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Abstract In this paper we suggest that the spillover of knowledge may not occur automatically as typically assumed in models of endogenous growth. Rather, a mechanism is required to serve as a conduit for the spillover and commercialization of knowledge from the source creating it, to the firms 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 from 18 countries, we provide empirical evidence that, in addition to measures of Research & Development and human capital, entrepreneurial activity also serves to promote economic growth.

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1 Introduction

Solow's (1956) seminal article triggered a large 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 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 responded to the endogenous growth theory by emphasizing investments in research and human capital. However, knowledge investments have resulted in disappointing economic growth.

What is termed "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 (Audretsch and Keilbach 2008). This development 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.

The second section of this paper explains 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.

2 Entrepreneurship as a missing link in economic growth

Solow (1956) 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.[1] 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, knowledge is only partially excludable, and all firms benefit from spillovers originating in aggregate knowledge investments,

$$A = \sum_{i=1}^{n} a_i = \sum_{i=1}^{n} l_{i,R} \tag{1}$$

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 in which there are two methods of developing new products. As in the original model, incumbents undertake Research & Development (R&D) by employing researchers (L_R) who generate new knowledge. This process 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 (Audretsch 2007). Such start-ups may serve as a conduit for the spillover of knowledge from other firms, which constitute the second means

[1] See Rostow (1990) and Barro and Sala-i-Martin (1995) for a survey. See also Kaldor (1961) and Denison (1967).

by which knowledge is commercialized. Thus, entrepreneurship also influences the stock of knowledge (Acs et al. 2004, Agarwal et al. 2007) and, eventually, growth (Block and Zhou 2009, De Clerq et al. 2007).

New knowledge developed in this way can be thought of as either a new type of physical capital, blueprints/patents or "business models" that can be used in the section of the economy producing final goods.[2] Specifically, new varieties of capital goods and new knowledge are produced as:

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

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 ($\gamma \prec 1$),

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

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 Eq. 2 as

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

shows that the rate of technological progress is an increasing function in R&D, entrepreneurship and the efficiency of these two activities. As shown in the "Appendix", combining Eqs. 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

$$g = f(A, R, E, \lambda) \tag{5}$$

where A is the existing stock of knowledge, R is expenditure on R&D, E is the level of entrepreneurship and λ refers to all other variables influencing growth (capital, labour, institutions, etc.).[3] 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).

The model implies a number of (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 skills may differ across countries. This latter point illustrates the importance of carefully assessing the policy conclusions derived from standard endogenous growth models (taxes and subsidies to influence R&D) as these may not suffice to enhance the rate of growth.

3 Empirical model and measurement

The model presented in the previous section is tested here by incorporating a measure of entrepreneurship with 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,

[2] As, for example, 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.

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

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

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 λ. We will implement different specifications for these variables, as 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.[4] 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 gross domestic product (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 Eq. 6—growth—is specified in two alternative ways. The first specification refers to either the 5-year moving average of growth in per capita GDP or year-to-year differences. The second is a 5-year moving average of growth in GDP, i.e., not weighted by the population. The 5-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 a 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 spillovers, entrepreneurship is expected to be positively associated with economic growth (Audretsch and Keilbach 2007; Braunerhjelm et al. 2010).

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 >25 years of age (EDU). These measures of knowledge are expected to positively influence growth.

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, 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, we include a dummy variable (D90) 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 Schuman 1985; Storey 2003). 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, a two-stage least squares estimation may be appropriate, where the first stage consists of estimating:

$$E_{i,t} = \beta_1 + \beta_2 A_{1,i,t} + \beta_3 AGE_{i,t} + \beta_4 UNEMP_{i,t} + \beta_5 \lambda_{i,t} + \varepsilon_{i,t} \qquad (7)$$

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 years. Studies using demographic variables have shown that individuals in this age cohort are most likely to undertake entrepreneurial activities (Storey 2003). The other instrument is UNEMPL, defined as the unemployment rate.[5] In the

[4] The dummy variable for one country is left out, i.e., the control country.

[5] As Storey (2003) shows in his rich review of the literature, there have been a large number of studies linking unemployment to entrepreneurship.

Table 1 Definition of variables and data sources

Variable	Definition	Sources
GROWTH	Dependent variable. 5-year moving average of gross domestic product growth per capita [at the price levels and purchasing power parities (PPP) of 1995]	OECD [25], Statistical Compendium via Internet, accessed 9 Nov 2003 (National Accounts vol. 1, and own calculations)
ENT	Entrepreneurship (excluding agricultural sector): self-employed, as a percentage of total non-agricultural employment.	OECD [25], Statistical Compendium via Internet, accessed 9 Nov 2003 (Labour Market Statistics)
R&D	Gross domestic expenditure on Research & Development (R&D) as percentage of gross domestic product (GDP). All values in constant 1995 prices and PPP	OECD [25], Statistical Compendium via Internet, accessed 4 March 2004 (Industry Science and Technology)
EDU	Education: average years of schooling in the population >25 years of age	Penn World tables. Values only available every fourth year. Values in between are approximated by assuming constant change between the years
GEXP	Government expenditures as percentage of GDP	OECD [25], Statistical Compendium via Internet, accessed 4 March 2004 (Historical Statistics)
D.CAP/L	Capital stock, divided by employment. Values in yearly differences	OECD [25], Statistical Compendium via Internet, accessed 20 September 2004 (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 in between are approximated by assuming constant change between the years
UNEMP	Unemployment as percentage of total labour force	OECD [25], Statistical Compendium via Internet, accessed 20 September 2004 (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 1 if year >1989, and 0 otherwise	Own calculations

Table 2 Correlation matrix

Variable	ENT	R&D	EDU	GEXP	D.CAP/L	AGE
R&D	−0.4263					
EDU	−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 3 Correlation matrix (all variables in differences)

Variable	ΔENT	ΔR&D	ΔEDU	ΔGEXP	ΔCAP/L	ΔAGE	ΔUNEMP
ΔR&D	0.0278						
ΔEDU	−0.1156	0.0361					
ΔGEXP	−0.0076	0.1683	0.0653				
ΔCAP/L	−0.1741	0.0094	0.3072	0.0780			
ΔAGE	0.1103	0.0063	−0.2652	0.1267	−0.4770		
ΔUNEMP	0.1930	0.0131	0.0690	0.5645	0.0223	0.0821	
ΔURBAN	0.0758	0.1198	0.1008	−0.1036	0.0315	−0.3700	0.0290

second stage, the estimated values of entrepreneurship ($E_{i,t}$) from Eq. 7 are then inserted into Eq. 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.[6] This assures that the estimated standard errors are robust with respect both to arbitrary heteroscedasticity and arbitrary autocorrelation up to some specified lag (a 3-year lag is the standard in the results reported here).

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 is explained by the instrumental variables. This test together with the partial p value—i.e., the probability that the joint F value for 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.

4 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 (Fig. 1). 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 to be 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, 0.00, suggests, the estimated results in Regression 1 (Table 4) 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 to be 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 verify that this result is not dependent on the lag length of the autocorrelation structure, the regression was tested with a lag length of 1 year up to 6 years without any significant changes in the coefficients or significance.[7]

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 of Table 4. The results remain basically unchanged. Again, entrepreneurship

[6] For a more detailed description of heteroscedastic and autocorrelation consistent variance (HAC), see, for example, Cushing and McGarvey (1999) or Wooldridge (2002).

[7] This has been done with all the two-stage least squares results, with the same conclusion.

Table 4 Results of the feasible general least square (FGLS) and two-stage least squares (2SLS) regression techniques

	Regression 1 1981–1998 FGLS	Regression 2 1981–1998 2SLS	Regression 3 1990–1998 FGLS	Regression 4 1990–1998 2SLS
ENT[a]	1.61***	11.36***	1.99***	11.31***
	(3.68)	(4.97)	(3.04)	(2.90)
R&D[a]	0.61**	0.00	0.44	1.87**
	(2.84)	(0.00)	(1.64)	(2.21)
EDU	0.02*	0.02***	0.00*	0.01***
	(2.09)	(3.92)	(1.76)	(3.61)
GEXP[a]	0.04	−0.51	−0.11	−0.52
	(0.31)	(−1.09)	(−0.72)	(−1.14)
D.CAP/L[a]	−16.11**	10.53	−16.15**	−21.06
	(−2.26)	(0.44)	(−2.53)	(−1.32)
DUMMY-90	−0.01***	−0.02***		
	(−5.09)	(−4.99)		
Constant	−0.02	−0.24***	−0.03	−0.26***
	(−1.45)	(−3.88)	(−1.19)	(−2.88)
Wald	43.66		19.13	
p value	0.00		0.00	
Exogeneity test	0.00		0.00	
$p > F$		0.00		0.00
Partial instrumental variables (IV) R^2		0.22		0.30
Partial *p* value		0.00		0.00
Valid instruments		0.81		0.20
Number of observations	268	268	127	127

*, ** and *** denote significance at the 10, 5 and 1% level, respectively

Note: Dependent variable: 5-year moving average for growth in gross domestic product (GDP) per capita. Instruments for ENT: AGE and UNEMP. *t* statistics are given in parenthesis

Estimates for country dummies are not presented but can be supplied upon request

[a] Variable has been divided by 1,000

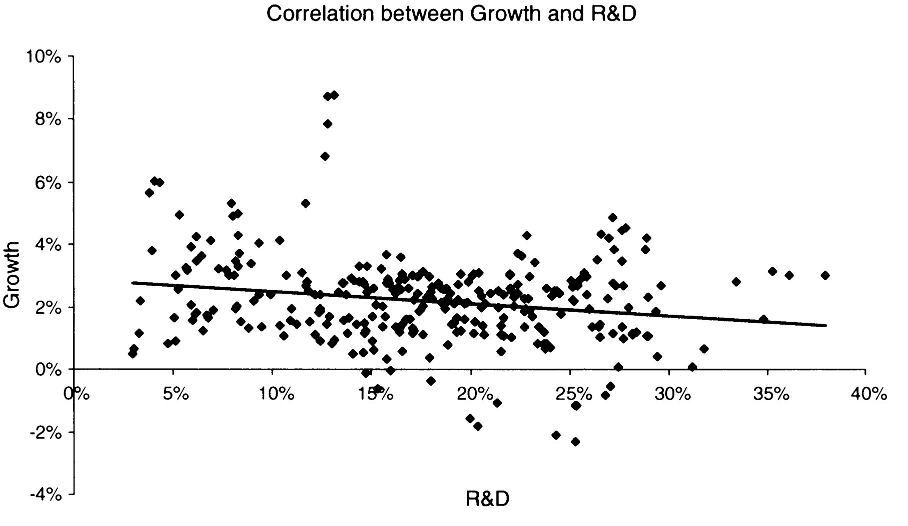

Fig. 1 Correlation between growth and Research and Development (R&D). *Source* Acs, Audretsch, Braunerhjelm and Carlsson, 2005

Table 5 Results of the FGLS and 2SLS regression techniques

	Regression 1 1981–1998 FGLS	Regression 2 1981–1998 2SLS	Regression 3 1990–1998 FGLS	Regression 4 1990–1998 2SLS
ΔENT[a]	1.32**	14.26***	1.16	14.02***
	(2.01)	(2.30)	(1.07)	(2.72)
ΔR&D[a]	−0.00	0.19	−0.72*	−1.25*
	(−0.01)	(0.28)	(−1.74)	(−1.81)
ΔEDU	0.03***	0.04***	0.04***	0.06***
	(4.05)	(3.46)	(4.86)	(3.36)
ΔGEXP[a]	−0.36*	−0.33	−0.70***	−0.70
	(−1.94)	(−1.20)	(−2.64)	(−1.54)
ΔCAP/L[a]	−8.99***	−27.84***	−12.54***	−17.24***
	(−2.66)	(−4.13)	(−5.00)	(−3.65)
DUMMY-90	−1.64**	0.69		
	(−2.01)	(0.54)		
Constant	−0.00	−0.00	−3.28***	−0.00
	(−0.82)	(−1.54)	(−3.47)	(0.32)
Wald	29.81		54.33	
p value	0.00		0.00	
Exogeneity test	0.00		0.00	
$P > F$		0.00		0.00
Partial IV R^2		0.06		0.10
Partial *p* value		0.01		0.00
Valid instruments		0.26		0.65
Number of observations	247	237	118	110

*, ** and *** denote the significance at the 10, 5 and 1% level, respectively

Note: Dependent variable: first year differences in a 5-year moving average for growth in GDP per capita (ΔGROWTH). Instruments for ΔENT: ΔAGE, ΔURBAN and ΔUNEMP. *t* statistics are given in parenthesis

Estimates for country dummies are not presented but can be supplied upon request

[a] Variable has been divided by 1,000

is 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 5-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 this table. 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 modelled in differences, the Hansen's *J* statistic rejected the null hypothesis for the basic set of variables but not the extended set.[8] As found for the two original instruments, the degree of population living in urban regions is shown to influence entrepreneurial effort, as reported in previous studies (Acs et al. 2005).

The results in Tables 4 and 5 remain basically unchanged, with the exception of the feasible least squares estimation for the 1990s in column 3. The

[8] Test statistics can be supplied upon request.

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.

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.

5 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 through the creation of a new firm, entrepreneurship is shown to positively influence growth (Fig. 2). Implicitly, this provides evidence for start-ups as a conduit for facilitating the spillover of knowledge.

Table 6 Results of the FGLS and 2SLS regression techniques

Dependent variable: GROWTH	Regression 1 1981–1998 FGLS	Regression 2 1981–1998 2SLS	Regression 3 1990–1998 FGLS	Regression 4 1990–1998 2SLS
ENT[a]	1.51***	8.93***	0.67	9.85**
	(3.62)	(4.10)	(1.29)	(2.53)
R&D[a]	0.57***	0.63	0.27	1.79**
	(2.85)	(0.79)	(1.14)	(2.10)
EDU[a]	2.19***	13.04***	0.72	14.23***
	(2.94)	(3.41)	(.87)	(3.57)
GEXP[a]	−0.21*	−0.89**	−0.42***	−0.63
	(−1.65)	(−2.06)	(−2.86)	(−1.30)
D.CAP/L[a]	−17.95**	−13.45	−27.35***	−17.37
	(−2.52)	(−0.64)	(−4.42)	(−1.03)
DUMMY-90	−0.01***	−0.02***		
	(−5.06)	(−4.25)		
Constant	−5.62	−0.17***	0.03*	−0.23**
	(−0.44)	(−2.78)	(1.81)	(−2.51)
Wald	58.45		28.43	
p value	0.00		0.00	
Exogeneity test	0.00		0.01	
$p > F$		0.00		0.00
Partial IV R^2		0.22		0.30
Partial p value		0.00		0.00
Valid instruments		0.51		0.25
Number of observations	2681	268	127	127

*, ** and *** denote the significance at the 10, 5 and 1% level, respectively

Note: Dependent variable: 5-year moving average for growth in GDP. Instruments for ENT: AGE and UNEMP. t statistics are given in parenthesis

Estimates for country dummies are not presented but can be supplied upon request

[a] Variable has been divided by 1,000

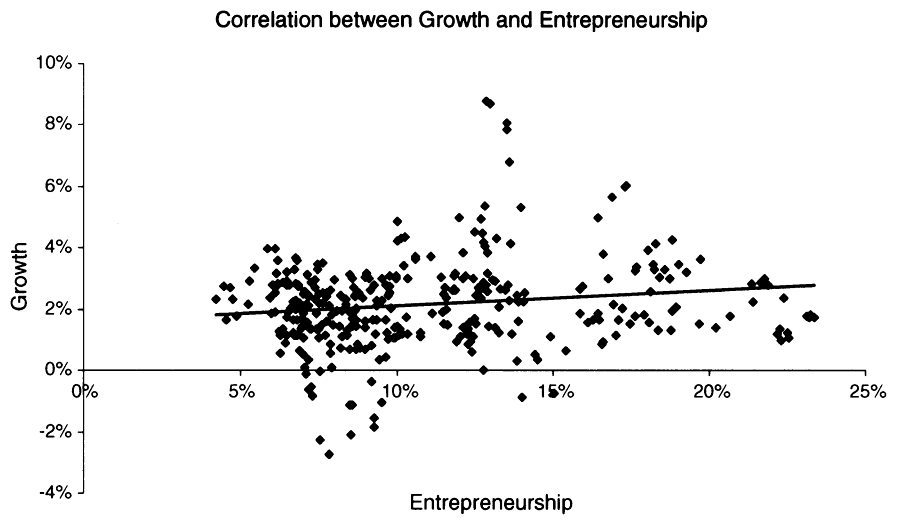

Fig. 2 Correlation between growth and entrepreneurship. *Source* Acs, Audretsch, Braunerhjelm and Carlsson, 2005

This study is based on a cross-section time-series panel of country-specific measure of entrepreneurship, and 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 is, thereby, 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 promote R&D investments, but also take the role of spillover mechanism into account, such as entrepreneurship.

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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).

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

Entrepreneurial activities take the following form

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

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

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

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

$$Y = L_m^\alpha A\bar{x}^{1-\alpha} \tag{A1.4}$$

Assume that capital goods are produced with the same technology as final goods and that it takes K units of capital goods to produce one unit of capital (see, for example, Chiang 1992). Then it can be shown that

$$K = \kappa A\bar{x} \tag{A1.5}$$

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

$$Y = L_m^\alpha A^\alpha K^{1-\alpha}\kappa^{\alpha-1} \tag{A1.6}$$

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

$$L = L_m + L_R + L_E \tag{A1.7}$$

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

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

We form the Hamiltonian for the representative consumer

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

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

$$\lambda_K = C^{-\theta} \rightarrow \frac{\dot{\lambda}_K}{\lambda_K} = -\theta\frac{\dot{C}}{C} \tag{A1.10}$$

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

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

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

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

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 γ is less than 1, entry into entrepreneurship is increasing in σ_E and decreasing in σ_R. The maximization of (A1.9) also gives the equations of motion for the shadow prices of knowledge and capital as

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

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

where ρ 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

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

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

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

where it can be shown that the growth rate is increasing in L, σ_R and σ_E. but decreasing in ρ. 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. However, the resulting expression provides few new insights and is not shown here.

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