Modelling the Dynamics of Innovation

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Introduction

- Existing Literature

  - Knowledge based Models of Endogenous Growth (Romer, 1990; Jones, 1995 e.t.c)

  – Coe & Helpman (1995) & the related literature

  – Porter & Stern (2000)

The Usual Specification

- Allows separate effects of the domestic (A^d) and foreign (A^f) ideas stocks

$$\dot{A}_{i,t} = \alpha_i + \gamma_t + \lambda \dot{A}_{i,t-1} + \beta R_{i,t} + \phi A^d_{i,t} + \psi A^f_{i,t} + \varepsilon_{i,t} \quad (1)$$

- ϕ nets out the "*standing on the shoulders*" and "*fishing out*" effects
- If $\phi>0$, then SoS *effect* dominates the *fishing out effect.*
- ψ nets out the positive "*international knowledge spillovers*" *and the "raising the bar"* effect.
- A positive ψ implies that the beneficial externalities of A^f dominate the *raising the bar* effect.

MOTIVATION

- Specification (1) does not allow for cross-country heterogeneity in idea production,
- It Implies homogeneous slope parameters, adjustment dynamics and error variances across-countries,
- Implication: New-to-the-world Idea production appears equivalent across all the sample countries. This is unlikely to be the case.
- Our motivation is to address cross-country heterogeneity in idea production. Our specification is:

$$\begin{aligned}\dot{A}^{d}_{i,t} = {} & a_i + g_t + l_1 \dot{A}^{d}_{i,t-1} + l_2(\dot{A}^{d}_{i,t-1} * \bar{R}_i) + l_3(\dot{A}^{d}_{i,t-1} * \bar{A}^{d}_i) + b_1 R_{i,t} \\ & + f_1 A^{d}_{i,t} + y_1 A^{f}_{i,t} + b_2(R_{i,t} * \bar{R}_i) + b_3(R_{i,t} * \bar{A}^{d}_i) + f_2(A^{d}_{i,t} * \bar{R}_i) \\ & + f_3(A^{d}_{i,t} * \bar{A}^{d}_i) + y_2(A^{f}_{i,t} * \bar{R}_i) + y_3(A^{f}_{i,t} * \bar{A}^{d}_i) + x_{i,t}\end{aligned}$$

- A dynamic heterogeneous model - Pesaran & Smith (1995), Haque et al., (1999).
- Allows slope parameters (β, ϕ and Ψ) and adjustment dynamics (λ) of ideas production function to be different across countries.
- Cross country parameter heterogeneity is modelled as the linear functions of mean RSE and mean stock of knowledge

- If $\lambda_j=\beta_{j\neq1}=\phi_{j\neq1}=\psi_{j\neq1}=0$, then relationship is static
- If $\lambda_2=\lambda_3=0 \cup \beta_j=\phi_j=\psi_j \neq0$, relationship is heterogeneous in slope parameters & homogeneous in adjustment dynamics
- If $\lambda_1=\lambda_2\neq0 \cup \beta_j=\phi_j=\psi_j \neq0$, relationship is heterogeneous in slope parameters as well as in adjustment dynamics

- Data & Methods:
- Triadic Family Data

(EPO), (JPO) & (USPTO)

- Global nature, close correspondence to new ideas
- Problems of home bias & double counting
- Priority date based data (lag-structure)

- We allow cross-country heterogeneity in slope parameters and adjustment dynamics.
- We address endogeneity.

❑*Econometric methods*

- Static OLS / GLS
- Static IV
- AR(1) OLS/GLS
- Dynamic Heterogeneous panels: (OLS) & IV
- Dynamic heterogeneous panels: GMM single equation
- Dynamic heterogeneous panels: Augmented- GMM single equation
- Dynamic heterogeneous panels: GMM system
- Dynamic heterogeneous panels: Augmented-GMM system

❑Results are robust

Descriptive Statistics

Variable	Mean	SD
Patent Families	1559.9	2957.9
Patent Families / million pop	31.8	28.4
Researchers [thousands]	125.1	240.0
Domestic Patent Stock	6887.7	13915.2
Domestic Patent Stock / million pop	171.1	265.6
Foreign Patent Stock	877.9	1393.2
Regional Patent Stock	7161.2	6351.2
Share Language Patent Stock	2372.1	3649.7
GDP [billions]	886.0	1525.8
Population [millions]	40.8	59.3
Labour [millions]	18.9	29.6

Number of observation: 380
Patent data refer to OECD’s triadic patent families

Table 3: Panel Estimates

Specification: $\dot{A}^{d}_{i,t} = a_i + g_t + b\, R_{i,t} + f\, A^{d}_{i,t} + y\, A^{f}_{i,t} + e_{i,t}$ (1)

	OLS-Static Model-1.A	Model-1.B	IV- Static Model -1.A	Model-1.B	OLS-AR(1) Model-1.A	Model-1.B
Constant	1.540 (0.134)		1.168 (0.275)	0.773 (0.262)	0.795 (0.355)	
$\dot{A}_{t-1}$	-	-	-	-	0.357 (0.001)	
R_t	0.342 (0.004)		0.262 (0.074)	0.262 (0.074)	0.198 (0.036)	
A^d_t	0.658 (0.000)		0.668 (0.000)	0.668 (0.000)	0.379 (0.004)	
A^f_t	0.401 (0.000)		0.402 (0.000)	0.402 (0.000)	0.291 (0.000)	
Y_0	-	*	-	0.000 (0.120)	-	*
GDP78	-	*	-	0.041 (0.258)	-	*
Trend	-	-0.078 (0.000)	-	-0.081 (0.000)	-	-0.048 (0.001)
α_I	Sig		Sig	Sig	Sig	
γ_t	Sig		Sig	Sig	Sig	
R^2	0.994		NA	NA	0.995	
σ^2	0.023		0.022	0.022	0.020	
AR(-1)	0.007		0.005	0.005	0.110	
AR(-2)	0.467		0.367	0.367	0.629	
Observations	380		361	361	361	

Table 4: Dynamic Heterogeneous Panel Estimates (OLS)

Heterogeneous adjustment dynamics

Model- 3

	(A)	(B)
Constant	-0.969 *(0.074)*	-0.943 *(0.086)*
$\dot{A}^{d}_{t-1}$	1.453 *(0.000)*	1.453 *(0.000)*
$(\dot{A}^{d}_{i,t-1} * \bar{R}_i)$	-0.161 *(0.006)*	-0.161 *(0.006)*
$(\dot{A}^{d}_{i,t-1} * \bar{A}^{d}_{i})$	0.223 *(0.000)*	0.223 *(0.000)*
$A^{d}_{i,t}$	-	-
$A^{f}_{i,t}$	-	-
$(R_{i,t} * \bar{R}_i)$	0.135 *(0.007)*	0.135 *(0.007)*
$(R_{i,t} * \bar{A}^{d}_{i})$	-0.091 *(0.003)*	-0.091 *(0.003)*
$(A^{d}_{i,t} * \bar{R}_i)$	-	-
$A^{d}_{i,t} * \bar{A}^{d}_{i}$	-0.047 *(0.000)*	-0.047 *(0.000)*
$A^{f}_{i,t} * \bar{A}^{d}_{i}$	-0.021 *(0.000)*	-0.021 *(0.000)*
Observations	361	361
Y0	-	*
GDP78	-	*
Trend	-	-0.026 *(0.004)*
AR(2)	0.693	0.693

Table 5 : GMM Single Equation

Heterogeneous adjustment dynamics Model-5

	(A)	(B)
Constant	-0.854 *(0.119)*	-1.591 *(0.000)*
$\dot{A}^{d}{}_{t-1}$	1.516 *(0.000)*	1.518 *(0.000)*
$(\dot{A}^{d}{}_{i,t-1} * \overline{R}_i)$	-0.170 *(0.003)*	-0.171 (0.002)
$(\dot{A}^{d}{}_{i,t-1} * \overline{A}^{d}{}_i)$	0.236 *(0.000)*	0.236 *(0.000)*
$A^{d}_{i,t}$	-	-
$(R_{i,t} * \overline{R}_i)$	0.140 *(0.005)*	0.140 *(0.005)*
$(R_{i,t} * \overline{A}^{d}{}_i)$	-0.094 *(0.002)*	-0.094 *(0.002)*
$(A^{d}{}_{i,t} * \overline{R}_i)$	-	-
$(A^{d}{}_{i,t} * \overline{A}^{d}{}_i)$	-0.047 *(0.000)*	-0.047 *(0.000)*
$(A^{f}{}_{i,t} * \overline{R}_i)$	-	-
$(A^{f}{}_{i,t} * \overline{A}^{d}{}_i)$	-0.022 *(0.000)*	-0.022 *(0.000)*
Observations	361	361
Y0	-	-0.000 *(0.001)*
GDP78	-	0.067 *(0.108)*
Trend	-	-0.031 *(0.006)*
AR(2)	0.689	0.689
Sargan	1.00	1.00

Table 6: GMM System approach
Heterogeneous adjustment dynamics
Model –7

	(A)	(B)
Constant	-1.026 (*0.106)*	-1.569 *(0.000)*
$\dot{A}^{d}{}_{t-1}$	1.305 *(0.000)*	1.349 *(0.000)*
$(\dot{A}^{d}{}_{i,t-1} * \overline{R}_i)$	-0.134 *(0.013)*	-0.155 (*0.002)*
$(\dot{A}^{d}{}_{i,t-1} * \overline{A}^{d}{}_i)$	0.191 *(0.000)*	0.210 *(0.000)*
$A^{d}_{i,t}$	-	-
$(R_{i,t} * \overline{R}_i)$	0.135 *(0.039)*	0.162 *(0.007)*
$(R_{i,t} * \overline{A}^{d}{}_i)$	-0.085 *(0.043*)	-0.102 *(0.010)*
$(A^{d}{}_{i,t} * \overline{R}_i)$	-	
$(A^{d}{}_{i,t} * \overline{A}^{d}{}_i)$	-0.046 *(0.001)*	-0.048 *(0.001)*
$(A^{f}{}_{i,t} * \overline{A}^{d}{}_i)$	-0.023 *(0.000)*	-0.021 *(0.000)*
Observations	361	361
Y0	-	0.000 *(0.031)*
GDP78	-	0.037 *(0.346)*
Trend	-	-0.026 *(0.021)*
AR(2)	0.714	0.763
Sargan	1.000	1.000
Dif. Sargan	0.56	0.78

Table 7a: Dynamic Heterogeneous Panel Estimates of Ideas production function.

OLS: Model-3.B				
	λ	β(=R)	ϕ(=A^d)	ψ(=A^f)
Australia	0.334	0.359	0.514	0.230
Austria	0.563	0.115	0.780	0.349
Belgium	0.528	0.218	0.698	0.312
Canada	0.357	0.405	0.502	0.224
Denmark	0.444	0.188	0.653	0.292
Finland	0.401	0.230	0.608	0.272
France	0.691	0.540	0.748	0.334
Germany	0.825	0.809	1.079	0.482
Ireland	0.207	0.166	0.564	0.252
Italy	0.501	0.406	0.584	0.261
Japan	0.739	0.960	0.654	0.292
Netherlands	0.699	0.207	0.928	0.414
New-Zealand	0.185	0.190	0.546	0.244
Norway	0.252	0.251	0.537	0.240
Spain	0.084*	0.357	0.439*	0.196*
Sweden	0.640	0.227	0.815	0.364
Switzerland	0.836*	-0.170	1.628*	0.727*
UK	0.640	0.539	0.663	0.296
USA	0.739	1.105*	0.583	0.261
Mean	0.509	0.374	0.712	0.318
SD	0.228	0.308	0.272	0.121

Table 7c: Dymanic Heterogeneous panel Estimates of Ideas production function.

GMM- System: Model 7.B				
	λ	β(=R)	ϕ(=A^d)	ψ(=A^f)
Australia	0.306	0.338	0.503	0.220
Austria	0.526	0.017	0.735	0.321
Belgium	0.492	0.144	0.662	0.289
Canada	0.326	0.390	0.489	0.214
Denmark	0.414	0.119	0.633	0.277
Finland	0.372	0.175	0.593	0.259
France	0.638	0.456	0.653	0.286
Germany	0.763	0.595	0.814	0.356
Ireland	0.194	0.111	0.567	0.248
Italy	0.461	0.369	0.553	0.242
Japan	0.679	0.854	0.542	0.237
Netherlands	0.651	0.092	0.817	0.357
New-Zealand	0.173	0.142	0.549	0.240
Norway	0.233	0.213	0.534	0.234
Spain	0.071*	0.357	0.442*	0.193*
Sweden	0.595	0.132	0.741	0.324
Switzerland	0.782	-0.340*	1.249*	0.546*
UK	0.590	0.479	0.595	0.260
USA	0.677	0.998*	0.481	0.210
Mean	0.471	0.297	0.639	0.280
SD	0.211	0.303	0.183	0.080

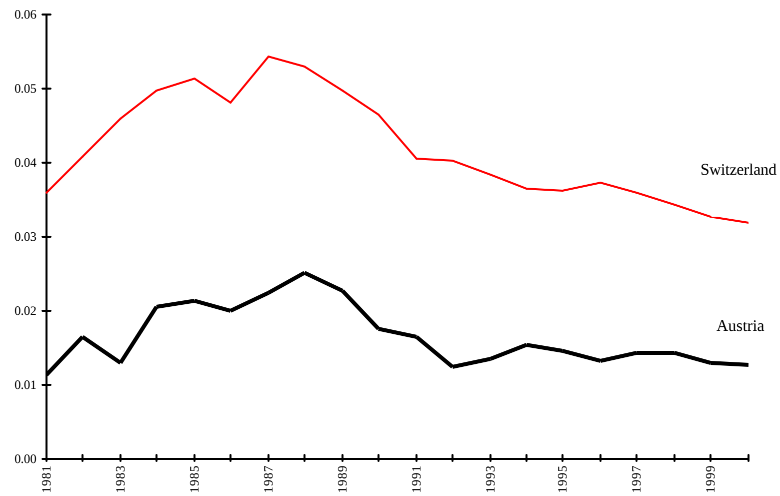
Findings in brief

- Production of new-to-the-world ideas is heterogeneous.
- Domestic and foreign ideas stocks exert significantly positive effects on the production of new-to-the world ideas
- Results suggest "standing on shoulders effect" and cross-boarder complementarities (positive international knowledge spillovers) in ideas production.
- Sharp contrast to the findings of Porter and Stern who report the existence of a *substantial "raising the bar effect"*.

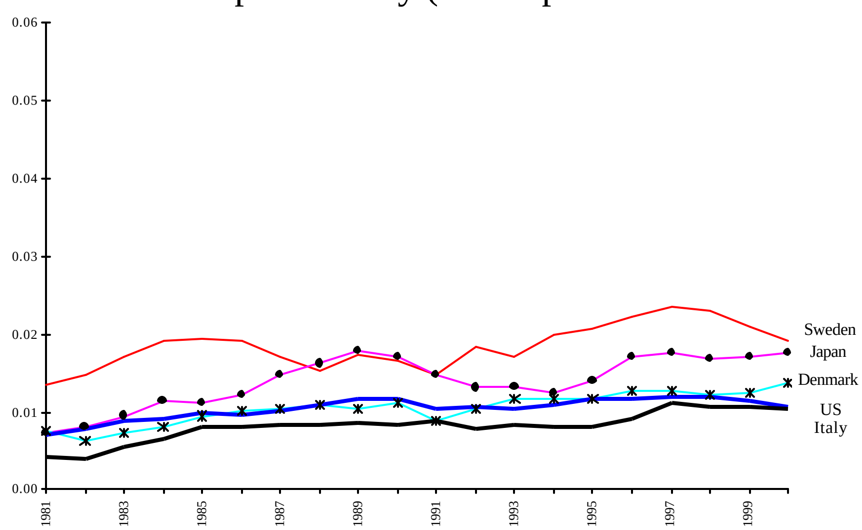
Finding in brief

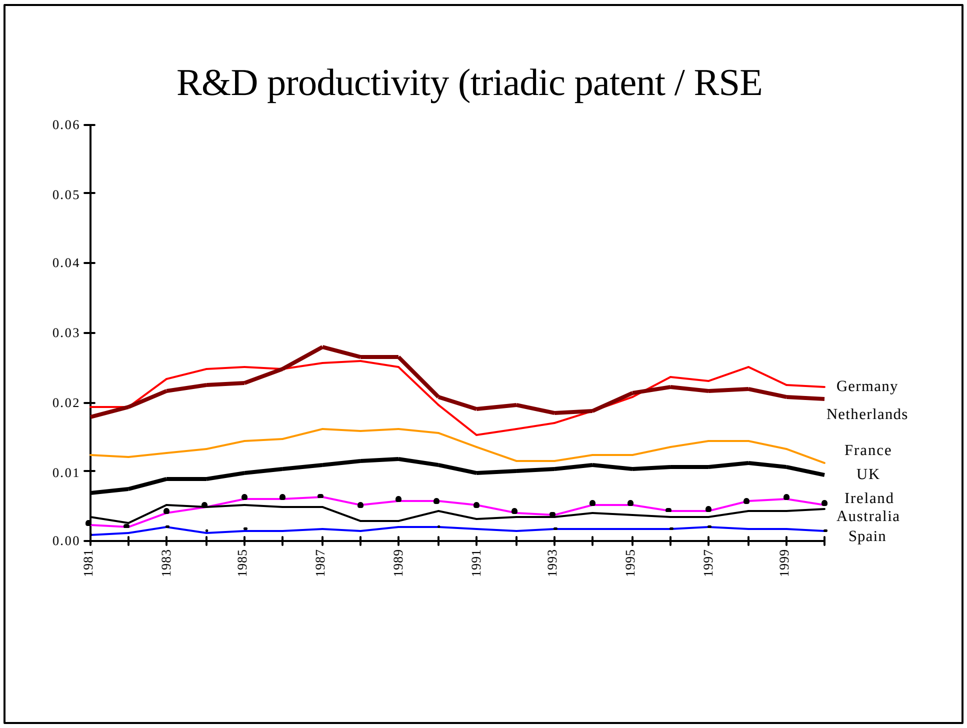
- We find the elasticity of idea production with respect to domestic knowledge stock to be less than unity for all but one country. P&S report the elasticity of unity
- All countries, <u>except USA</u>, exhibit the elasticity of RSE to be less than unity. This suggests duplicative R&D otherwise known as *stepping on toes effect*. For the USA the elasticity of researchers is unity.
- Swiss RSE show negative productivity, which is surprising. The negative point elasticity for Switzerland reflects her downward sloping productivity curve.

R&D productivity (triadic patent / RSE



R&D productivity (triadic patent / RSE




R&D productivity (triadic patent / RSE
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
Germany
Netherlands
France
UK
Ireland
Australia
Spain