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No. 5409

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Braunerhjelm and Bo Carlsson

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Discussion Paper No. 5409  
December 2005

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CEPR Discussion Paper No. 5409

December 2005

## **ABSTRACT**

### **Growth and Entrepreneurship: An Empirical Assessment\***

This paper suggests that the spillover of knowledge may not occur automatically as has typically been assumed in models of endogenous growth. Rather, a mechanism is required that serves as a conduit for the spillover and commercialization of knowledge from the source creating it to the firm actually commercializing the new ideas. In this paper, entrepreneurship is identified as one such mechanism facilitating the spillover of knowledge. Using a panel of entrepreneurship data for 18 countries, empirical evidence is found that in addition to measures of R&D and human capital, entrepreneurial activity also serves to promote economic growth.

JEL Classification: M13, O40 and R11

Keywords: entrepreneurship and growth

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\* Financial support is gratefully acknowledged from Marianne and Marcus Wallenberg's Foundation. Excellent research assistance has been provided by Benny Borgman, The Royal Institute of Technology.

Submitted 29 November 2005

## **1.Introduction**

The publication of Solow's (1956) seminal article triggered a major literature linking the traditional factors of production, capital and labor, to economic growth. With the development of the endogenous growth theory, knowledge was added to the traditional factors as explicitly explaining economic growth (Romer, 1986; Lucas, 1988). In contrast to the traditional factors of production, knowledge had a particularly potent impact on economic growth because of its propensity to spill over for use by third-party firms.

Public policy has responded to the endogenous growth theory by emphasizing investments in research and human capital. However, knowledge investments have proven sufficiently disappointing in generating economic growth. What has been termed as "the European Paradox", which reflects modest growth even with high levels of investment in human capital and research, has become a characteristic of many European countries (Figure 1). This suggests that the spillover of knowledge may not be as automatic as has been assumed in endogenous growth models (Acs et al, 2004). Rather, mechanisms may be needed to facilitate the spillover of knowledge.

The purpose of this paper is to suggest and empirically test one such mechanism that facilitates the spillover of knowledge, which should therefore generate additional economic growth – the startup of new firms. An important motivation for starting a new firm is to commercialize ideas that otherwise might not be commercialized in the context of an incumbent firm. Thus, entrepreneurship serves as a conduit for the spillover of knowledge, thereby contributing to economic growth.

In the second section of this paper the reasons why entrepreneurship should have a positive impact on economic growth are explained. In the third section an empirical model is specified linking entrepreneurship to economic growth. This model is then estimated using a time-series panel of country-specific observations in the fourth section. Finally, in the last section a summary and conclusions are provided. In particular the results suggest that entrepreneurial activity has a positive and systematic impact on economic growth.

### **Entrepreneurship as a missing link in economic growth**

Solow (1957) observed that the contributions of additional labor and capital could not explain increases in growth over time. After accounting for the contributions provided by increased labor and investment, he attributed that unexplained effect to technical progress (the “technical residual”). Notwithstanding the importance of Solow’s observation, the mechanisms that resulted in technical progress and knowledge accumulation were still unspecified.<sup>3</sup> That gap was bridged by the knowledge based – endogenous - growth theory developed in the late 1980s (Romer 1986, 1990; Lucas 1988).

In the endogenous growth models profit-maximizing firms produce knowledge (A) in one period, which is used as inputs in subsequent periods. Part of the production of new knowledge at the firm level cannot be appropriated by the firms themselves and spills over into an aggregate knowledge stock that becomes potentially accessible to other firms and agents within a country. At the same time knowledge production at the firm level is assumed to be characterized by (strongly) diminishing returns to scale. Thus,

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<sup>3</sup> See Rostow (1990) and Barro and Sala-i-Martin (1995) for a survey. See also Kaldor (1961) and Denison (1967).

knowledge is only partially excludable and all firms benefit from spillovers originating in aggregate knowledge investments,

$$A = \sum_{i=1}^n a_i = \sum_{i=1}^n l_{i,R} \quad (1)$$

where  $a_i$  is each individual firm's (i's) contribution to the knowledge stock, which is achieved by employing high-skilled research workers ( $l_{i,R}$ ). The combination of partial excludability and non-rivalry thus suggested an important role for technology in explaining growth.

In the knowledge-based model the channels through which knowledge is converted into growth is explained as general externality (Arrow 1962) that feeds into the production function of incumbent firms. Hence, whereas knowledge, or technology, was exogenous in the neoclassical growth models, the diffusion of knowledge is exogenous in the endogenous growth models.

As pointed out by Acs et al (2004) entrepreneurship is one mechanism that converts knowledge into growth. Building on Romer (1990) they elaborate a model where there are two methods of developing new products. As in the original model, incumbents undertake R&D by employing researchers ( $L_R$ ), which generate new knowledge. That constitutes the first mechanism to convert knowledge into growth. To the degree that new knowledge is not completely commercialized by incumbents, potential opportunities are created for entrepreneurs to start new firms in order to exploit knowledge that otherwise would not be commercialized. Such start-ups may serve as a

conduit for the spillover of knowledge from other firms, which constitute the second means by which knowledge is commercialized. Thus, entrepreneurship also influences the stock of knowledge (Acs et al, 2005) and, eventually, growth.

New knowledge developed in that way can be thought of as either new type of physical capital, blueprints/patents or “business models” that is used in the section of the economy producing final goods.<sup>4</sup> Specifically, new varieties of capital goods and new knowledge are produced as:

$$\dot{A} = \sigma_R L_R A + \sigma_E Z(L_E) A \quad (2)$$

where the  $\sigma : s$  are efficiency parameters in R&D carried out by incumbents ( $L_R$ ) and in knowledge-based entrepreneurship ( $L_E$ ), respectively. Knowledge is thus produced by labour employed in either R&D-labs or those engaged in entrepreneurial activities, while  $A$  is the stock of available knowledge at a given point in time. Entrepreneurial activity is assumed to be characterized by decreasing returns to scale ( $\gamma < 1$ ),

$$Z(L_E) = L_E^\gamma, \gamma < 1 \quad (3)$$

since entrepreneurial skill is unevenly distributed among the population. Hence, doubling the number of people engaged in entrepreneurial activities will not double the output of new knowledge and varieties. Rewriting equation 2 as

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<sup>4</sup> As e.g. Grossman and Helpman (1991) have shown, the new varieties of capital goods can just as well be thought of as new varieties of goods entering consumers’ utility functions directly.

$$\frac{\dot{A}}{A} = \sigma_R L_R + \sigma_E Z(L_E) \quad (4)$$

shows that the rate of technological progress is an increasing function in R&D, entrepreneurship and the efficiency in these two activities. As shown in the Appendix, combining equations 2 and 3 with a standard consumer optimization problem, and a production function for final goods, yields a well-defined balanced growth path. Thus, growth is a function of

$$g = f(A, R, E, \lambda) \quad (5)$$

where  $A$  is the existing stock of knowledge,  $R$  is expenditure on R&D,  $E$  is the level of entrepreneurship and  $\lambda$  refers to all other variables influencing growth (capital, labour, institutions, etc.).<sup>5</sup> One implication of the model is that in steady state growth is increasing in both R&D and entrepreneurial activities. An economy endowed with a labour force having high entrepreneurial skill enjoys higher growth rates. Apart from these model-specific properties, the model shares a number of characteristics with previous models (e.g., growth is decreasing in the discount factor but increasing with a larger labour force).

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<sup>5</sup> A certain level of entrepreneurial activities will always be profitable ( $L_E > 0$ ), while R & D may or may not be profitable, which depends in a non-trivial way on a range of parameters. The degree of entrepreneurial activity is, for instance, decreasing in the productivity of R&D as long as R&D is profitable. Thus, R&D and entrepreneurship are to some extent substitutes.

The model implies some (testable) predictions. First, at the country level growth is influenced by both R&D-spending and entrepreneurship. Second, countries with relatively low R&D-spending may still enjoy high growth due to a larger share of entrepreneurship. Depending on the range, R&D and entrepreneurship may however vary from being substitutes to complements. Note that the level of entrepreneurship may not necessarily be the best indicator of the level of entrepreneurial efforts in a country, as the distribution of entrepreneurial skill may differ across countries. This points to the importance of carefully assessing the policy conclusions derived from standard endogenous growth models (taxes and subsidies to influence R&D). These may not suffice to enhance the rate of growth.

### **Empirical Model and Measurement**

The model presented in the previous section is tested by incorporating a measure of entrepreneurship to the traditional factors that have been linked to economic growth. While empirical estimations of growth models have typically specified investments in new knowledge as exerting a direct impact on economic growth, in this approach we include knowledge transmitted through entrepreneurial activities by estimating the following model,

$$g_{i,t} = \alpha_1 + \alpha_2 A_{1,i,t} + \alpha_3 E_{i,t} + \alpha_4 \lambda_{i,t} + \varepsilon_{i,t} \quad (6)$$

where the subscripts  $i$  and  $t$  refer to countries and years, respectively. The dependent variable is economic growth while the variables explaining economic growth are investments in new knowledge (A), entrepreneurship (E), and a set of other variables

represented by the vector  $\lambda$ . We will implement different specifications for these variables, discussed below.

To control for country-specific factors, the model is estimated using fixed effects where a dummy variable is included for each country, implying that we control for all unobserved time-invariant differences among the countries.<sup>6</sup> The error term can be expected to violate the classic i.i.d. assumptions with regard to both autocorrelation and heteroscedasticity. Autocorrelation is induced in the model since lagged values of GDP are used to construct the dependent variable. Heteroscedasticity is also a reasonable assumption considering the use of country-level data. Therefore the model will be estimated using the feasible generalized least squares technique that account for heteroscedastic error structure between panels and panel-specific autocorrelation.

The dependent variable in equation 6 – growth – is specified in two alternative ways. The first specification refers to either the five-year moving average of growth in per capita GDP or year-to-year differences. The second is a five-year moving average of growth in GDP, i.e. not weighted by the population. The five-year moving averages are used to smooth out short-run cyclical variations.

The independent variables are specified in a similar way. Entrepreneurship (E) is approximated by the self-employment rate (excluding the agricultural sector). While this variable certainly may not be the ideal measure reflecting entrepreneurial activity, it is the only measure available for cross-country, multi-year analysis of entrepreneurship. Self-employment rates have emerged as the standard measure for reflecting entrepreneurial activity in cross-country studies (Parker, 2004). Because it facilitates knowledge

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<sup>6</sup> The dummy variable for one country is left out, i.e. the control country.

spillovers, entrepreneurship is expected to be positively associated with economic growth.

Knowledge is captured by two variables frequently used in the empirical growth literature. The first is total expenditures on research and development as a percentage of GDP (R&D). The second knowledge measure is the mean years of schooling in the population (over 25 years old), (EDU). These measures of knowledge are expected to influence growth positively.

In addition, we include a set of control variables that have been shown to influence growth in previous empirical work. First, the central variable influencing economic growth in the traditional Solow (1956) model is the capital-labor ratio (CAP/L). According to this model, the economic growth is positively related to capital intensity.

The next control variable we insert is the share of government expenditures in GDP (GEXP). To test for any evidence of structural change between the decade of the 1980s and 1990s, a dummy variable (D90) is included for the years in the 1990s along with the country level fixed effects which likewise are captured through dummies (not shown). The variables are precisely defined in Table 1. Summary statistics are provided in Table 2. A correlation matrix is shown in Table 3.

An important qualification is that the role of new and small firms has long been hypothesized and found to be influenced by economic growth (Mills and Schumann, 1985; Storey, 1991). Thus, entrepreneurial activity may be endogenous to economic growth. To control for the possible endogeneity of entrepreneurship and the simultaneous

relationship between economic growth and entrepreneurship, two-stage least squares estimation may be appropriate, where the first stage consists of estimating;

$$E_{i,t} = \beta_1 + \beta_2 A_{i,t} + \beta_3 AGE_{i,t} + \beta_4 UNEMP_{i,t} + \beta_5 \lambda_{i,t} + \varepsilon_{i,t} \quad (7)$$

and the variables are defined as above, with the exception of the instrument variables AGE and UNEMPL. AGE refers to the share of the population between 30 and 44. Studies using demographic variables have shown that individuals in this age cohort are most likely to undertake entrepreneurial activities (Storey, 1991). The other instrument is UNEMPL, defined as the unemployment rate.<sup>7</sup> In the second stage the estimated values of entrepreneurship ( $E_{i,t}$ ) from equation (7) are then inserted into equation (6). Because of the assumed heteroscedastic and autocorrelated structure of the error term the two-stage least squares estimation will report results using the HAC standard errors and covariance estimation technique.<sup>8</sup> This assures that the estimated standard errors are robust with respect both to arbitrary heteroscedasticity and arbitrary autocorrelation up to some specified lag (a three-year lag is the standard in the reported results).

Each of the two-stage least squares estimations also report the test statistic describing the probability that the reported F-value for the estimation is zero. The partial instrumental variables  $R^2$  is also reported and describes how much of the squared residuals in the first stage regression that are explained by the instrumental variables. This test together with the partial p-value – i.e., the probability that the joint F-value for

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<sup>7</sup> As Storey (1991) shows in his rich review of the literature, there have been a large number of studies linking unemployment to entrepreneurship.

<sup>8</sup> For a more detailed description of heteroscedastic and autocorrelation consistent variance (HAC), see for example Cushing and McGarvey (1999) or Wooldridge (2002).

the instrumental variables is zero – describes how good the instrumental variables are at explaining entrepreneurship. The Hansen's J statistic for valid instruments is also reported. The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and the reported value is the p-value stating the probability that the test statistic is zero, which would imply acceptance of the null hypothesis.

In the feasible generalized least squares estimation the Wald test statistic and its associated p-value are reported. Similarly, we also show the Davidson and MacKinnon (1993) test of exogeneity comparing a standard fixed effects model with its instrumental variable counterpart. The null hypothesis states that the standard fixed effects model yields consistent estimates, and the reported value is the p-value stating the probability that the test statistic is zero, which would imply acceptance of the null hypothesis.

### **Empirical Results**

Table 4 present the empirical results from estimating country-level GDP per capita growth rates. Both feasible general least square and two-stage least squares estimations are used. The first column shows the results using the entire sample period, 1981-1998, where no simultaneity is assumed to exist between economic growth and entrepreneurship.

As the positive and statistically significant coefficient of the entrepreneurship rate suggests, growth rates tend to be positively related to the extent of entrepreneurial activity. The coefficients of R&D and education are both statistically significant and

positive, indicating that, as the models of endogenous growth suggest, economic growth tends to respond positively to investments in research and human capital.

The coefficient of the control variables for government expenditures cannot be considered statistically significant. The negative and statistically significant coefficient of the capital-labor ratio suggests that capital intensity is negatively related to economic growth. The dummy variable for the 1990s is statistically significant. The Wald statistic and its associated p-value indicate that this specification does explain a significant part of the variation in growth.

As the value of the exogeneity tests of 0.00 suggests, the estimated results in Regression 1 may be influenced by the endogeneity of entrepreneurship to economic growth. Thus, in the second column the model is estimated using two-stage least squares. The coefficient of entrepreneurship not only remains positive and statistically significant but also actually becomes even stronger. While the coefficient of R&D cannot be considered statistically significant, the coefficient of education remains positive and statistically significant. The only other difference is that the coefficient of the capital-labor ratio is no longer statistically significant. To make sure that this result is not dependent on the lag length of the autocorrelation structure the regression has been tested with a lag length of one year up to six years without any significant changes in coefficients or significance.<sup>9</sup>

To test for the impact on the results of structural change that might have occurred in the 1990s, the model is estimated using only the years 1990-1998 in the third and fourth columns. The results remain basically unchanged. Again, entrepreneurship is

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<sup>9</sup> This has been done with all the two-stage least squares results, with the same conclusion.

found to be positively related to economic growth. Similarly, both R&D and education are positively related to economic growth, although the coefficient of R&D is only statistically significant in the two-stage estimation reported in the last column.

To examine the sensitivity of the results to the measure of the dependent variable economic growth used, an alternative measure of economic growth, the year-to-year change in the five-year moving average for growth in GDP per capita is substituted and the results are shown in Table 5. To correspond with the dependent variable, changes in the independent variables are used for the estimations presented in Table 5. The instruments for entrepreneurial activity presented in the previous section are extended to include the share of the population living in urban regions. The reason for this added instrument is that, when modeled in differences, the Hansen's J statistic rejected the null hypothesis for the basic set of variables but not the extended set.<sup>10</sup> Like the two original instruments the degree of the population living in urban regions have been shown to influence entrepreneurial effort in previous studies (Acs et al, 2005).

When comparing the results in table 4 and table 5 they remain basically unchanged, with the exception of the feasible least squares estimation for the 1990s in column three. The change in entrepreneurship rates is found to have a positive impact on the change in economic growth rates. In addition, the change in R&D is found to have a positive impact on the change in economic growth only in the sample period of the 1990s but not over the entire period.

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<sup>10</sup> Test statistics can be supplied upon request.

Finally, we also estimate the model with growth rates that are not weighted by the population as the dependent variable. As shown in Table 6, this does not significantly change the results. Thus, the results prove to be strikingly robust with respect to the impact of entrepreneurship on economic growth. The empirical evidence supports the view that entrepreneurial activity is conducive to economic growth.

## **Conclusions**

Investments in new economic knowledge have an especially potent impact in endogenous growth models because of the assumed externality, or what has become known as knowledge spillovers. This paper has suggested that such knowledge spillovers may not, in fact, be automatic, but rather depend on important spillover mechanisms, such as entrepreneurial activity. By taking ideas that otherwise might not be commercialized and introducing them in the market by creating a new firm, entrepreneurship is shown to positively influence growth. Implicitly this provides evidence for start-ups as a conduit for facilitating the spillover of knowledge.

Based on a cross-section time series panel of country-specific measure of entrepreneurship, the empirical results suggest that, in fact, entrepreneurial activity does make a positive contribution to economic growth. These results do not contest the importance, and even primacy, of knowledge investments in generating economic growth. As the endogenous growth theory predicts, the empirical evidence identifies knowledge as an important source of economic growth. However, those countries with a

greater degree of entrepreneurial activity exhibit systematically higher rates of economic growth. Thus, the empirical evidence is consistent with the view that entrepreneurship can serve as a conduit for the spillover of knowledge, and thereby is conducive to economic growth.

Future research may identify other types of mechanisms facilitating the spillover of knowledge and their impact on economic growth. Such spillover mechanisms may prove to be the missing link between investments in new knowledge and subsequent economic growth. The results also emphasize the importance of policies that not only promotes R&D-investments, but also takes the role of spillover mechanism into account, such as entrepreneurship.

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**Table 1. Definition of variables and data sources.**

Variable	Definition	Sources
GROWTH	Dependent variable. Five year moving average of gross domestic product growth per capita (at the price levels and PPPs of 1995).	OECD, Statistical Compendium via Internet 2003-10-09 (National Accounts vol1, and own calculations).
ENT	Non-agricultural self-employed, as percentage of total non-agricultural employment.	OECD, Statistical Compendium via Internet 2003-10-09 (Labour Market Statistics).
R&D	Gross domestic expenditure on R&D as percentage of GDP. All values in constant 1995 prices and PPP.	OECD, Statistical Compendium via Internet 2004-03-04 (Industry Science and Technology).
EDUCATION	Average years of schooling in the population over 25 years of age.	Penn World tables. Values only available every fourth year. Values inbetween are approximated by assuming constant change between the years.
GEXP	Government expenditures as percentage of GDP.	OECD, Statistical Compendium via Internet 2004-03-04 (Historical Statistics).
D.CAP/L	Capital stock, divided by employment. Values in yearly differences.	OECD, Statistical Compendium via Internet 2004-09-20 (OECD Economic Outlook Stat & Proj).
AGE	Share of population between 30 and 44 years of age.	Values only available for 1978, 1985, 1990, 1994 and 1998. Values inbetween are approximated by assuming constant change between the years.
UNEMP	Unemployment as percentage of total labour force.	OECD, Statistical Compendium via Internet 2004-09-20 (National Accounts and Historical Statistics).
URBAN	The share of the total population living in urban areas.	World Bank (2002), World Development Indicators CD-ROM. Washington: World Bank.
DUMMY-90	Time dummy that assumes the value one if year>1989 and zero otherwise.	Own calculations.

Table 2a. Statistics of variables

Country	GROWTH			GROWTH/CAPITA			ENT			R&D		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Australia	.022	.034	.044	.008	.020	.031	11.7	12.5	13.5	0.94	1.34	1.75
Austria	.015	.023	.036	.011	.020	.028	6.0	7.0	8.6	1.12	1.51	1.95
Belgium	.009	.021	.030	.006	.009	.028	11.6	13.0	14.1	1.46	1.65	1.89
Canada	.007	.027	.044	-.006	.016	.033	6.5	8.0	10.0	1.24	1.54	1.79
Denmark	.005	.019	.032	.003	.017	.031	6.3	7.1	8.5	1.05	1.53	2.05
Finland	-.013	.025	.051	-.018	.021	.048	6.0	8.7	10.3	1.17	1.94	2.89
France	.010	.021	.032	.006	.016	.027	8.0	9.2	10.2	1.92	2.23	2.40
Germany	.009	.022	.041	-.027	.006	.027	7.0	8.5	9.4	2.20	2.40	2.54
Ireland	.018	.053	.098	.012	.048	.087	9.7	12.4	14.0	0.64	0.93	1.31
Japan	.006	.028	.049	.004	.024	.045	9.4	11.4	13.6	2.29	2.74	2.95
Netherlands	.009	.026	.037	.003	.020	.030	7.7	8.7	10.0	1.79	1.98	2.20
New Zealand	-.001	.022	.041	-.008	.013	.027	8.9	15.0	16.8	0.90	0.94	0.99
Norway	.016	.032	.045	.011	.027	.039	4.8	6.1	7.8	1.35	1.56	1.74
Spain	.013	.028	.044	.008	.025	.042	16.1	17.8	18.8	0.47	0.71	0.89
Sweden	-.001	.020	.032	-.008	.016	.031	4.2	7.1	9.3	2.17	2.95	3.79
U.K.	.008	.025	.039	.005	.023	.037	8.0	11.0	12.4	1.79	2.10	2.38
U.S.	.020	.032	.044	.010	.022	.035	6.6	7.4	8.0	2.34	2.59	2.76

Table 2b. Statistics of variables, continued.

Country	GEXP			EDUCATION			D.CAP/L		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Australia	34.5	37.5	40.0	9.8	10.0	10.1	-.13	.16	.49
Austria	52.1	54.6	57.9	6.3	7.0	7.7	.24	.34	.47
Belgium	49.4	55.3	63.7	8.0	8.4	9.0	.11	.36	.64
Canada	41.2	46.8	53.3	9.7	10.1	10.7	-.10	.11	.72
Denmark	53.7	57.9	61.7	10.1	10.7	11.9	-1.80	3.24	7.71
Finland	42.3	51.8	64.4	9.0	9.5	10.1	-.58	.43	1.76
France	49.4	52.8	55.5	5.5	6.3	7.3	.08	.32	.51
Germany	44.0	47.5	50.3	8.3	8.6	9.1	-1.11	.14	.53
Ireland	31.9	44.8	54.5	7.0	7.8	8.4	-.48	.08	.43
Japan	30.5	33.7	38.6	7.6	8.6	9.9	-.04	.03	.16
Netherlands	45.3	53.8	59.9	7.8	8.2	8.8	-.07	.10	.41
New Zealand	36.1	39.5	45.2	10.4	11.4	11.9	-.35	.11	.58
Norway	43.5	50.3	56.3	6.9	7.5	8.3	-.97	.78	3.57
Spain	36.9	42.4	49.4	4.8	5.7	6.9	-.06	.16	.42
Sweden	56.9	62.9	73.0	8.4	9.4	10.0	-.13	3.21	11.18
U.K.	37.0	43.5	47.8	8.0	8.4	9.0	-.13	.09	.32
U.S.	33.6	35.9	38.0	10.7	11.7	12.2	-.08	.05	.27

Table 2c. Statistics of variables, continued.

Country	URBAN			AGE			UNEMP		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Australia	84.69	85.13	85.70	20.0	22.1	23.4	5.6	8.1	10.7
Austria	64.30	64.56	64.86	19.8	21.3	23.5	2.5	3.6	4.3
Belgium	95.52	96.41	97.18	19.0	21.3	23.2	8.7	11.4	13.2
Canada	75.80	76.47	76.93	20.2	23.3	25.7	7.5	9.6	11.9
Denmark	83.82	84.63	85.10	21.1	21.9	22.4	5.4	8.0	11.4
Finland	59.80	61.96	66.14	21.8	23.2	24.7	3.1	8.3	16.4
France	73.38	74.14	75.24	19.1	21.1	22.4	7.4	10.2	12.5
Germany	82.89	85.10	87.10	20.1	21.5	23.6	4.5	7.0	9.8
Ireland	55.50	56.96	58.56	16.5	18.5	19.9	7.8	13.7	17.0
Japan	76.30	77.35	78.52	19.9	22.5	24.1	2.1	2.7	4.1
Netherlands	88.42	88.72	89.24	20.8	22.8	24.1	4.3	8.3	11.9
New Zealand	83.48	84.73	86.50	18.9	21.0	22.4	3.5	6.4	10.3
Norway	70.66	72.34	74.78	18.8	20.9	22.1	2.0	3.9	6.0
Spain	73.08	75.21	77.16	18.2	19.6	21.7	13.8	19.1	23.8
Sweden	83.10	83.11	83.22	20.1	20.9	22.2	1.5	5.1	10.2
U.K.	88.82	89.06	89.38	19.3	20.5	21.6	6.1	9.2	11.8
U.S.	73.89	75.22	76.76	19.2	22.4	24.6	4.5	6.5	9.5

**Table 3a. Correlation matrix**

	ENT	R&D	EDUCATION	GEXP	D.CAP/L	AGE
R&D	-0.4263					
EDUCATION	-0.4252	0.3776				
GEXP	-0.3668	0.0521	-0.1012			
D.CAP/L	0.0987	0.3762	0.0221	-0.3979		
AGE	-0.2799	0.3363	0.4616	-0.1181	-0.0278	
UNEMP	0.6685	-0.4934	-0.3184	0.0970	-0.3467	-0.3063

**Table 3b. Correlation Matrix, all variables in differences**

	$\Delta$ ENT	$\Delta$ R&D	$\Delta$ EDUCATION	$\Delta$ GEXP	$\Delta$ CAP/L	$\Delta$ AGE	$\Delta$ UNEMP
$\Delta$ R&D	0.0278						
$\Delta$ EDUCATION	-0.1156	0.0361					
$\Delta$ GEXP	-0.0076	0.1683	0.0653				
$\Delta$ CAP/L	-0.1741	0.0094	0.3072	0.0780			
$\Delta$ AGE	0.1103	0.0063	-0.2652	0.1267	-0.4770		
$\Delta$ UNEMP	0.1930	0.0131	0.0690	0.5645	0.0223	0.0821	
$\Delta$ URBAN	0.0758	0.1198	0.1008	-0.1036	0.0315	-0.3700	0.0290

**Table 4: Results, FGLS and 2SLS regression techniques.**

Dependent variable: Five year moving average for growth in GDP per capita.

Instruments for ENT:AGE &amp; UNEMP

	Reg 1 1981 – 1998 FGLS	Reg 2 1981 – 1998 2SLS	Reg 3 1990 – 1998 FGLS	Reg 4 1990 – 1998 2SLS
ENT <sup>□</sup>	1.61*** (3.68)	11.36*** (4.97)	1.99*** (3.04)	11.31*** (2.90)
R&D <sup>□</sup>	.61** (2.84)	.00 (.00)	.44 (1.64)	1.87** (2.21)
EDU	.02* (2.09)	.02*** (3.92)	.00* (1.76)	.01*** (3.61)
GEXP <sup>□</sup>	.04 (.31)	-.51 (-1.09)	-.11 (-.72)	-.52 (-1.14)
D.CAP/L <sup>□</sup>	-16.11** (-2.26)	10.53 (.44)	-16.15** (-2.53)	-21.06 (-1.32)
DUMMY-90	-.01*** (-5.09)	-.02*** (-4.99)		
Constant	-.02 (-1.45)	-.24*** (-3.88)	-.03 (-1.19)	-.26*** (-2.88)
Wald	43.66		19.13	
P-value	.00		.00	
Exogeneity test	.00		.00	
P > F		.00		.00
Partial IV R <sup>2</sup>		.22		.30
Partial P-value		.00		.00
Valid Instruments		.81		.20
No. of obs.	268	268	127	127

*Note:* t-statistics in parentheses. \*, \*\* and \*\*\* denote the significance at the 10, 5 and 1 percent level, respectively. Estimates for country dummies are not presented but can be supplied upon request.

<sup>□</sup> Variable has been divided by 1 000.

**Table 5: Results, FGLS and 2SLS regression techniques.**

Dependent variable: First year differences in a five year moving average for growth in GDP per capita ( $\Delta$ GROWTH).

Instruments for  $\Delta$ ENT:  $\Delta$ AGE,  $\Delta$ URBAN &  $\Delta$ UNEMP

	Reg 1	Reg 2	Reg 3	Reg 4
	1981 – 1998	1981 – 1998	1990 – 1998	1990 – 1998
	FGLS	2SLS	FGLS	2SLS
$\Delta$ ENT <sup>□</sup>	1.32** (2.01)	14.26*** (2.30)	1.16 (1.07)	14.02*** (2.72)
$\Delta$ R&D <sup>□</sup>	-.00 (-.01)	.19 (.28)	-.72* (-1.74)	-1.25* (-1.81)
$\Delta$ EDU	.03*** (4.05)	.04*** (3.46)	.04*** (4.86)	.06*** (3.36)
$\Delta$ GEXP <sup>□</sup>	-.36* (-1.94)	-.33 (-1.20)	-.70*** (-2.64)	-.70 (-1.54)
$\Delta$ CAP/L <sup>□</sup>	-8.99*** (-2.66)	-27.84*** (-4.13)	-12.54*** (-5.00)	-17.24*** (-3.65)
DUMMY-90	-1.64** (-2.01)	.69 (.54)		
Constant	-.00 (-.82)	-.00 (-1.54)	-3.28*** (-3.47)	-.00 (.32)
Wald	29.81		54.33	
P-value	.00		.00	
Exogeneity test	.00		.00	
P > F		.00		.00
Partial IV R <sup>2</sup>		.06		.10
Partial P-value		.01		.00
Valid Instruments		.26		.65
No. of obs.	247	237	118	110

*Note:* t-statistics in parentheses. \*, \*\* and \*\*\* denote the significance at the 10, 5 and 1 percent level, respectively. Estimates for country dummies are not presented but can be supplied upon request.

<sup>□</sup> Variable has been divided by 1 000.

**Table 6: Results, FGLS and 2SLS regression techniques.**

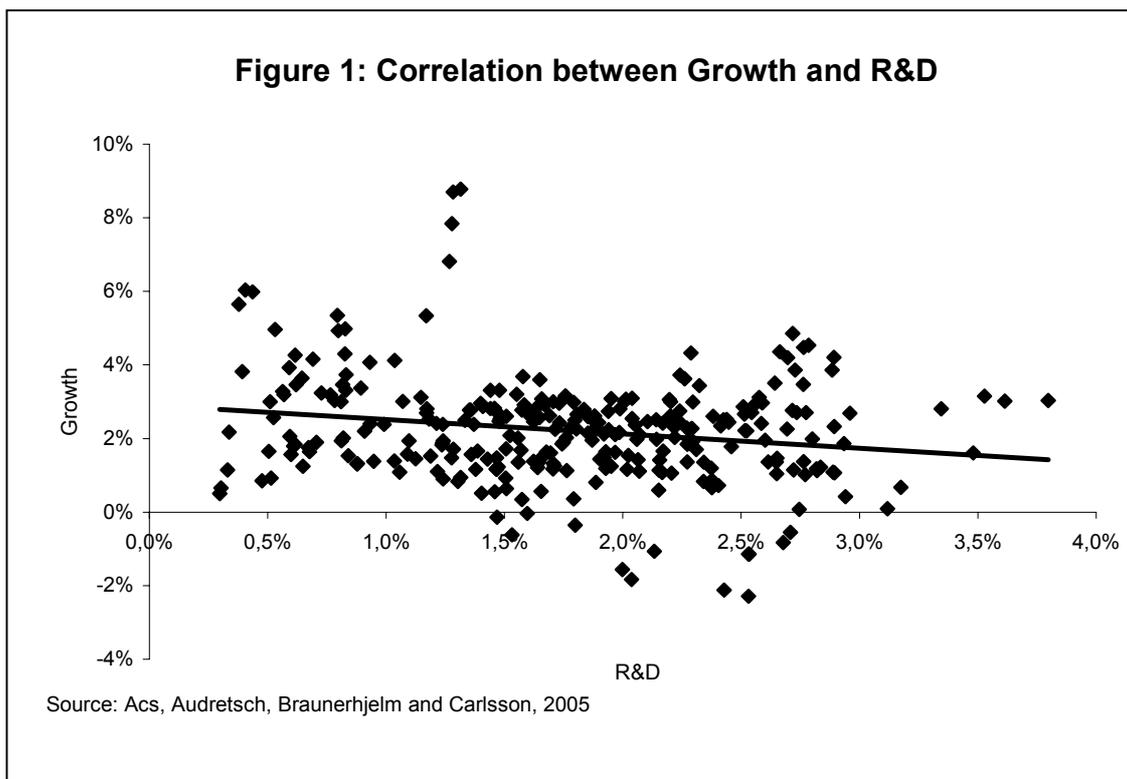
Dependent variable: Five year moving average for growth in GDP.

Instruments for ENT: AGE &amp; UNEMP

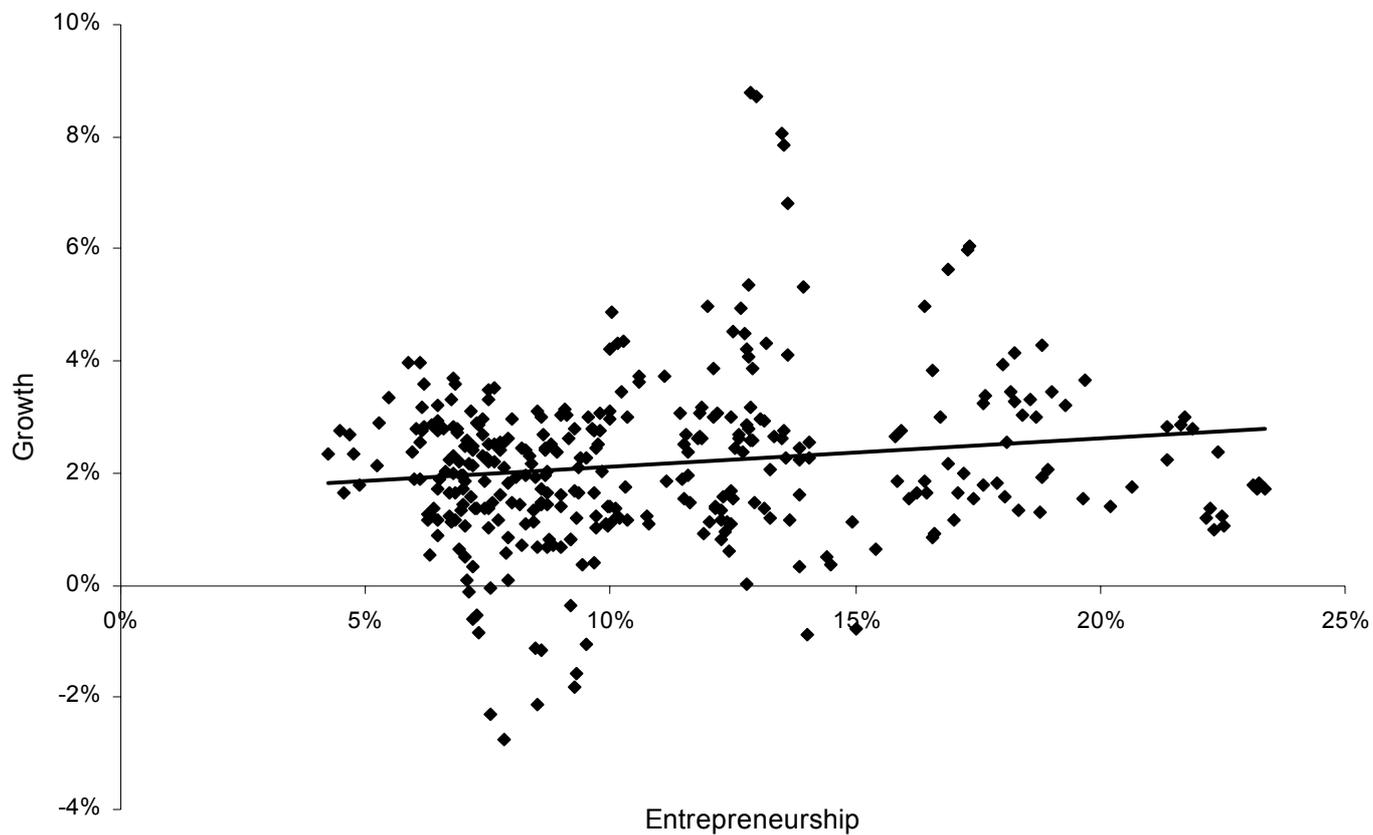
Dependent variable:	Reg 1 1981 – 1998	Reg 2 1981 – 1998	Reg 3 1990 – 1998	Reg 4 1990 – 1998
GROWTH	FGLS	2SLS	FGLS	2SLS
ENT <sup>□</sup>	1.51*** (3.62)	8.93*** (4.10)	.67 (1.29)	9.85** (2.53)
R&D <sup>□</sup>	.57*** (2.85)	.63 (.79)	.27 (1.14)	1.79** (2.10)
EDU <sup>□</sup>	2.19*** (2.94)	13.04*** (3.41)	.72 (.87)	14.23*** (3.57)
GEXP <sup>□</sup>	-.21* (-1.65)	-.89** (-2.06)	-.42*** (-2.86)	-.63 (-1.30)
D.CAP/L <sup>□</sup>	-17.95** (-2.52)	-13.45 (-.64)	-27.35*** (-4.42)	-17.37 (-1.03)
DUMMY-90	-.01*** (-5.06)	-.02*** (-4.25)		
Constant	-5.62 (-.44)	-.17*** (-2.78)	.03* (1.81)	-.23** (-2.51)
Wald	58.45		28.43	
P-value	.00		.00	
Exogeneity test	.00		.01	
P > F		.00		.00
Partial IV R <sup>2</sup>		.22		.30
Partial P-value		.00		.00
Valid Instruments		.51		.25
No. of obs.	268	268	127	127

*Note:* t-statistics in parentheses. \*, \*\* and \*\*\* denote the significance at the 10, 5 and 1 percent level, respectively. Estimates for country dummies are not presented but can be supplied upon request.

<sup>□</sup> Variable has been divided by 1 000.



**Figure 2: Correlation between Growth and Entrepreneurship**



Source: Acs, Audretsch, Braunerhjelm and Carlsson, 2005

## Appendix

Entrepreneurs and researchers engage in knowledge production in order to develop a new variety of a differentiated capital good that is used in final production. Different varieties of capital goods compete in a monopolistic competition fashion, meaning that they never become obsolete and earn an infinite stream of profits. As a side effect of their efforts, researchers and entrepreneurs produce new knowledge that will be publicly available for use in future capital good development. Equation (A1.1) describes the production of new knowledge, i.e. the evolution of the stock of knowledge, in relation to resources channelled into R&D ( $L_R$ ) and entrepreneurial activity ( $L_E$ ).

$$\frac{\dot{A}}{A} = \sigma_R L_R + \sigma_E Z(L_E) \quad (\text{A1.1})$$

Entrepreneurial activities takes the following form

$$Z(L_E) = L_E^\gamma, \gamma < 1 \quad (\text{A1.2})$$

Production of final goods ( $Y$ ) takes place using labor and the different varieties of capital-goods:

$$Y = L_m^\alpha \int_0^A x(i)^{1-\alpha} di \quad (\text{A1.3})$$

Given the symmetry of different varieties in (A1.3), demand for all varieties in equilibrium is symmetric, i.e.  $x_i = \bar{x}$  for all  $i \leq A$ . We therefore rewrite (A1.3) as

$$Y = L_m^\alpha A \bar{x}^{1-\alpha} \quad (\text{A1.4})$$

Assume that capital goods are produced with the same technology as final goods and that it takes  $\kappa$  units of capital goods to produce one unit of capital (See e.g. Chiang, 1992). Then it can be shown that

$$K = \kappa A \bar{x} \quad (\text{A1.5})$$

(A1.4) and (A1.5) then gives

$$Y = L_m^\alpha A^\alpha K^{1-\alpha} \kappa^{\alpha-1} \quad (\text{A1.6})$$

Labour market equilibrium implies that employment in R&D, entrepreneurship and final production equals total labor supply.

$$L = L_m + L_R + L_E \quad (\text{A1.7})$$

Finally, we assume that consumer preferences can be described by constant elasticity utility

$$U(C) = \frac{C^{1-\theta}}{1-\theta} \quad (\text{A1.8})$$

We form the Hamiltonian for the representative consumer

$$H_C = \frac{C^{1-\theta}}{1-\theta} + \lambda_A (\sigma_R L_R A + \sigma_E L_E^\gamma A) + \lambda_K (\kappa^{\alpha-1} A^\alpha K^{1-\alpha} (L - L_R - L_E) - C) \quad (\text{A1.9})$$

Maximizing (A1.9) gives the first-order conditions

$$\lambda_K = C^{-\theta} \rightarrow \frac{\dot{\lambda}_K}{\lambda_K} = -\theta \frac{\dot{C}}{C} \quad (\text{A1.10})$$

$$\Delta = \frac{\lambda_A \sigma_R A}{\lambda_K \alpha} (L - L_R - L_E) \quad (\text{A1.11})$$

$$\Delta = \frac{\lambda_A \gamma \sigma_E L_E^{\gamma-1} A}{\lambda_K \alpha} (L - L_R - L_E) \quad (\text{A1.12})$$

where  $\Delta = (\kappa^{\alpha-1} A^\alpha K^{1-\alpha} (L - L_R - L_E))$ . Combining (A1.11) and (A1.12) gives

$$L_E = \left( \frac{\sigma_R}{\gamma \sigma_E} \right)^{\frac{1}{\gamma-1}} \quad (\text{A1.13})$$

Thus, on a balanced growth path, where both R&D and entrepreneurship is profitable, the amount of resources engaged in entrepreneurial activities is independent of consumer preferences. As  $\gamma$  is less than 1, entry into entrepreneurship is increasing in  $\sigma_E$  and decreasing in  $\sigma_R$ . The maximization of (A1.9) also gives the equations of motion for the shadow prices of knowledge and capital as

$$\frac{\dot{\lambda}_K}{\lambda_K} = -(1-\alpha) K^{-1} \Delta + \rho \quad (\text{A1.14})$$

$$\frac{\dot{\lambda}_A}{\lambda_A} = -\sigma_R L_0 - \sigma_E L_E^\gamma + \sigma_R L_E + \rho \quad (\text{A1.15})$$

where  $\rho$  denotes the subjective discount rate (rate of time preferences). On the balanced growth, knowledge, final production and consumption all grow at the same rate, while

$\frac{\dot{\lambda}_K}{\lambda_K} = \frac{\dot{\lambda}_A}{\lambda_A}$ . Combining (A1.10) and (A1.15) gives

$$L_R = \frac{1}{\theta\sigma_R} \left( \sigma_R (L_0 - L_E) + (1 - \theta) \sigma_E L_E^\gamma - \rho \right) \quad (\text{A1.16})$$

Combining (A1.16) with (A1.13) and (A1.1) gives

$$g = \frac{1}{\theta} \left( (\sigma_R L - \rho) - \sigma_R^\gamma \gamma^{\gamma-1} \sigma_E^{\gamma-1} + \sigma_E^{\frac{2\gamma-1}{\gamma}} \gamma^{\frac{\gamma-1}{\gamma}} \sigma_R^{\frac{\gamma}{\gamma-1}} \right) \quad (\text{A1.17})$$

where it can be shown that the growth rate is increasing in  $L, \sigma_R$  and  $\sigma_E$  but decreasing in  $\rho$ . It should be noted that (A1.17) only applies when both R&D and entrepreneurship is profitable. The given specification implies that some entrepreneurial activity will always be profitable as long as  $A > 0$ . This does not apply to R&D activities however. If R&D is not sufficiently profitable (following from A1.16), then we can combine (A1.10), (A1.12), (A1.14) and (A1.15) to derive the reduced-form growth rate. The resulting expression however provides little new insights and is not shown here.