.4	37.8
lowest tertiary	11.0	13.0
lower-degree (bachelor)	18.0	5.4
higher-degree (master)	35.4	5.2
doctorate	13.6	0.4
unknown	7.6	38.3
Field of education		
general	5.5	4.4
teacher education	0.3	1.9
humanities & arts	0.6	2.0
social science & business	2.7	11.9
natural sciences	11.2	1.2
engineering	65.9	22.2
agriculture and forestry	1.6	3.4
health and welfare	4.0	6.6
services	0.8	8.2
unknown	7.6	38.3
University engineering (master/doctor)	33.1	2.21
Age (years)	37	39
Female	7.9	49.3
Finnish-speaking	92.6	94.1
Swedish-speaking	6.5	5.4
Birth cohort		
1931<born<1950	43.5	51.2
1949<born<1960	41.3	35.3
1959<born<1964	15.2	13.5
Labor market status		
employed	95.7	83.6
unemployed	0.6	4.1
student	1.8	1.8
retired	0.5	5.4
other	1.5	5.1
Entrepreneur	6.4	11.9

Notes: The numbers are percentages, except for age which is in years.

Figure 1. New engineering students at universities

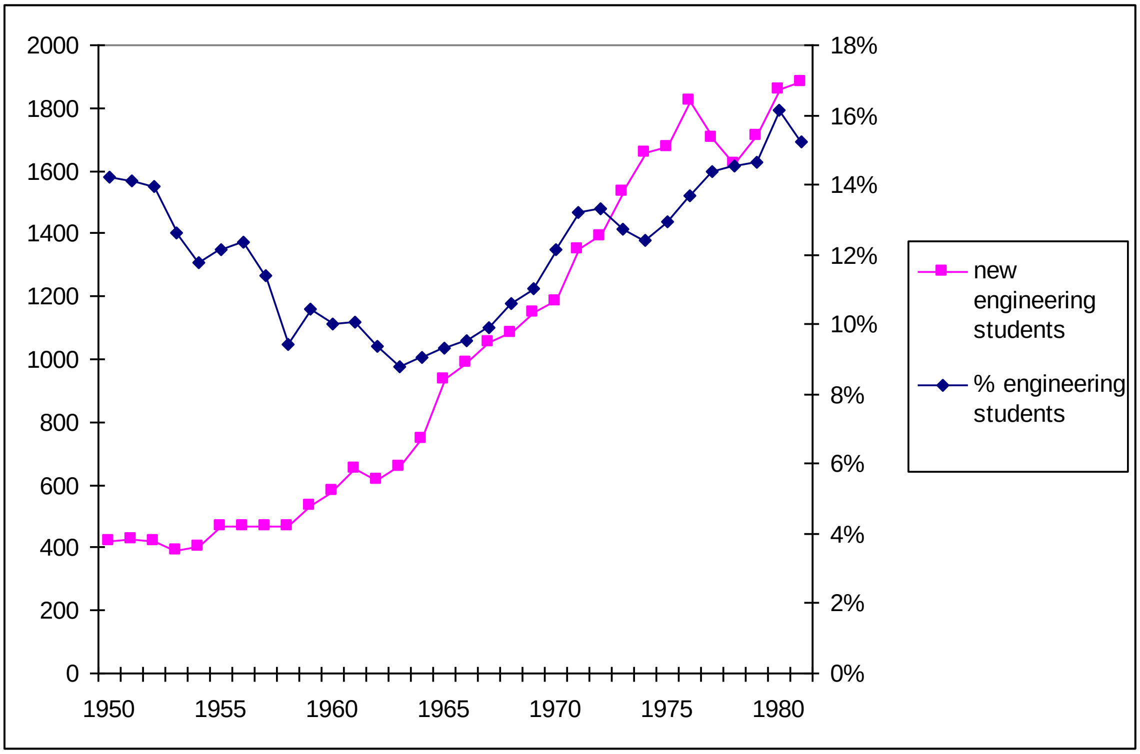

Figure 2. Number of patent applications to the USPTO

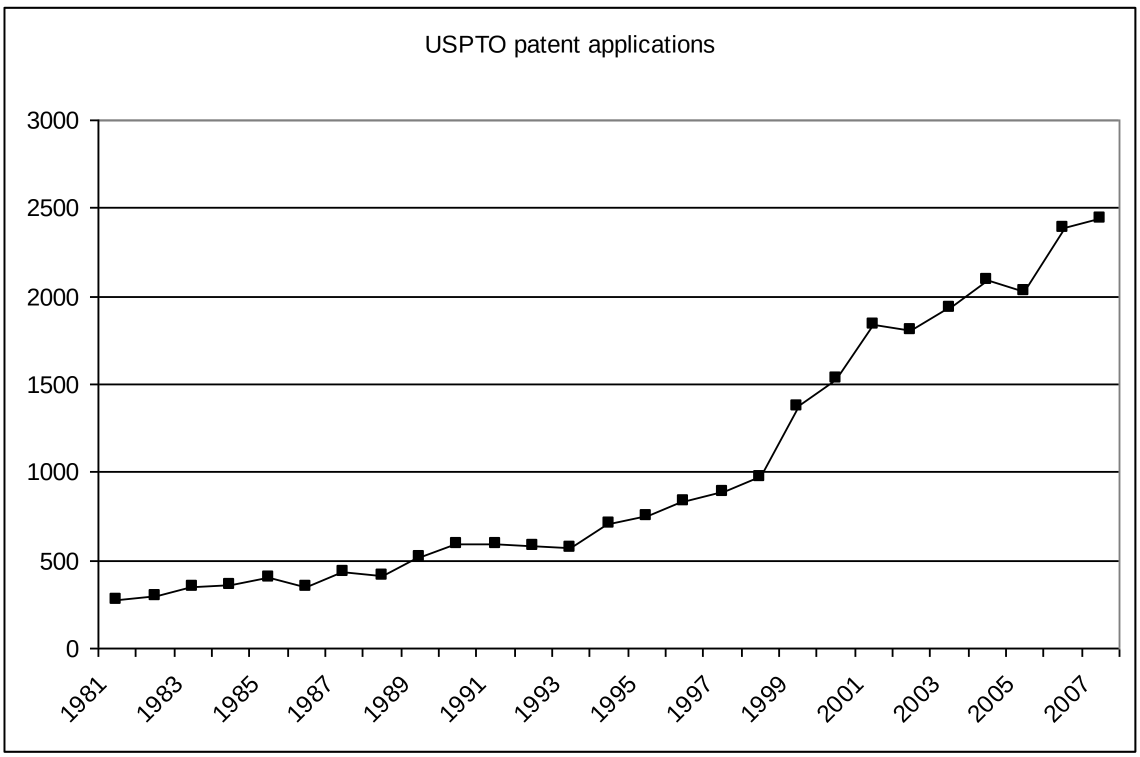

Figure 3. Histogram of patent count for the sample of inventors

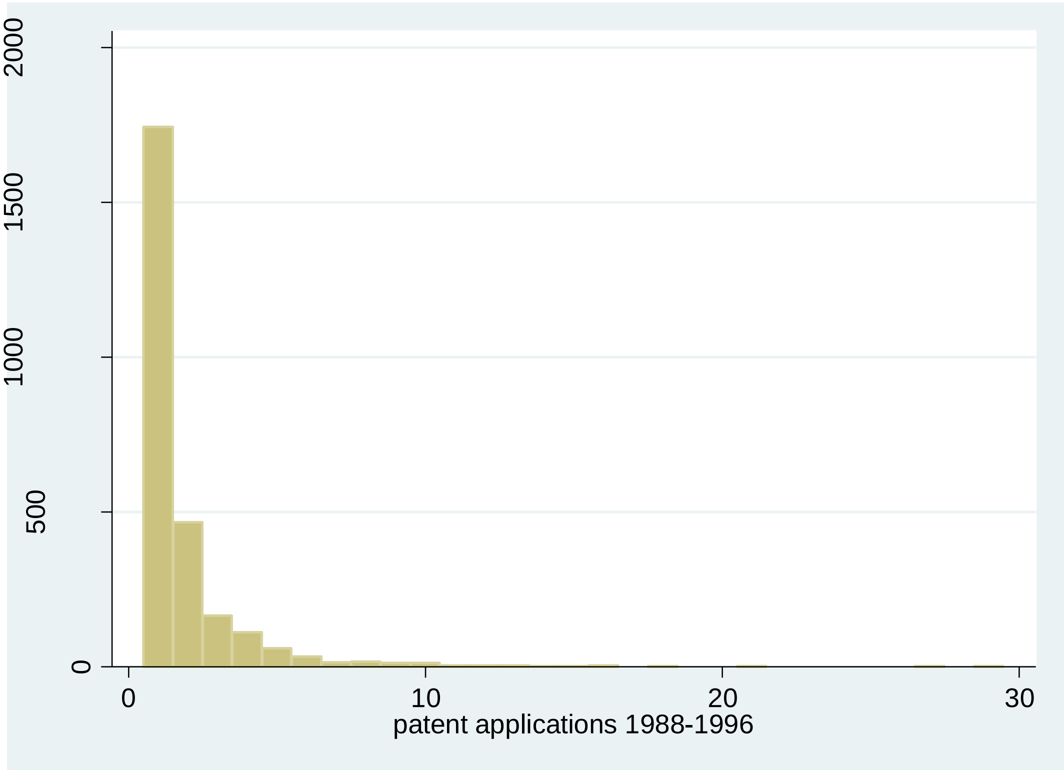

Figure 4. Coefficients on education dummies (from OLS regression)

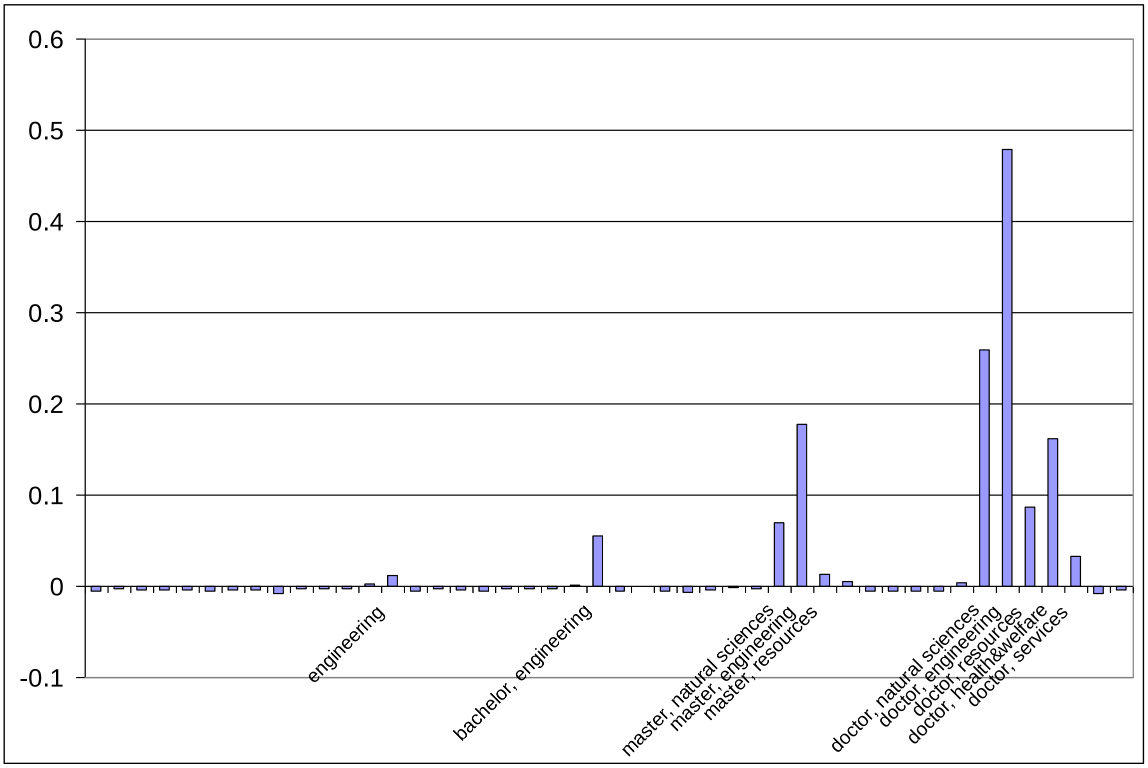

Figure 4. Number of new engineering students at each of the universities

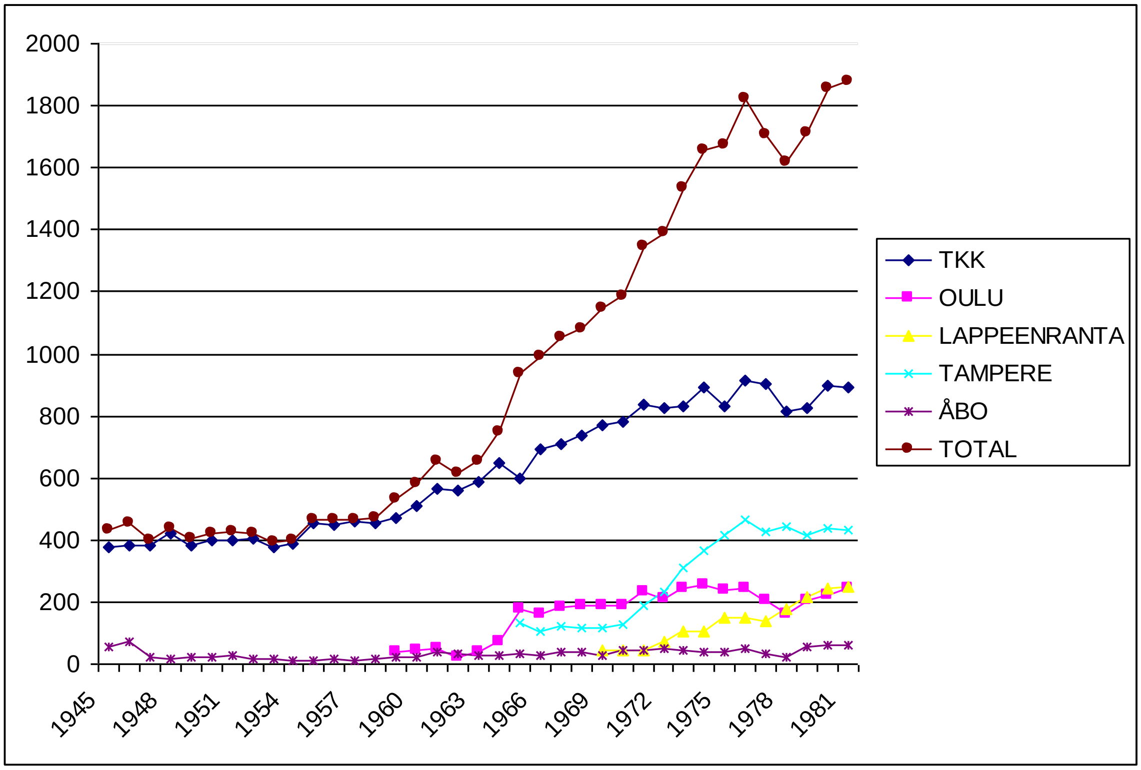

Table 2. Estimation results

Specification	OLS	IV	instrument
cohort dummies	0.110***	0.234***	-0.0026***
	0.007	0.038	0.00029
cohort + father's education	0.118***	0.302**	-0.0016***
	0.009	0.150	0.00061

Notes: Dependent variable is the sum of patents in the period 1988-1996. In both specifications, the control variables include gender, nationality, native tongue, and cohort dummies. Father's education is included as 45 dummies representing educational field-level combinations. The instrumental variable is the distance (in 100kms) to the nearest university offering engineering education.