The Final Frontier: The Effects of International Technology, R&D and Human Capital on Productive Inefficiency

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- Importance of productivity as an explanation of cross-country differences in income (Prescott, 1998; Hall & Jones, 1999)
- 4 explanations
  - 1 Institutional design (Prescott, 1998)
  - 2 Appropriate technology (Acemoglu & Zilibotti, 1999)
  - 3 Geography (Keller, 2000, 2001a,b)
  - 4 Absorptive Capacity (Eaton & Kortum, 1999; Griffiths, Redding & Van Reenan, 2000; Xu, 2000)
- Technical adoption depends on human capital (Abromovitz, 1986; Cohen & Levinthal, 1989)
- Innovation improves absorption of foreign technology (Fagerberg, 1988; Verspagen, 1991)

- Panel of 9 manufacturing industries in 12 OECD countries from 1973 to 1992
- SFA rather than a 2-stage productivity regression
- Overview
  - Model of Production & Data
  - Results
  - Robustness
  - Conclusions

$$y_{ijt} = \beta_0 + \beta_1 k_{ijt} + \beta_2 l_{ijt} + \beta_3 h_{jt} + \beta_4 r_{jt} + \beta_5 d_j - \nu_{ijt} + \upsilon_{ijt}$$

- C-D production function (in logged form)
- *y* is output
- *k* is the capital stock
- *l* is effective labour supply (number of workers adjusted for average hours per week)
- Data taken from the OECD ISDB database
- Deflated to 1985 international prices and converted to US $ at PPP exchange rates.
- Hours worked data from OECD and O'Mahony (1999)

$$y_{ijt} = \beta_0 + \beta_1 k_{ijt} + \beta_2 l_{ijt} + \beta_3 h_{jt} + \beta_4 r_{jt} + \beta_5 d_j - \nu_{ijt} + \upsilon_{ijt}$$

- *h* is stock of human capital
- Average years of schooling de la Fuente & Domenech (2000)
- Allow for possible complementarity between H and K, H is included as a separate term
- Recognises possible dual role of human capital on production

$$y_{ijt} = \beta_0 + \beta_1 k_{ijt} + \beta_2 l_{ijt} + \beta_3 h_{jt} + \beta_4 r_{jt} + \beta_5 d_j - \nu_{ijt} + \upsilon_{ijt}$$

- *r* is total stock of knowledge in industry *j*
- Knowledge is global
- Consistent with modern theories of economic growth
- Data from OECD EBRD
- Stock of R&D in country *i* calculated using perpetual inventory method

$$R_{ijt} = (1 - \Delta) R_{ijt-1} + RD_{ijt-1}$$

$$R_{ij0} = \frac{RD_{ij}}{(g^{RD} + \Delta)}$$

- How should we measure the stock of industry knowledge?
- 2 types of measure might be used from the previous literature
- Stock of accessible knowledge (Coe & Helpman, 1995; Coe et al, 1997; Keller, 2000, 2001a,b)
- Stock of accessible in foreign technology in country *i* equals the stock of R&D in country *a* weighted by the level of trade between *i* and *a*, plus stock of R&D in country *b* weighted by the level of trade between *i* and *b*…..
- Assumes the technical frontier differs for each country according to the level of trade
- Growth models: knowledge is global

- Simplified if 1 country determines the stock of industry knowledge
- Used in measures of relative productivity (Griffiths et al., 2000; Kneller, 2002)
- Assumes this country solely defines the technical frontier
- Technical progress is described by this one country
- SFA determines shape of the frontier
- Stock of knowledge equals sum of R&D stock in France, Germany, Japan, UK & US
- Account for close to 90% of R&D stock in the 12 countries in 1990
- Kneller (2002) an absorptive capacity effect but no frontier effect for remaining countries

$$y_{ijt} = \beta_0 + \beta_1 k_{ijt} + \beta_2 l_{ijt} + \beta_3 h_{jt} + \beta_4 r_{jt} + \beta_5 d_j - \nu_{ijt} + \upsilon_{ijt}$$

- d_j industry dummies to capture fixed industry factors
- *v* economic efficiency
- *u* measurement error, or effects not captured by the model
- Allows countries to operate inside the technical frontier
- Efficiency is obtained from the truncated normal $N(\mu_{it}, \sigma^2)$ – *Battese & Coelli (1995)*

$$\mu_{ijt} = \delta_0 + \delta_1 r\&d_{ijt} + \delta_{20} h_{ijt} + \sum_{j=1}^{8} \delta_{2j} h_{ijt} ind_{j \neq 0} + \sum_{i=1}^{11} \delta_{3i} country_{i \neq 0}$$

- Inefficiency depends on
  - – level of investment in R&D
  - – level of human capital (allowed to vary across industries)
  - – country specific fixed effects - capture unobservable fixed factors
- Expect negative coefficients (they reduce distance from the frontier)

Table 1 Results

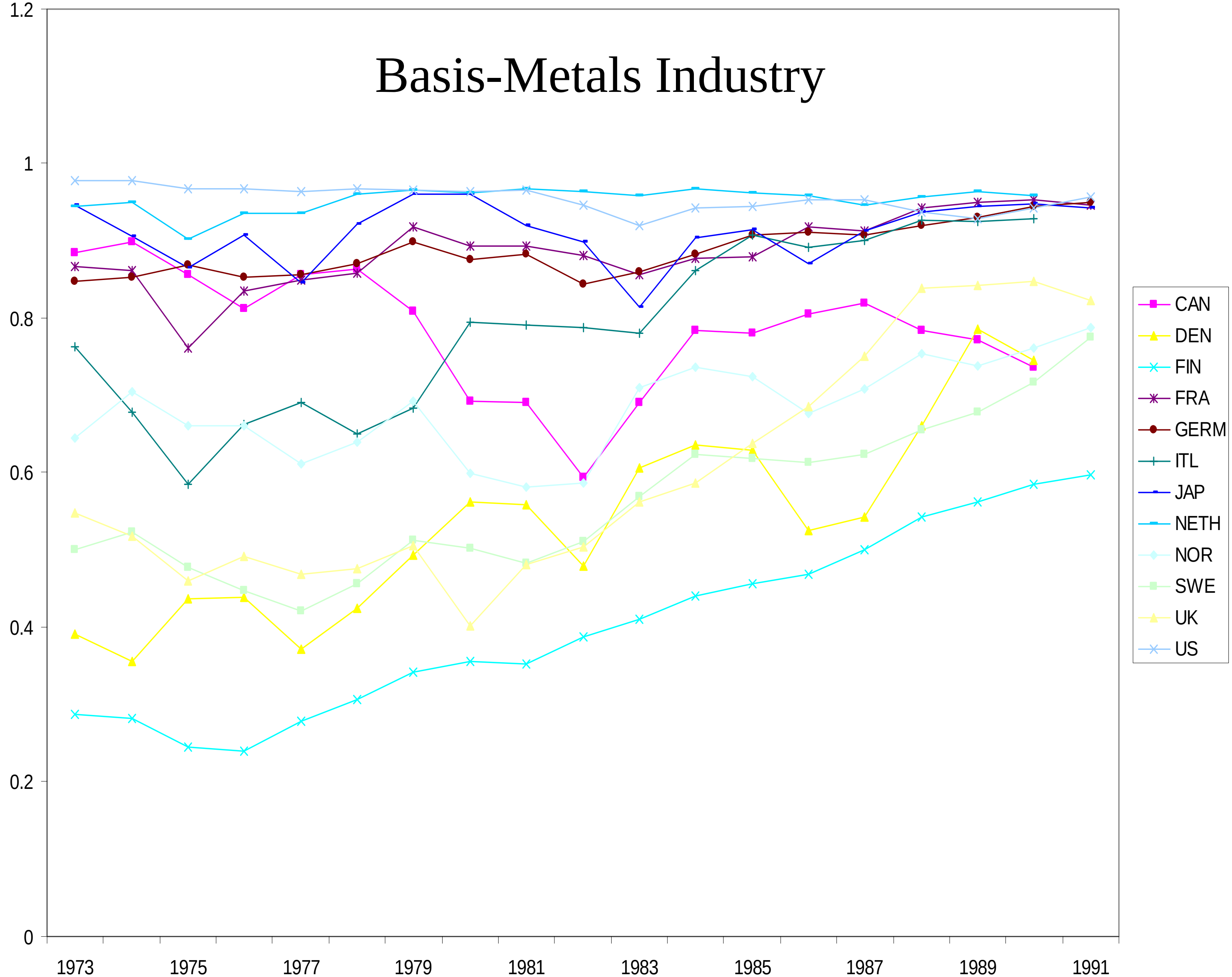
Number of observations: 1731, Time-periods: 19

Model No.	**(1)***			**(2)**		
	Coef.	*s.e.*	*t*	*Coef.*	*s.e.*	*t*
			Production Function			
n	0.708	0.014	49.9	0.722	0.019	40.0
k	0.301	0.013	23.2	0.301	0.017	17.6
$\bar{r}_5$	0.126	0.011	11.1	0.080	0.011	7.6
h	0.226	0.043	5.2	-0.238	0.085	2.8
			Inefficiency Effects			
h	-1.170	0.406	2.9	-1.983	0.353	5.6
$r\&d$	-0.035	0.014	2.5	-0.010	0.011	0.9
$CHE \times h$	0.080	0.023	3.501	-0.204	0.095	2.2
$FOD \times h$	-0.079	0.025	-3.225	0.050	0.063	0.8
$MEQ \times h$	-0.061	0.030	-2.008	-0.597	0.189	3.2
$MNM \times h$	-0.054	0.027	-2.013	0.458	0.078	5.9
$MOT \times h$	-0.193	0.032	-6.062	-0.271	0.103	2.6
$PAP \times h$	0.010	0.025	0.415	0.370	0.114	3.2
$TEX \times h$	-0.010	0.027	-0.360	0.179	0.101	1.8
$WOD \times h$	-0.193	0.037	-5.214	0.149	0.088	1.7
σ^2	0.093	0.005	19.8	0.064	0.003	19.3
γ	0.863	0.012	69.3	0.898	0.021	41.9
Log likelihood function			379.33			236.71
LR test of the one-sided error			1237.2			1373.5

* *a* Model 1 includes industry dummies within the production function

Table 3: Mean Efficiency Levels and Standard Deviation, by country and industry.

Country		*Industry* BMI	CHE	FOD	MEQ	MNM	MOT	PAP	TEX	WOD	*Unwtd. ALL*	*Wtd. ALL*
CAN	*Mean*	0.785	0.583	0.865	0.925	0.881	0.884	0.737	0.868	0.861	*0.818*	*0.828*
	s.d.	0.079	0.027	0.040	0.014	0.064	0.039	0.048	0.040	0.051	*0.115*	*0.036*
DEN	*Mean*	0.536	0.602	0.655	0.711	0.674	0.893	0.698	0.668	0.705	*0.684*	*0.681*
	s.d.	0.125	0.059	0.055	0.056	0.065	0.045	0.063	0.074	0.045	*0.112*	*0.058*
FIN	*Mean*	0.402	0.601	0.623	0.638	0.624	0.690	0.636		0.759	*0.622*	*0.629*
	s.d.	0.117	0.058	0.018	0.106	0.064	0.120	0.066		0.047	*0.125*	*0.075*
FRA	*Mean*	0.887	0.950	0.943	0.948	0.946	0.958	0.943	0.954	0.936	*0.938*	*0.944*
	s.d.	0.047	0.011	0.010	0.012	0.012	0.001	0.008	0.008	0.017	*0.028*	*0.013*
GERM	*Mean*	0.887	0.934	0.901	0.947	0.922	0.948	0.874	0.876	0.947	*0.915*	*0.927*
	s.d.	0.033	0.010	0.012	0.005	0.016	0.013	0.018	0.041	0.012	*0.036*	*0.012*
ITL	*Mean*	0.789	0.747	0.915	0.887	0.894		0.864	0.906		*0.859*	*0.871*
	s.d.	0.111	0.103	0.049	0.061	0.046		0.067	0.056		*0.094*	*0.065*
JAP	*Mean*	0.912	0.577	0.842	0.685	0.634	0.781	0.299	0.314	0.240	*0.630*	*0.692*
	s.d.	0.039	0.064	0.087	0.144	0.054	0.053	0.015	0.044		*0.225*	*0.102*
NETH	*Mean*	0.953		0.758				0.920	0.900		*0.882*	*0.855*
	s.d.	0.016		0.051				0.011	0.044		*0.083*	*0.032*
NOR	*Mean*	0.683	0.325	0.532	0.464	0.393	0.683		0.499	0.693	*0.544*	*0.534*
	s.d.	0.061	0.041	0.060		0.037	0.120		0.018	0.069	*0.153*	*0.055*
SWE	*Mean*	0.564	0.628	0.570	0.692	0.766		0.586	0.706	0.789	*0.648*	*0.657*
	s.d.	0.099	0.061	0.022	0.053			0.039	0.029	0.061	*0.096*	*0.051*
UK	*Mean*	0.602	0.632	0.941	0.793	0.798	0.721	0.864	0.699	0.685	*0.756*	*0.792*
	s.d.	0.150	0.062	0.005	0.041	0.045	0.068	0.033	0.028		*0.127*	*0.041*
US	*Mean*	0.955	0.959	0.969	0.967	0.966	0.966	0.965	0.952	0.977	*0.964*	*0.965*
	s.d.	0.016	0.005	0.004	0.007	0.005	0.011	0.007	0.017	0.002	*0.012*	*0.007*
Unwtd. ALL	*Mean*	*0.745*	*0.685*	*0.793*	*0.818*	*0.773*	*0.820*	*0.761*	*0.756*	*0.834*	0.772	-
	s.d.	*0.197*	*0.196*	*0.158*	*0.140*	*0.183*	*0.130*	*0.197*	*0.202*	*0.114*	0.179	
Wtd. ALL	*Mean*	*0.889*	*0.848*	*0.908*	*0.879*	*0.860*	*0.862*	*0.867*	*0.848*	*0.947*	-	*0.877*
	s.d.	*0.042*	*0.026*	*0.028*	*0.043*	*0.028*	*0.037*	*0.019*	*0.032*	*0.011*	-	*0.034*



Basis-Metals Industry
1.2
1
0.8
0.6
0.4
0.2
0
1973
1975
1977
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1983
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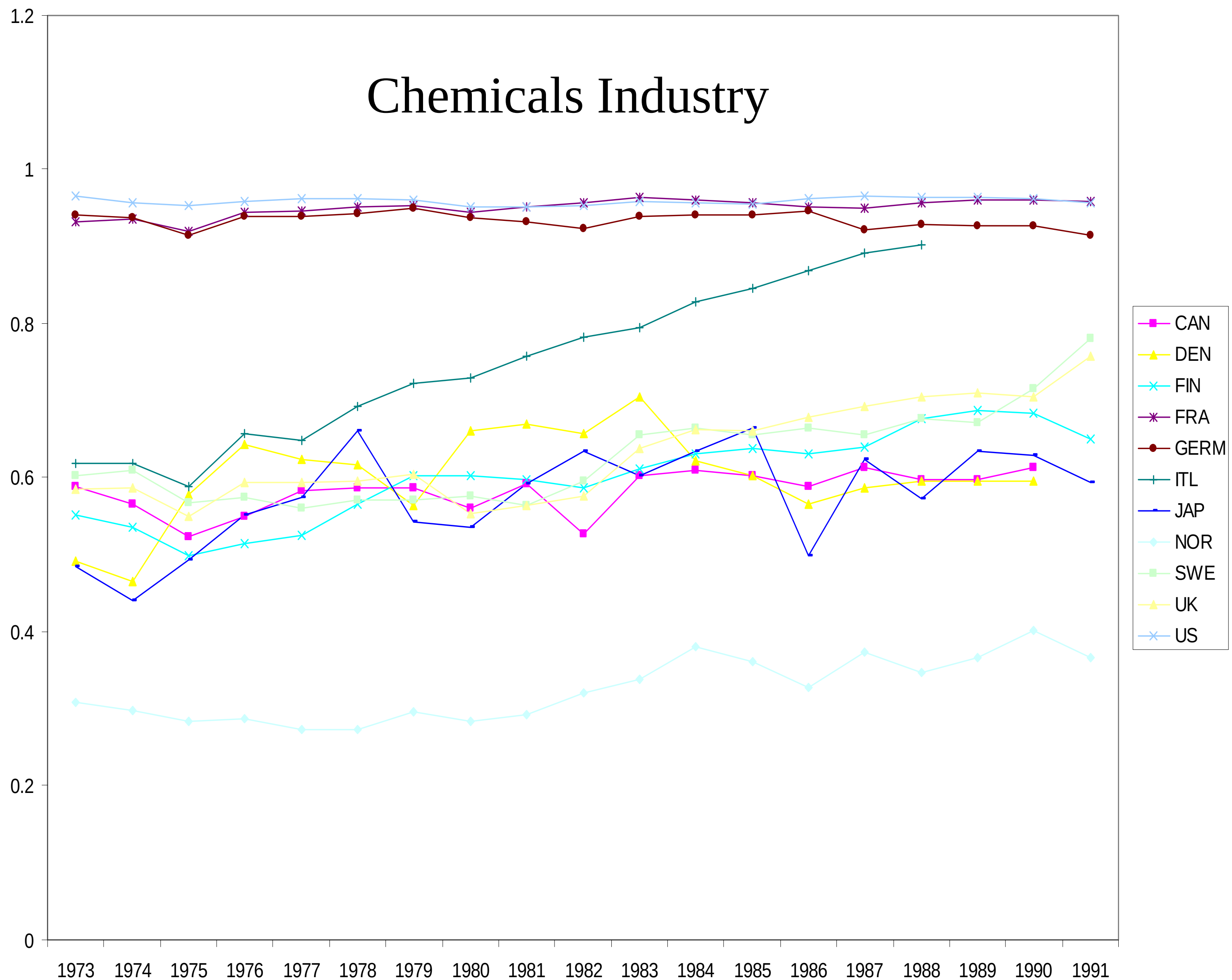
1987
1989
1991
CAN
DEN
FIN
FRA
GERM
ITL
JAP
NETH
NOR
SWE
UK
US


Chemicals Industry
1.2
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0.8
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0.2
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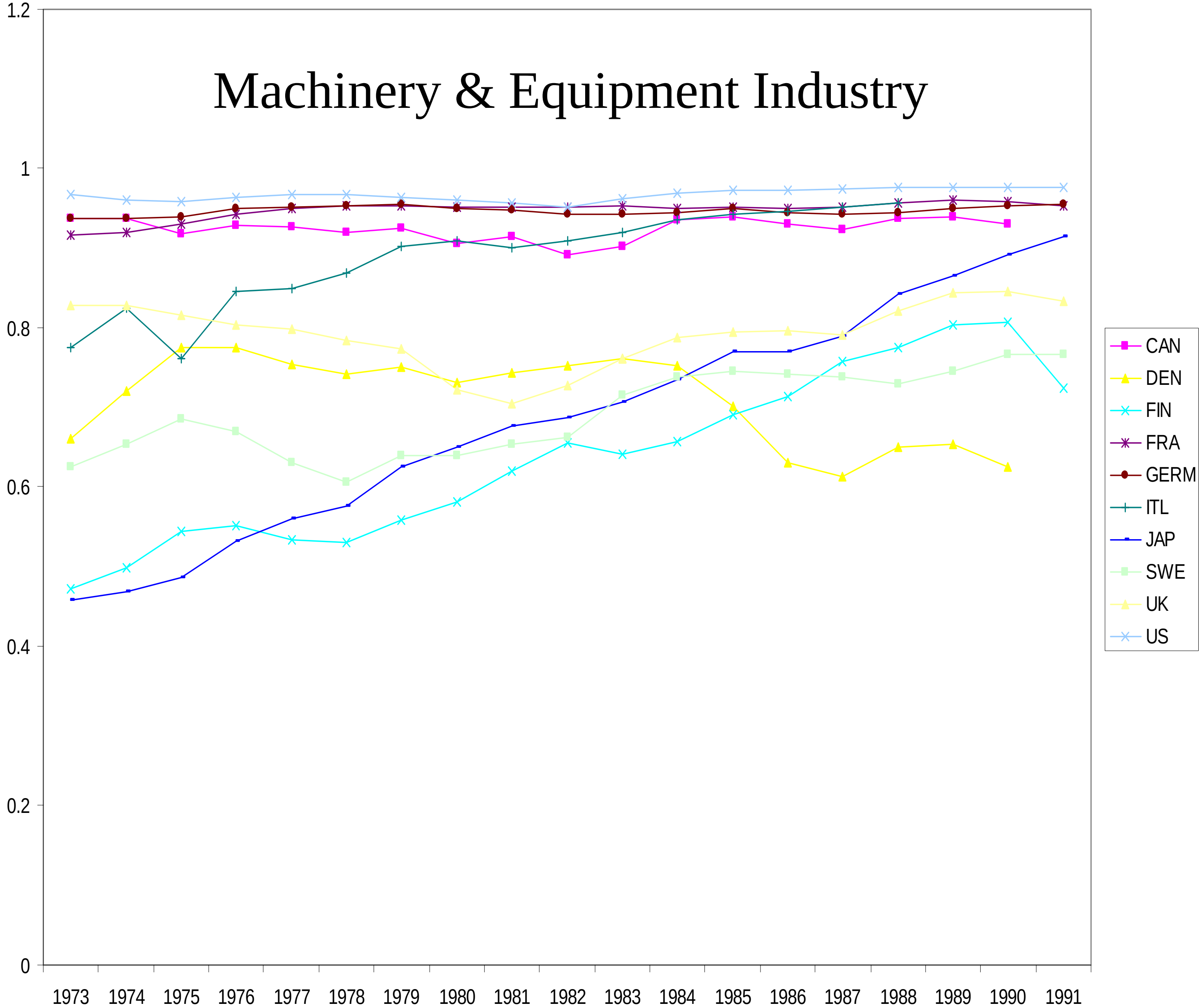

Machinery & Equipment Industry
1.2
1
0.8
0.6
0.4
0.2
0
1973
1974
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1985
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1987
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CAN
DEN
FIN
FRA
GERM
ITL
JAP
SWE
UK
US

UK Summary Table

	BMI	*CHE*	*FOD*	*MEQ*	*MNM*	*MOT*	*PAP*	*TEX*
Efficiency Average	0.60	0.63	0.94	0.79	0.80	0.72	0.86	0.70
1973	0.55	0.59	0.94	0.83	0.87	0.85	0.91	0.69
1991	0.82	0.76	0.94	0.83	0.72	0.62	0.89	0.69
Predicted Change in Efficiency	0.20	0.24	0.24	0.24	0.21	0.24	0.23	0.17
Contribution of Human capital	0.19	0.18	0.20	0.20	0.20	0.22	0.19	0.19
Contribution of R&D	0.01	0.07	0.04	0.04	0.02	0.02	0.04	-0.02
Increase in Human capital required to eliminate inefficiency (years)	1.80	2.74	0.52	1.60	2.83	3.53	1.10	3.37

	No. of obs:933 Time-periods: 19			*No of obs: 1731 Time-periods: 19*		
Model No.	**(6)[a]**			**(7)**		
Production Function	*Coef.*	*s.e.*	*t*	*Coef.*	*s.e.*	*t*
n	0.752	0.019	40.383	0.706	0.015	48.505
k	0.183	0.016	11.204	0.303	0.013	23.317
$\bar{r}_5$	0.132	0.013	10.503	0.093	0.009	9.874
H	-1.291	0.106	-12.200	0.204	0.045	4.515
Inefficiency Effects						
h	-2.989	0.330	-9.058	-1.399	0.411	-3.403
$r\&d$	-0.025	0.009	-2.721	-0.032	0.014	-2.229
$CHE \times h$	-0.108	0.024	-4.410	0.072	0.026	2.708
$FOD \times h$	-0.016	0.023	-0.709	-0.086	0.027	-3.208
$MEQ \times h$	0.030	0.026	1.157	-0.071	0.033	-2.124
$MNM \times h$	0.073	0.029	2.544	-0.060	0.026	-2.298
$MOT \times h$	-0.183	0.025	-7.233	-0.200	0.032	-6.187
$PAP \times h$	-0.134	0.021	-6.367	0.002	0.025	0.093
$TEX \times h$	-0.071	0.026	-2.695	-0.018	0.027	-0.674
$WOD \times h$	-0.135	0.024	-5.714	-0.197	0.042	-4.655
σ^2	0.039	0.002	18.998	0.094	0.005	17.633
γ	0.918	0.021	44.647	0.872	0.010	89.693
Log likelihood function			345.44			375.75
LR test of the one-sided error			676.93			1236.0

Number of observations: 1731, Time-periods: 19

Model No.	**(4)[a]**			**(5)**		
Production Function	*Coef.*	*s.e.*	*t*	*Coef.*	*s.e.*	*t*
n	0.687	0.014	47.6	0.690	0.275	2.507
k	0.293	0.014	21.7	0.404	0.246	1.641
$\bar{r}_5$	0.135	0.011	11.8	0.159	0.124	1.284
H	0.233	0.032	7.3	-	-	-
Inefficiency Effects						
h	0.35	0.208	1.7	-0.091	0.858	-0.106
$r\&d$	-0.046	0.014	3.4	0.012	0.610	0.020
$CHE \times h$	0.498	0.152	3.3	0.041	0.997	0.041
$FOD \times h$	0.985	0.124	8.0	-0.115	0.999	-0.115
$MEQ \times h$	1.63	0.169	9.6	-0.074	0.998	-0.074
$MNM \times h$	2.38	0.116	20.5	-0.054	0.997	-0.054
$MOT \times h$	1.58	0.135	11.7	0.013	0.999	0.013
$PAP \times h$	2.46	0.123	20.0	0.100	0.995	0.100
$TEX \times h$	2.23	0.113	19.7	0.077	0.993	0.077
$WOD \times h$	2.00	0.112	17.8	-0.153	0.999	-0.153
σ^2	0.084	0.005	15.9	0.143	0.436	0.329
γ	0.862	0.014	62.5	0.869	0.413	2.107
Log likelihood function						83.39
LR test of the one-sided error						785.25

Model No.	**(3)***		
	Coef.	*s.e.*	*t*
	Production Function		
n	1.97	0.178	11.1
k	-0.336	0.15	2.2
n^2	-0.052	0.008	6.5
k^2	0.003	0.007	0.4
nk	0.053	0.014	3.8
$\bar{r}_5$	0.084	0.014	6.1
h	0.347	0.056	6.2
	Inefficiency Effects		
h	-1.91	0.37	5.2
$r\&d$	-0.019	0.016	1.2
$CHE\times h$	-0.867	0.102	8.5
$FOD\times h$	-0.344	0.065	5.3
$MEQ\times h$	-1.36	0.203	6.7
$MNM\times h$	0.132	0.076	1.7
$MOT\times h$	-1.81	0.123	14.7
$PAP\times h$	-0.362	0.107	3.4
$TEX\times h$	-0.581	0.099	5.9
$WOD\times h$	-0.288	0.083	3.5
σ^2	0.077	0.005	16.4
γ	0.811	0.014	56.7

Conclusions

- Tested for absorptive capacity effect from human capital and R&D using SFA
- Allows us to specify the model in a way that is closer to that predicted by growth models
- Initial evidence suggests that human capital and R&D are statistically important

Conclusion contd…..

- But, R&D not quantitatively important
- These results are not dependent on the specification of the technical frontier
- There are issues over the data used to measure human capital and the prior assumption in the current literature that human capital only has an indirect effect on production

Conclusion contd…..

- The results for R&D are not robust to functional form
- C-D production function does not adequately fit the data