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Basic, Applied and Experimental Knowledge and Productivity: Further Evidence

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Abstract

Analyzing a novel dataset we find significantly positive effects of basic, and applied and experimental knowledge stocks on domestic output and productivity for a panel of 10 OECD countries. This letter updates the work of, among others, Mansfield (1980), Griliches (1986) and Adams (1990), at an international setting.

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Key Words: Basic and Applied Research; TFP; Panel Co-integration.

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I. Introduction

R&D activities are grouped into three distinct types: basic research, applied research and experimental development. Frascati Manual (2002) defines basic research as “experimental or theoretical work undertaken primarily to acquire new knowledge… without any particular application or use in view (p.77)”. National Science Foundation defines it as “original investigation for the advancement of scientific knowledge…which do(es) not have immediate commercial objectives”. [1]

These distinctions imply that basic research is fundamental to knowledge breakthroughs. Economists and policy makers have long debated its role on productivity. Mansfield (1980, p. 863) succinctly puts it: “A hotly debated topic among economists, scientists, technologists and policymakers is: Does basic research, as contrasted with applied research and development, make a significant contribution to an industry’s or firm’s rate of technological innovation and productivity change?” Griliches (1986, p. 145) asks: “whether different types of R&D (basic vs. applied) are equally potent in generating productivity growth”. Whilst there is large empirical literature on R&D and productivity, studies linking basic research and applied and experimental development to productivity are rare.

Mansfield (1980), for the first time, tested this debate on US micro data and found significantly positive effects of basic and applied research on productivity growth. [2] Grilliches (1986) confirmed this with the proviso that his results are based on “level regressions” and may suffer from “biases” (p. 147). [3] Succeeding studies on this issue are

[1] Mansfield (1980, p. 863).
[2] “My results seem to be the first data on this subject, about which there is so much discussion (Mansfield, op. cit, p. 863)”.
[3] See also Link (1981).

sparse. Furthermore, a study that captures basic versus applied and experimental knowledge across all R&D performing institutions is lacking. This letter bridges this gap.

We measure types of knowledge across all institutions: academic, business, government and private non-profit sector. This is distinct from existing studies confined to particular institutions only. We also incorporate the measures of foreign knowledge stocks. Thus, we extend this topic to an international setting corresponding to the recent literature on international R&D spillover. We use non-stationary panel data econometrics which addresses the concerns of level regressions.

II. Specification

We estimate separate models for output and productivity. Following Mansfield (1980), Griliches (1986), Adams (1990) and Coe et al. (2009), an augmented Cob-Douglas production function that permits types of knowledge stocks as factor inputs is:

$$\log y_{it} = \alpha_i + \beta_k \log k_{it} + \beta_l \log l_{it} + \beta_h \log h_{it} + \beta_b \log s_{it}^{b} + \beta_a \log s_{it}^{ae} + \beta_f \log s_{it}^{f} + e_{it} \qquad (1)$$

where ‘i’ denotes countries (i=1,…,N) and ‘t’ is the time subscript. y_{it}, k_{it}, l_{it} and h_{it} respectively denote real output, physical capital stock, labor input and the stock of human capital. s_{it}^{b}, s_{it}^{ae} and s_{it}^{f} respectively denote the stocks of basic, applied and experimental, and foreign knowledge stocks. α_i are country-specific intercepts and βs are the respective point elasticities. We specify a productivity relationship:

$$\log tfp_{it} = \theta_i + \lambda_h \log h_{it} + \lambda_b \log s_{it}^{b} + \lambda_a \log s_{it}^{ae} + \lambda_f \log s_{it}^{f} + \varepsilon_{it} \qquad (2)$$

where tfp_{it} is domestic total factor productivity; θ_i and λs are parameters. Equation (2) is directly obtained from equation (1) by imposing constant returns to scale on capital and labor - a well-known specification in the literature. In estimations, we employ four types of foreign knowledge stocks, in turn (see below).

III. Data and Sample

We analyze an unbalanced panel of 10 OECD countries with 346 observations. [4] R&D expenditure data on basic research, applied research and experimental development are used to compute respective stocks - S_{it}^{b} and S_{it}^{ae} - through perpetual inventory method (PIM) at 15% and 10% depreciation rates. The foreign knowledge stocks are computed employing import ratios as weights. For example, the foreign basic knowledge stock for the i[th] country (s_{it}^{f-b}) is:

$$s_{it}^{f-b} = \sum_{j=1}^{N-i} (m_{ijt} / y_{jt}) * s_{jt}^{b} \qquad (4)$$

where, y_j is GDP of country j; m_{ij} is the capital goods imports of country i from country j; s_{jt}^{b} denotes the basic knowledge stock of j; (j=1,…, N-1) and N=10. Likewise, we compute foreign applied and experimental R&D capital stocks (s_{it}^{f-ae}), foreign business sector R&D capital stocks (s_{it}^{f-bus}) and foreign total R&D stock (s_{it}^{f-tl}) for each of the sample country. [5] k_{it} is computed from the fixed capital formation using PIM at 8% depreciation rate. All data are from OECD except the tfp_{it} and h_{it}, which respectively are from the European Commission and Bassanini and Scarpetta (2002).

IV. Empirical Results

The panel unit root tests proposed by Im, Pesaran and Shin (2003) and Fisher-ADF

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[4] Sample countries are: Australia (29), France (37), Iceland (36), Ireland (37), Italy (37), Norway (37), Portugal (36), Japan (32), Spain (28) and USA (37); where (.) indicates annual data points. The longest sample of 37 data points pertain to 1970-2006 and the shortest 28 data points spans for 1979-2006.

[5] s_{it}^{f} is usually computed from within the sample but, data permitting, we see no reason to restrict international knowledge spillovers to mere 9 countries as we have 10 sample countries. Therefore, due to data constraints, our measures of s_{it}^{f-b} and s_{it}^{f-ae} are based on 10 sample countries but s_{it}^{f-bus} and s_{it}^{f-tl} embrace 19 OECD countries.

(Maddala and WU, 1999) both confirm that our panel data are unit root processes. For brevity, results are available on request.

We apply Pedroni's (1999) group-t-statistic (parametric) for co-integration test as it (i) allows for heterogeneous co-integrating vectors across panel units, and (ii) is the most powerful test (Pedroni, 2004). The co-integrating parameters are estimated by FMOLS.

Table 1 reports the results for output. Griliches (1986) and Adams (1990) highlight the importance of the lag of s_{it}^{b}; we estimate up to its fourth order lag. Data limitations precluded us to venture beyond four lags. Three models, showing alternative use of s_{it}^{b} and s_{it}^{ae}, are reported under each lag. Column (i) would be identical across all lags because it excludes s_{it}^{b}.

Panel A reports the group-t-statistic which rejects non co-integration across all specifications. All models are co-integrated. Panel B reports the co-integrating parameters when s_{it}^{f-bus} is included. s_{it}^{b} and s_{it}^{ae} are positive and significant throughout. s_{it}^{ae} shows bigger point elasticity than that of s_{it}^{b} which peaks at L=2 suggesting that the former's effect is eleven times larger. This may seem dramatic but the parameter of s_{it}^{ae} are not unreasonably high. This simply implies that domestically s_{it}^{ae} appears more important than s_{it}^{b} vis-à-vis output, which is plausible. s_{it}^{f-bus} and l_{it} are also positive and significant. h_{it} is positive and significant in all models but one, [column (iii) under L=4]. k_{it} appears insignificant in column (iii) except for L=4, which is due to collinearity. We regress h_{it} on k_{it} and l_{it} and use the resulting residual series as orthogonalized human capital (h_{it}^{0}). This improves the significance of k_{it} without affecting qualitatively any other estimates (compare columns (iii) and (iv) across all lags).

Panel C reports the results from the other three measures of foreign knowledge stocks - s_{it}^{f-b}, s_{it}^{f-ae} and s_{it}^{f-tl}. Their uses, in turn, in equation (1) do not alter the qualitative nature of other parameters of panel B. s_{it}^{f-b} and s_{it}^{f-tl} are significant throughout.[6] s_{it}^{f-ae} appears mostly significant under L=1 and L=2 but largely insignificant at L=3 and L=4. The international spillover effects of s_{it}^{f-tl} are somewhat higher than those of s_{it}^{f-bus} which is plausible. Both s_{it}^{f-tl} and s_{it}^{f-bus} show larger effects than those of s_{it}^{f-b} and s_{it}^{f-ae}.

Table 2 reports TFP results. All models are co-integrated. Panel B shows that s_{it}^{b}, s_{it}^{ae} and s_{it}^{f-bus} are positive and significant throughout. With regard to TFP, the parameter of s_{it}^{ae} appear bigger than those of s_{it}^{b} in most cases, nonetheless, the difference is not as large as before. h_{it} appears insignificant in several specifications which is due to collinearity with s^{ae}. Column (iv), which uses the orthogonalized s^{ae} (i.e., s^{Oae}), resolves the problem.[7]

As before, s_{it}^{f-tl} is significant throughout (Panel C); the significance of s_{it}^{f-b} is more prominent at the higher lags of s_{it}^{b}. s_{it}^{f-ae} shows mixed results, consistently significant at the 4th lags of s^{b} only. The use of these alternative measures of s_{it}^{f}, in turn, does not change the qualitative nature of other parameters in panel B.

Results are robust to knowledge stocks calculated at 10% depreciation rate. The significance of s^{b} and s^{ae} remains to alternative weightings by bilateral R&D collaboration or FDI flows for computing s_{it}^{f}. Our findings of the positive contributions of s_{it}^{b} are consistent with Mansfield (1980), Griliches (1986) and Adams (1990) whereas we find more robust

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[6] The only exception is s_{it}^{f-b} in column (ii) under L=3.

[7] s_{t}^{ae} is regressed on h_{it} and the residual is s^{Oae}.

contribution of s_{it}^{ae} than Mansfield (op. cit). On international knowledge spillovers, our findings are consistent with the literature (e.g., Coe et al., 2009). [8]

V. Conclusion

Two types (basic vs. applied and experimental) of knowledge stocks are measured across all players in the R&D sector. Both contribute to domestic output and productivity. The international knowledge spillovers associated with basic R&D, total R&D and business sector R&D appear prominent but those with applied and experimental R&D appear less robust. Evidence is consistent that basic knowledge exerts its effects over a long period.

[8] Luintel and Khan (2004) argue that, with sufficiently long time series, one approach to modelling would be to check cross-country data poolability. This issue is not pursued here.

Table 1: Results for Output

$$\log y_{it} = \alpha_i + \beta_k \log k_{it} + \beta_l \log l_{it} + \beta_h \log h_{it} + \beta_b \log s_{it}^{b} + \beta_e \log s_{it}^{ae} + \beta_f \log s_{it}^{f} + e_{it}$$

Panel A: Panel co-integration tests

		L=1			L=2			L=3			L=4		
	(i)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)
Group-t-stats	-2.591[a]	-4.384[a]	-2.965[a]	-2.965	-4.173[a]	-3.749[a]	-3.749	-2.980[a]	-4.783[a]	-4.783[a]	-1.568[c]	-2.485[a]	-2.485
Panel B: FMOLS Results													
k_{it}	0.114[a] [6.543]	0.328[a] [2.665]	0.123 [0.814]	0.200[a] [3.329]	0.216[b] [1.998]	0.098 [0.243]	0.185[b] [2.428]	0.154[a] [2.733]	0.095 [1.344]	0.169[b] [2.215]	0.119[a] [3.815]	0.022[a] [2.801]	0.119[b] [2.519]
l_{it}	0.730[a] [12.83]	0.485[a] [12.15]	0.642[a] [14.02]	0.580[a] [10.53]	0.505[a] [12.03]	0.583[a] [14.65]	0.513[a] [10.84]	0.578[a] [12.89]	0.531[a] [14.46]	0.471[a] [11.02]	0.549[a] [12.75]	0.530[a] [13.46]	0.453[a] [10.82]
h_{it}	0.252[a] [2.985]	0.264[a] [6.465]	0.405[a] [4.899]	-	0.576[a] [7.202]	0.459[a] [4.765]	-	0.738[a] [5.833]	0.391[a] [3.044]	-	0.853[a] [5.585]	0.511 [1.532]	-
h_{it}^{o}	-	-	-	0.405[a] [4.899]	-	-	0.459[a] [4.765]	-	-	0.391[a] [3.044]	-	-	0.511 [1.532]
s_{it}^{ae}	0.134[a] [3.959]	-	0.158[a] [3.736]	0.158[a] [3.736]	-	0.170[a] [3.821]	0.170[a] [3.821]	-	0.150[a] [3.388]	0.150[a] [3.388]	-	0.111[a] [3.178]	0.111[a] [3.178]
s_{it}^{f-bus}	0.045[a] [4.727]	0.068[a] [8.482]	0.029[a] [4.778]	0.029[a] [4.778]	0.092[a] [9.876]	0.047[a] [6.400]	0.047[a] [6.400]	0.092[a] [8.912]	0.051[a] [4.902]	0.051[a] [4.902]	0.111[a] [10.21]	0.073[a] [6.335]	0.073[a] [6.335]
s_{it-1}^{b}	-	0.082[a] [4.143]	0.020[a] [2.707]	0.020[a] [2.707]	-	-	-	-	-	-	-	-	-
s_{it-2}^{b}	-	-	-	-	0.086[a] [4.592]	0.015[a] [3.494]	0.015[a] [3.494]	-	-	-	-	-	-
s_{it-3}^{b}	-	-	-	-	-	-	-	0.099[a] [5.314]	0.038[a] [4.027]	0.038[a] [4.027]	-	-	-
s_{it-4}^{b}	-	-	-	-	-	-	-	-	-	-	0.095[a] [5.117]	0.063[a] [4.669]	0.063[a] [4.669]
Panel C: Foreign Knowledge Stocks based on Basic (s_{it}^{f-b}), Applied and Experimental (s_{it}^{f-ae}) and total (s_{it}^{f-tl}) R&D.													
s_{it}^{f-b}	0.031[a] [4.384]	0.024[b] [2.218]	0.018[a] [4.011]	0.018[a] [4.011]	0.029[b] [2.125]	0.028[a] [3.478]	0.028[a] [3.478]	0.020 [1.017]	0.028[c] [1.910]	0.028[c] [1.910]	0.037[b] [2.291]	0.048[a] [3.189]	0.048[a] [3.189]
s_{it}^{f-ae}	0.020[a] [2.603]	0.017 [1.080]	0.008[a] [2.911]	0.008[a] [2.911]	0.019 [1.209]	0.013[b] [2.519]	0.013[b] [2.519]	0.005 [0.010]	0.009 [0.140]	0.009 [0.140]	0.025[c] [1.914]	0.029 [0.946]	0.029 [0.946]
s_{it}^{f-tl}	0.060[a] [6.162]	0.081[a] [8.607]	0.041[a] [5.765]	0.041[a] [5.765]	0.103[a] [9.590]	0.058[a] [7.004]	0.058[a] [7.004]	0.101[a] [8.797]	0.060[a] [5.480]	0.060[a] [5.480]	0.120[a] [10.56]	0.083[a] [7.155]	0.083[a] [7.155]

For details please refer notes to Table 2.

Table 2: Results for Total Factor Productivity

$$\log tfp_{it} = \theta_i + \lambda_h \log h_{it} + \lambda_b \log s_{it}^{b} + \lambda_a \log s_{it}^{ae} + \lambda_f \log s_{it}^{f} + \varepsilon_{it}.$$

Panel A: Co-integration Test

		L=1			L=2			L=3			L=4		
	(i)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)	(ii)	(iii)	(iv)
Group-t-stats	-3.021[a]	-1.905[b]	-2.929[a]	-2.929[a]	-2.674[a]	-3.497[a]	-4.723[a]	-2.674[a]	-3.497[a]	-3.497[a]	-1.920[b]	-2.969[a]	-2.969[a]

Panel B: FMOLS Results.

	(i)	L=1 (ii)	L=1 (iii)	L=1 (iv)	L=2 (ii)	L=2 (iii)	L=2 (iv)	L=3 (ii)	L=3 (iii)	L=3 (iv)	L=4 (ii)	L=4 (iii)	L=4 (iv)
h_{it}	0.423 [a] [2.430]	0.421 [1.445]	0.242 [0.000]	0.544 [a] [2.809]	0.435 [1.378]	0.273 [0.238]	0.704 [a] [3.060]	0.703 [c] [1.770]	0.325 [0.123]	0.759 [a] [3.040]	1.034 [b] [2.268]	0.331 [-0.356]	0.740 [a] [3.375]
s_{it}^{ae}	0.170 [a] [8.255]	-	0.069 [b] [2.186]	-	-	0.099 [a] [2.799]	-	-	0.100 [a] [3.278]	-	-	0.094 [a] [4.126]	-
s_{it}^{Oae}	-	-	-	0.069 [b] [2.186]	-	-	0.099 [a] [2.799]	-	-	0.100 [a] [3.278]	-	-	0.094 [a] [4.126]
s_{it}^{f-bus}	0.031 [a] [2.633]	0.037 [a] [4.798]	0.032 [a] [3.583]	0.032 [a] [3.583]	0.051 [a] [5.835]	0.041 [a] [4.185]	0.041 [a] [4.185]	0.076 [a] [6.618]	0.051 [a] [4.732]	0.051 [a] [4.732]	0.095 [a] [7.476]	0.059 [a] [5.589]	0.059 [a] [5.589]
s_{it-1}^{b}	-	0.149 [a] [7.504]	0.109 [a] [3.231]	0.109 [a] [3.231]	-	-	-	-	-	-	-	-	-
s_{it-2}^{b}	-	-	-	-	0.131 [a] [7.652]	0.070 [a] [3.550]	0.070 [a] [3.550]	-	-	-	-	-	-
s_{it-3}^{b}	-	-	-	-	-	-	-	0.072 [a] [7.605]	0.062 [a] [4.163]	0.062 [a] [4.163]	- -	-	-
s_{it-4}^{b}	-	-	-	-	-	-	-	-	-	-	0.007 [a] [7.383]	0.063 [a] [4.077]	0.063 [a] [4.077]

Panel C: Foreign Knowledge Stocks based on Basic (s_{it}^{f-b}), Applied and Experimental (s_{it}^{f-ae}) and total (s_{it}^{f-tl}) R&D.

	(i)	L=1 (ii)	L=1 (iii)	L=1 (iv)	L=2 (ii)	L=2 (iii)	L=2 (iv)	L=3 (ii)	L=3 (iii)	L=3 (iv)	L=4 (ii)	L=4 (iii)	L=4 (iv)
s_{it}^{f-b}	0.016 [b] [1.862]	0.126 [b] [2.347]	-0.004 [0.205]	-0.004 [0.205]	0.129 [b] [2.556]	0.015 [1.014]	0.015 [1.014]	0.014 [a] [3.507]	0.039 [a] [2.853]	0.039 [a] [2.853]	0.061 [a] [5.243]	0.053 [a] [4.407]	0.053 [a] [4.407]
s_{it}^{f-ae}	-0.001 [0.677]	-0.010 [1.30]	-0.014 [-0.58]	-0.014 [-0.58]	0.013 [c] [1.94]	-0.004 [-0.00]	-0.004 [-0.00]	0.011 [a] [3.045]	0.015 [1.072]	0.015 [1.072]	0.057 [a] [4.974]	0.031 [a] [2.717]	0.031 [a] [2.717]
s_{it}^{f-tl}	0.043 [a] [3.476]	0.038 [a] [5.087]	0.035 [a] [3.869]	0.035 [a] [3.869]	0.052 [a] [6.108]	0.049 [a] [4.538]	0.049 [a] [4.538]	0.081 [a] [7.030]	0.062 [a] [5.381]	0.062 [a] [5.381]	0.106 [a] [8.114]	0.071 [a] [6.563]	0.071 [a] [6.563]

Panel A contains group-t-statistic under the null of no co-integration. They are asymptotically standard normal left-sided tests. All measures of s_{it}^{f} pertain to 15% depreciation rate. Superscripts a, b and c respectively denote significance at 1%, 5% and 10%. [.] are t-ratios. Results are computed by RATS procedures. Section II contains variable definitions. L indicates lag length.

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