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Science and society

S&T culture: a blooming dimension

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In this paper we present an overview of available indicators and discuss new elements of analysis, qualitative and quantitative, drawn from the practices involved in the promotion of scientific culture. In this exercise, indicators for scientific culture and literacy were matched with a broad set of data covering S&T, social and economical aspects. For this purpose we have resorted to Eurobarometer data (2001) on the relationship of Europeans (EU15) with science and technology and current socio-economic indicators in the various Member States. Forty-six variables were grouped into sets of composite indicators, which represent eight major dimensions: scientific culture and literacy, Investment in education, Educational attainment, S&T activities, technology diffusion and innovation, economic performance and structure, social and institutional development, and access to information and culture. Cluster analysis grouped countries into four sets whose weaker and stronger aspects are discussed.

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THE APPROPRIATION OF scientific culture is a lifelong process. Beyond the formal schooling and curricular education of science, there is an ever-growing dimension of out-of-school resources. The actors involved range from the scientific community to the media, including public and private laboratories, science communicators and cultural agents such as museums, galleries, libraries and publishers.

In past few years, 'science and society' schemes have mushroomed within S&T programmes. Indeed, science brings about the major changes in the daily life of citizens but issues a duality of responses, typical of the modern risk societies. Back in 2001, the EC released the *Science and Society Action Plan*, proposing the promotion of science education and culture and the closeness of science policy to citizens. Nevertheless, concern has been growing about the sustainability of public support for research and the decreasing demand of youngsters for scientific careers (ESF, 2003), challenging policy-makers to address S&T culture as a blooming dimension.

Moreover, as the promotion of S&T culture is itself a *bona fide* objective, quite prone to warm-hearted intentions, it easily delivers uncoordinated and unaccounted-for actions. Prospective and monitoring efforts require the application of national and international assessment exercises, urging for the development of improved tools in this area (EC, 2002).

Meanwhile, the field has been growing heterogeneously and still lacks the necessary theoretical development that issues a paradigm and a supporting methodology. But the widespread criticism over the concept of scientific literacy (Miller, 1983) — and especially its measurement through a survey — is confronted by the need to consubstantiate this insubstantial dimension before including it in the policy agenda. For example, the OECD, the most prominent forum for international statistics of S&T, has acknowledged the rising of this dimension in the fall of 2002 with a sparse collection of data in their website, but has rarely updated it since.

Traditionally, scientific literacy surveys have followed the layout of ordinary literacy tests and popularised benchmarking knowledge according to scientists' views and beliefs, now referred to as the deficit model (Sturgis and Allum, 2004). The main point of criticism is generally illustrated by the knowledge quiz of scientific facts that places each country within a scale of mean correct answers. Nevertheless, given the availability of horizontal (across countries) and vertical (time series) data, these results have been used as a proxy for the population's knowledge about science and technology. Also, growing awareness of the model's limitations has prompted the collection from the public of attitudinal data. In Europe, the most recent body of information for the EU15 is Eurobarometer 55.2 from 2001, with a follow-up in 2003 (CC-EB 2002.3) to include the new member countries of the EU25.

Pursuing the development of new frameworks of analysis for the limited available data, Durant and coworkers (2000) offered an interesting perspective, drawn from macro sociological models of the industrialisation process, using the 1992 Eurobarometer data. In 2002, the Expert group benchmarking the promotion of RTD culture for ERA recommended the crossing of the scientific literacy survey data with economic indicators (EC, 2002). In this work we have resorted to a selected group of available indicators to depict several relevant dimensions of the relationship of society with science and culture.

Results and discussion

Crossing looks — the method

The rationale that drives this study is to interpret S&T culture as a living face of the whole economic and societal system. Among the ever-growing variety of socio-economic indicators available, 46 variables were chosen and grouped into eight dimensions (Table 1), characterising 14 countries of the former EU15 (given the frequent lack of data, Luxembourg had to be excluded from this analysis). After that, we used cluster analysis to identify related groups of countries. This exploratory exercise had already been used in the mapping of innovation systems (Godinho *et al*, 2004).

Plucking indicators from statistical reservoirs is of course the first interpretative deed of such an analysis, which makes it one of many possible ensembles. We arrived at the final group of data after an iterative process of choice, while trying to keep a balanced number of variables per dimension. It should be noted that the arithmetic of variables within each dimension introduces a weighting formula that influences the final result.

Data mining — the variables

Scalar measures of knowledge, interest and attitude towards science and technology were retrieved from the original Eurobarometer 55.2 results (see Appendix), the most recent source of empirical data regarding the relationship of Europeans with science and technology. As mentioned above, the measurement of knowledge of science by a true/false quiz has been the subject of many criticisms and should be regarded with caution. It is prone to culture bias as it does not correlate strongly with declared interest, a positive attitude towards science or even educational attainment. Still, it has been used as a proxy in many countries (including the widely replicated surveys run by the National Science Foundation in the USA) and bears some interesting features for critical analysis.

Figure 1 shows the relation between the average knowledge of science of the adult population and their economic wealth, as given by GDP *per capita*. Although a significant regression cannot be drawn,

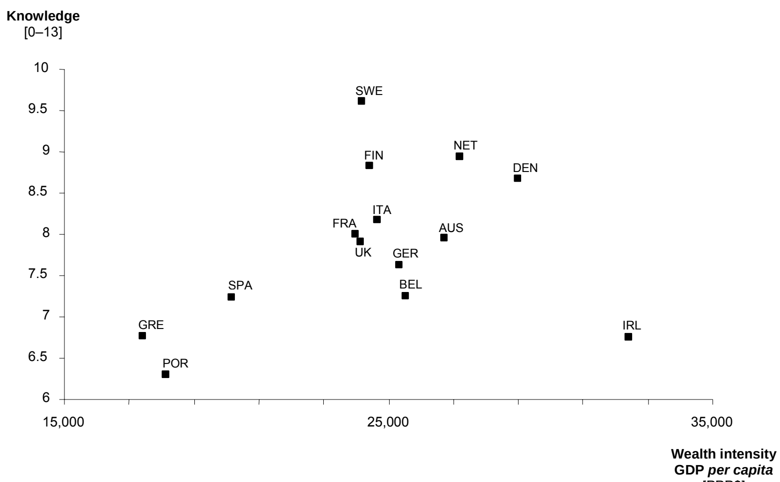

Figure 1. Knowledge results in the 13 quiz questions of Eurobarometer 55.2 *versus* wealth intensity (measured as GDP *per capita*) of countries (excluding IRL and SWE, r^2 = 0.654, *t* = 4,344)

Table 1. List of variables used to construct the eight dimensions of analysis

Code	Dimension/variable	Source	Year
	D1. ***Scientific culture and literacy***		
V1	Interest	1	2001
V2	Knowledge	1	2001
V3	Attitude	1	2001
V4	Mathematical literacy	2	2000
V5	Scientific literacy	2	2000
	Construction of D1: [V1+V2+V3+(V4+V5)/2]/4		
	D2. ***Investment in education***		
V6	Total expenditure in education	3	1999
V7	Expenditure in tertiary public education	4	2000/01
V8	Pupil–teacher ratio in primary education	5	2001
V9	Enrolment ratio (combined 1st, 2nd, 3rd)	6	2000/01
V10	Participation in lifelong learning	7	2001
	Construction of D2: [(V6+V7)/2+1/V8+V9+V10]/4		
	D3. ***Educational attainment***		
V11	Literacy	8	2003
V12	Average years of schooling of adults	5	2000
V13	Youth education attainment	9	2001
V14	Population aged 25–64 with at least upper secondary education	4	2002
V15	Population with tertiary education	5	2001
	Construction of D3: [V11+V12+(V13+V14)/2+V15]/4		
	D4. ***S&T activities***		
V16	R&D intensity	4	2001
V17	Researchers	4	2001
V18	University graduates in S&T	4	2001
V19	Scientific publications	4	2002
V20	Citations	10	1997/2001
	Construction of D4: [V16+(V17+V18)/2+(V19+V20)/2]/3		
	D5. ***Technology diffusion and innovation***		
V21	European patents	11	2000
V22	US patents	11	2000
V23	Internet users	6	2001
V24	Internet hosts	12	2000
V25	PCs	13	2001
V26	ICT expenditures	12	2001
	Construction of D5: [(V21+V22)/2+(V23+V24+V25)/3+V26]/3		
	D6. ***Economic performance and structure***		
V27	GDP per capita	6	2001
V28	Productivity	14	2001
V29	High-tech exports	5	2001
V30	Employment in high- and medium-tech industries	4	2001
V31	Employment in knowledge intensive services	4	2001
	Construction of D6: (V27+V28+V29+(V30+V31)/2)/4		
	D7. ***Social and institutional development***		
V32	Social expenditure	15	1998
V33	Life expectancy	6	2000/05
V34	Infant mortality	6	2001
V35	Gender-related development index	6	2001
V36	Gini index	16	1995/98
V37	Corruption index	17	2003
	Construction of D7: [V32+(V33+1/V34)/2+V35+V36+V37]/5		
	D8. ***Access to information and culture***		
V38	Cinema attendance	15	1994/98
V39	Cinema screens	15	1998
V40	Feature films produced	15	1994/98
V41	Daily newspapers	15	1998
V42	Books	15	1998
V43	Recorded music sales	15	1998
V44	CD players	15	1998
V45	Radios	15	1997
V46	TVs	15	1997
	Construction of D8: [(V38+V39+V40)/3+V41+V42+(V43+V44)/2+(V45+V46)/2]/5		

Sources:
1. European Commission, 2001
2. OECD, 2000
3. OECD, 2004
4. European Commission, 2004b
5. UNESCO, Institute for Statistics, 2004
6. United Nations, 2003
7. European Commission, 2004a
8. CIA *World Factbook*, 2003
9. Eurostat, 2004
10. King, 2004
11. European Commission, 2002
12. OECD, 2002
13. ITU, 2003
14. Groningen Growth and Development Centre, 2004
15. UNESCO, 2000
16. United Nations Development Program, 2004
17. Transparency International Secretariat, 2003

the geography of coordinates ends up clustering the southern and less influential countries (Spain, Greece and Portugal) at one end, while distinguishing the more educated (Sweden, Finland, the Netherlands and Denmark) among the economically robust. Ireland shows up as an outlier due to its recent economic burst, although it is still catching up on human capital. In fact, education benefits from money and especially from sustainable and enduring investment.

The plotting of knowledge against R&D intensity (Figure 2) shows up a stronger correlation where three sets of countries can be distinguished. Spain, Ireland, Greece and Portugal have the lower performance positions in both investment and knowledge. Sweden and Finland are again leaders and, among the middle group, citizens of the Netherlands and Denmark do better in the science quiz.

Education indicators are thought to be particularly relevant and were organised in two different dimensions describing ‘investment inputs’ and ‘attainment outputs’, which actually do not correlate well, as discussed below. The enrolment rate is a significant insight into a country’s educational system, not only relative to the youngsters’ curricular formation, but also in adult life in the form of lifelong learning. Adult education, formal or informal, is particularly relevant in scientific matters, given the accelerated pace of discoveries and the necessity to update people’s ease with technological wares and consumer choices.

S&T activities are portrayed using standard indicators as well as technology diffusion and innovation. The economic structure dimension offers a biased look towards the S&T system by including the ‘high-tech exports’ variable and using sector employment indicators. Finally, we believed it was pertinent to include a dimension of social and institutional development as well as another one illustrating access to information and culture, which reflects habits of reading,visiting exhibitions or receiving broadcast information. Finding appropriate data to fill in these two dimensions is not straightforward and, even when

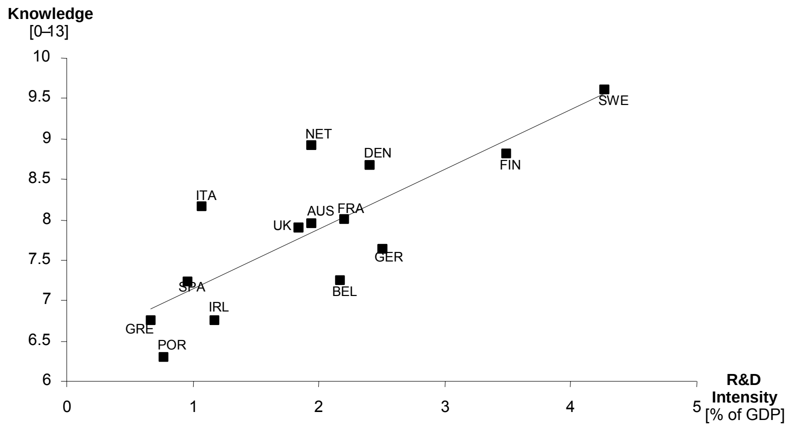

Figure 2. Knowledge results in the 13 quiz questions of Eurobarometer 55.2 *versus* R&D intensity (expressed as % of GDP) of countries (r^2 = 0.642, *t* = 4,637)

found, it is frequently not very up-to-date, which makes this a tentative exercise in the exploration of those important societal dimensions.

Octagons of diversity — dimension analysis

The main advantage of grouping indicators into dimensions is to obtain a more manageable body of data that still holds diversity, while it confines variance within a reasoned context.

The computed results of variables into dimensions are shown in Table 2. The 14 countries considered are ranked by their average value for the eight dimensions, with Sweden occupying the leading position and Portugal the last one. All in all, the results obtained do not come as a surprise, with the Nordic countries occupying the top of the table and the southern Mediterranean the very bottom.

Figure 3 graphically displays country scores, grouped by clusters. It facilitates the reading of positioning in the eight dimensions considered, and highlights the different performances contained in every axis of analysis. The variability within each of the eight dimensions is fairly equivalent among them, with D3, D4 and D5 exhibiting the higher dispersion of points in the axis of Figure 3. As far as S&T culture is concerned, Sweden, Finland and the Netherlands concur for the podium, which is theirs already (together with Denmark) when it comes to R&D performance.

A correlation analysis of the eight dimensions under study is shown in Table 3. Interestingly, the correlation of the S&T culture dimension is highest with D4 (Science) and D5 (Innovation), which adds to the premise that it is indeed a meaningful dimension of R&D and innovation systems. What is more, scientific culture is science-related but should not be overlooked as a meaningful aspect of culture as whole, a very common misplacement in literary and arts-dominated societies.

Table 2. EU 14 ranked by their averaged performance in the eight dimensions (D) of analysis, and clustered into four groups (A, B, C, D) of countries

	EU14	D1 S&T culture	D2 Educ. Invest.	D3 Educ. attainment	D4 S&T activities	D5 Tech. – innovation	D6 Economic structure	D7 Social develop.	D8 Info. – culture	AVG	*SD Countries*
A	Sweden	1.143	1.331	1.029	1.814	1.820	0.189	0.951	0.682	*1.120*	*0.549*
	Finland	0.905	0.327	1.006	1.393	0.869	0.100	0.597	0.672	*0.734*	*0.405*
B	Denmark	0.691	1.139	0.749	0.532	0.597	0.457	0.743	0.771	*0.710*	*0.207*
	Netherlands	0.835	0.084	0.239	–0.107	0.796	0.551	0.429	0.455	*0.410*	*0.328*
	UK	0.024	0.661	0.550	0.195	0.395	0.253	0.163	0.770	*0.376*	*0.263*
C	Germany	–0.244	–0.571	0.488	0.132	0.474	0.315	–0.087	0.253	*0.095*	*0.371*
	Belgium	–0.622	0.312	0.237	–0.021	0.039	0.252	0.605	–0.101	*0.088*	*0.362*
	Austria	0.122	–0.073	–0.232	–0.023	–0.009	0.046	0.336	0.115	*0.035*	*0.166*
	France	–0.061	–0.608	0.024	0.135	–0.040	0.544	0.027	0.088	*0.013*	*0.316*
	Ireland	–0.798	–0.647	0.110	–0.343	–0.628	1.254	–0.312	–0.150	*–0.189*	*0.653*
D	Italy	–0.131	–0.318	–0.905	–0.820	–0.786	–0.093	–0.567	–0.689	*–0.539*	*0.319*
	Spain	–0.330	–0.506	–0.570	–0.652	–1.240	–0.865	–0.474	–0.539	*–0.647*	*0.285*
	Greece	–0.266	–1.000	–0.362	–1.141	–1.259	–1.533	–1.223	–1.262	*–1.006*	*0.453*
	Portugal	–1.270	–0.129	–2.364	–1.256	–1.028	–1.469	–1.188	–1.067	*–1.221*	*0.612*
	SD Dimensions	*0.691*	*0.691*	*0.886*	*0.863*	*0.904*	*0.781*	*0.683*	*0.675*		

(Standardized values)

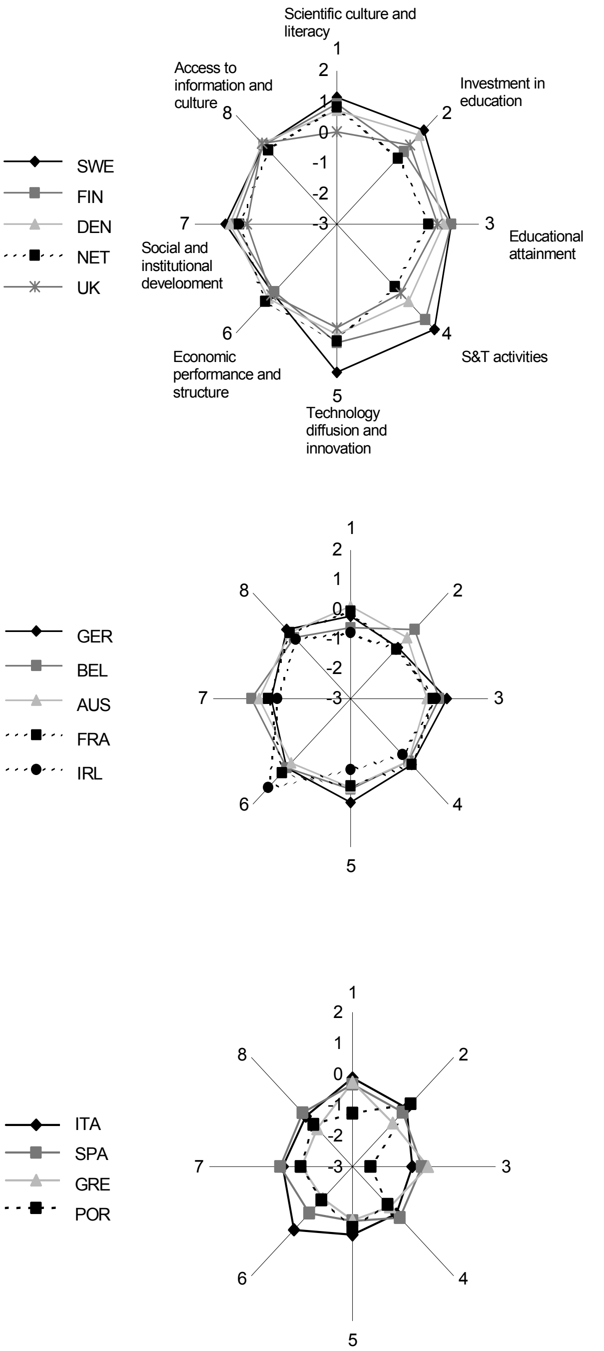

Figure 3. Science and society depicted in eight relevant dimensions constructed as composite indicators of 46 socio-economic variables (standardised, mean = 0)

Educational investment is the poorly correlated dimension, including educational attainment and economic structure. It frequently translates not only a budgetary initiative, but also a political commitment. Portugal is an exemplary case, showing average level of investment including spending and enrolment, but still very poor results. Social development expectedly relates to increased cultural interest and practices. Nevertheless, some economically robust countries such as Belgium, Germany or Ireland still do not live up to their expected cultural performance, including S&T culture indicators of knowledge, interest and attitude.

Europe as a foursome

Cluster analysis attempts to identify related groups of cases (or countries) based on selected characteristics. This analysis was performed using SPSS software and different algorithms were run, choosing the 46 variables or the eight dimensions as cases, which delivered analogous results: four clusters —A, B, C and D —whose composition is shown in Table 2.

Sweden and Finland (cluster A) are ahead and thriving, displaying a scientifically driven society, with a strong and sustainable knowledge base. The scores obtained by Sweden are always the maximum of EU14, with the exception of the economic dimension, surpassed by countries in cluster B. These countries delineate the outer boundaries of Figure 3, clearly illustrating the higher development of Nordic societies.

Denmark, the Netherlands and the UK (cluster B) also show themselves to be educated as well as economically and socially sound, although the level of investment in scientific activities, technology and innovation almost halves the values of cluster A.

Germany, Belgium, Austria, France and Ireland form cluster C, where dimensional asymmetries are more noteworthy, encompassing economical robustness and technological ease with a significantly lower investment in knowledge-creation. The investment in education, S&T activities and scientific culture falls below average levels, crossing the threshold of negative values. Within the cluster, France and Germany link closer to each other, then to Austria/Belgium and finally to Ireland.

Table 3. Correlation analysis of the eight dimensions

	D1 S&T culture	D2 Educ. invest.	D3 Educ. attainmt	D4 S&T activities	D5 Tech. & innov.	D6 Econ. struct.	D7 Social develop.	D8 Info. & culture
D1	1							
D2	0.615	1						
D3	0.733	0.490	1					
D4	0.784	0.715	0.831	1				
D5	0.796	0.757	0.775	0.913	1			
D6	0.342	0.279	0.652	0.528	0.564	1		
D7	0.734	0.757	0.807	0.871	0.880	0.679	1	
D8	0.726	0.709	0.830	0.855	0.889	0.722	0.902	1

Finally, Italy, Spain, Greece and Portugal (cluster D) tail the EU14, falling below average in all dimensions. In Figure 3 their data series represent the inner circles of the radar, particularly contracted in the cases of Portugal and Greece.

Conclusions

Scientific culture has an individual and a social dimension (Godin and Gingras, 2000). It is the product of schooling, curiosity, awareness and even recreational activities. The results presented in this work for 14 European countries show that educational and cultural performances are long-term social constructions and an important target for informed policies.

Empirical data on literacy (for which there are no universal definitions or standards) and attitudes towards S&T is difficult to grasp and generally comes from sparse surveys, which are necessarily frameworked by the question set. More research is clearly in demand as S&T culture has already made it to the high table of R&D statistics.

The methodology put forward in this report provides a panoramic picture of a very complex system. Given the multiplicity of actors and actions it is not possible to devise a causal model, although some correlations appear evident. It becomes clear that there is no widespread scientific culture outside a dynamic S&T system. What is more, it is a question not only of money but also of social development and knowledge sustainability. Knowledge is indeed a highly regarded asset, banked within individuals and societies, as human capital is frequently quoted as a crucial factor of growth and development in today's S&T-driven world.

Appendix

The Eurobarometer 55.2 (organised and supervised by DG Press and Communication, European Commission) fieldwork took place in July 2001 in the 15 Member States of the European Union (EU15).

Answers were collected among the population, aged 15 years and over, totaling 16,029 interviews. Science and technology was the subject of questions 1 to 28.

- *Interest in science and technology* (Q.3) Please tell me if you are fairly interested or not in each of the following topics … science and technology? (range of answers: fairly interested, fairly not interested, don't know). Data: percentage of declared interest in science and technology, range 0–100, mean = 47.93, sd = 11.29
- *Knowledge of science* (Q.8.1–13) Data: 13 factual questions, range 0–13, mean = 7.6, sd = 0.91
- *Attitudes toward science and technology* (Q.13.1, Q.13.8, Q.13.11, Q.14.2, Q.14.3, Q.14.6, Q.14.7, Q.14.9, Q.14.10, Q.14.12) Data: 10 attitudinal items that convey a positive view of science; scale 0–10; mean = 6.09, sd = 0.28

Variables V1 to V46 were standardised (mean = 0, sd = 1) by common procedures. Software used was Excel and SPSS (v.12). Since the Eurobarometer data is from 2001, the other indicators date from the most approximate available year.

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