DOES KNOWLEDGE TRADE CREATE GROWTH EVERYWHERE? QUESTIONS AND REPLY FROM A CROSS-COUNTRY COMPARISON.

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ABSTRACT

The knowledge is assuming a leading role between production factors, changing from enabling element to success critical factor in enterprises competition. The meaning of knowledge used in this paper is that of technological innovation (both of product and of process) useful in the industrial environment.

Following this approach, the usage of models to analyse knowledge development, exchange and international diffusion needs some specific indicators obtained by indirect measures, such as patents, R&D investments and productive efficiency relative degree.

The analysis of data about R&D investments supply information about the location of activities related to inventions, so enabling to identify the poles of knowledge creation, while data about productivity levels indicate the country's ability to adopt new inventions. Moreover, data about international patents enable to underline the existing relationships between knowledge creation location and the areas where its "consumption" introduce a productivity growth.

The compared analysis between different countries enhanced the primary role of technological infrastructure both for knowledge creation and for new inventions adoption.

KEYWORDS

Knowledge
Technology
Innovation
Infrastructures

1 THE KNOWLEDGE-BASED ECONOMY

The knowledge-based economy have peculiar characteristics with respect to all the economics formerly defined, including also totally different operating rules and behaviours for business.

Thomas A. Stewart (2001) defines the three main components of knowledge-based economy as follows:

- the knowledge became what we buy, sell or produce and represents the most relevant producing factor;
- the intangible assets became more important with respect to physical assets for the enterprises;
- the prospering in knowledge economics, joined with the exploitation of these innovative vital assets, needs the definition of a new vocabulary, new management techniques, new technologies and new strategies.

From these three main components derive the new economic paradigms that enterprises have to face to obtain a dominant position in the growing global competition.

1.1 KNOWLEDGE AS CORE COMPETENCE FOR ENTERPRISES

The shifting of entrepreneurial environment attention to intangible factors – knowledge as an example – induced economists and researchers to reconsider the role and the nature of critical success factors for enterprises. The main focus is actually an enterprise representation built starting from the knowledge: *a knowledge based view*.

The knowledge factor differs from all the others both because configures itself as a sort of meta-resource (able to become the source for innovation, reconfiguration and co-ordination of all remaining productive factors) and for its intangible nature.

In facts, an enterprise neither can be innovative without the contribution of knowledge, nor diversify the product to remain competitive in quickly obsolescing markets. Moreover, knowledge is necessary both to improve productive processes and to co-ordinate the activities of the value chain that are diffused in the world.

Nevertheless, the prevalence of intangibles among the productive factors introduces problems connected to both measuring and management tasks, because the traditional methods based on optimising algorithms become no more effective. The knowledge, differently from physical assets, is not scanty and have increasing returns. When it is plentiful, its value increases and cannot be determined by the equilibrium between demand and offer. Knowledge autonomously regenerates and renovates itself; in facts, the main discoveries rarely happen by chance, but are obtained from continuous adjustments and improvements.

Another relevant aspect is the everlasting linkage between knowledge and humans. It doesn't exist another productive factor so strongly related to human resources. The labour activities indeed are frequently realized by means of automata.

We need to consider peculiar aspects and meanings of the real sense of word "knowledge" to be able to locate those places where the knowledge factor is "more plentiful", so enabling us to identify the boundaries of its particular geography.

The meaning of knowledge used in this paper is that of technological innovation applicable in the industrial environment, that can be viewed as an element that really belongs to the value chain of a product, i.e.:

- a qualifying element characterizing a special product with respect to similar others (product innovation), or
- a technological enhancement that reduces costs or improves efficacy and/or effectiveness of production (process innovation).

Starting from this definition and always considering the strong relationship with the inventor role, it is allowed a mathematical description of the international diffusion phenomenon by means of patent study.

However patents represents a rough estimate of knowledge, because even measuring the number of inventions they are not able to collect the whole innovative activity. Many inventions never become patents indeed, and the simple patent of an invention supply no specific information about its real value.

Accordingly to OECD surveys, this paper will consider the innovation as main driver for economic growth. As a matter of fact, the innovation modifies the economic growth of a country both at micro and at macro level.

The innovation at micro level, both as radical and/or as incremental, enable enterprises to become more reactive in the challenge that involves so many competitors (also at international level). Moreover, enterprises are enabled to satisfy clients demand that become always more sophisticated in terms of expectation (a study, based on a sample of 12 European countries, shows that more than 30% of income in manufacturing is related to innovative or developed products - DTI, 1999).

The contribution of knowledge at macro level can be identified inside the three growth drivers: capital, work and MFP (MultiFactor Productivity). MFP measures the output for combined input units, that is an index conceived to measure the joined influence on economic growth of technological changes, efficiency improvements, return on scale, resources reallocation and other factors.
Following an OECD study, those countries that experimented an higher growth rate in terms of MFP in the ages of 80s and 90s (Australia, Canada, Denmark, Finland, Ireland, New Zeeland, Norway, Sweden and United States) usually show a patent number growth rate above the average.

Even if the international distribution of patents represents a rough estimate of both the innovation and the knowledge, its analysis can supply useful indications to point out the existing relations between the different places of knowledge creation and capitalization of its benefits consumption.

2 THE MODEL FOR KNOWLEDGE GENERATION CENTRES

In this model the main input for the process that will generate the invention is represented by the investment in knowledge. This investment is evaluated as the sum of expenditure on both the research and development (R&D) and the higher level education from private and public sources and the obtained value have to be adjusted avoiding the eventual overlap of the two components.

The former definition of investment in knowledge differs from that proposed by OECD because software expenses are not considered. The choice of excluding such a component is due to the remark that the computer technology changed its characteristic from critical factor to a more simpler enabling commodity, so reducing its influence in the general creative process.

To be able to confront the investment in knowledge among the 23 OECD countries we decided to consider the investment related to GDP (Gross Domestic Product) for each country, so taking into account the bias that both dimension and richness of each country can introduce in the evaluated indicators.

The investment in knowledge (or knowledge effort) as a percentage of GDP (**K)** in this model depends for each country on both the R&D expenditure and R&D employees involved in, as shown in (1).

The R&D can be subdivided into three main activities: basic research, applied research and experimental development. The basic research is devoted to theoretical or experimental activities mainly devoted to obtain more knowledge without any specific appliance or usage.

The definition of long term research can be used when a meaningful lack of time is necessary to apply the results obtained from the basic research. This definition implies a sort of distinction between cause and effect referring to knowledge generation and productive efficacy growth, nevertheless in this paper the basic R&D share will not be neglected. In facts, due to the self re-generating property of knowledge, the basic research investments enable the creation of new hints for future researches and further innovative capabilities for a country.

A measure generally used for international expense comparison in R&D is GERD (Gross Domestic Expenditure on R&D). The **X** variable was defined equal to GERD as a percentage of GDP in order to compare correctly the values of this indicator among the analysed countries.

The human resources involved in science and technology (HRST) are defined following "Canberra Manual" (1995), including also scientists and engineers devoted to research activities. These elements, joined with the ratio of scientists and researchers with respect to the total labour force, supply further information about the innovative ability of a country (**Y**). So, following the above definitions, the knowledge effort can be represented as:

$$\ln(K_i) = a \ln(X_i) + b \ln(Y_i) + e \qquad (1)$$

where **K**, **X** and **Y** are the indicators defined. The i index refers to each one of the 23 considered countries.

2.1 THE ANALYSED DATA

The data used for this analysis where collected from OECD publications and are related to year 1998.

All the logarithms with argument lower than one was forced to zero inside the model, because a negative value as indicator of knowledge investment is not meaningful.

COUNTRY	GERD as percentage of GDP	researchers per 10.000 labour force
Canada	1.71	58
United States	2.60	81[A]
Australia	1.49	67
Japan	3.04	96
Korea	2.55	43
Austria	1.80	34[B]
Belgium	1.83 [A]	54[A]
Republic of Cekia	1.27	24
Denmark	1.92	61[A]
Finland	2.89	94
France	2.18	61
Germany	2.31	60
Greece	0.51 [A]	26[A]
Hungary	0.68	29
Ireland	1.39	51[A]
Italy	1.02	33[A]
Netherlands	1.95	50
Norway	1.66 [A]	77[C]
Portugal	0.62 [A]	27[A]
Spain	0.9	37
Sweden	3.735 [C]	87.5[C]
Switzerland	2.73[D]	55[B]
United Kingdom	1.83	55

A: 1997 INSTEAD OF 1998
B: 1995 INSTEAD OF 1998
C: AVERAGE VALUE BETWEEN 1997 AND 1999
D: 1996 INSTEAD OF 1998

Tab. 1: Main indicators of knowledge investment in 1998
Source: OECD, 2001

2.2 THE RESULTS

Applying the model (1) to the available data we obtained the following values for α, β and ε:

α = 0,773026

β = 0,094528

ε = 0,161802

COUNTRY	Knowledge investment on GDP in 1998 (source: OECD, 2001)	Simulated knowledge investment
Canada	3,10	2,61
United States	4,50	3,73
Australia	2,70	2,38
Japan	3,60	4,27
Korea	4,80	3,46
Austria	2,60	2,58
Belgium	2,30	2,73
Republic of Cekia	2,10	1,91
Denmark	3,00	2,87
Finland	4,00	4,10
France	3,00	3,17
Germany	3,00	3,31
Greece	1,50	1,60
Hungary	1,50	1,62
Ireland	2,50	2,20
Italy	1,60	1,66
Netherlands	2,70	2,85
Norway	2,70	2,62
Portugal	1,40	1,61
Spain	1,70	1,65
Sweden	4,60	4,97
Switzerland	3,30	3,73
United Kingdom	2,60	2,74

Tab. 2: Results obtained from the model for knowledge generation centres

The results obtained from the model are the following: Sweden, Japan and Finland are the countries with the higher value of knowledge investments.
The evaluated multipliers show that the investment in R&D is more relevant with respect to the number of scientists involved in research activities.

3 PATENT FAMILIES AT EPO, USPTO AND JPO

Generally an idea become a patent in the inventor origin country, and in those countries with high productive efficiency and/or wide market. This happens because a patent, that is effective inside a country, protects from production and sale of goods or services based on the innovation patented.

The analysis of "patent families" - defined as a set of patents taken in various countries to protect a single invention (OECD, 2001) – in this paper will focus three main offices: the EPO (European Patent Office), the USPTO (US Patent and Trademark Office) and the JPO (Japanese Patent Office). These offices cover an area characterised by high income and high productive efficiency.

The collected data demonstrates that an half of the whole patenting activity of EPO comes from UE countries, the 29% from USA and 17% from Japan. Germany leads the European countries group participating at the 20% of total amount of patents applications, that is three times more with respect of France. There is also an high convergence among areas with high knowledge intensity and areas with strong care of inventors about patent warranty.

The countries with an high productive efficiency can take up more innovations and this will lead to a couple of different considerations: the first one is that the inventors will require a patent in those countries to prevent an unlicensed production; the second one is that both the growing yields of knowledge and its regenerating capability will lead these countries to become more innovative (spillover effect).

A single patent will not protect an invention in the whole world, but an invention can be patented in more than one country. This will imply two different kind of costs: the first one is linked to the necessary publication of invention characteristics (that can be copied without license in those countries for which the patent was not required), while the second is directly connected with rates. So, an inventor will require the patent only for those countries in which he presumes his invention will have a meaningful value.

The productive efficiency influences the total number of patent families in the three offices considered in this paper. An indicator for productive efficiency of a country can be the GDP per hour worked.

The number of patents in “triadic”[1] patent families related to population (**N**) can be estimated as a function of the square of the knowledge investment as a percentage of GDP (**K**) and the productive efficiency represented by GDP per hour worked (**Z**) for origin country of inventors. Following these remarks:

$$\ln(N_i) = g \ln(K_i^2) + h \ln_i(Z_i) + l \qquad (2)$$

3.1 THE ANALYSED DATA

While data about the value of knowledge investment as a percentage of GDP in 1995 evaluated by OECD are not available, it was estimated using the former model. So, the final data set became:

Data about productivity as GDP per hour worked in 1995 was inferred from OECD (2002). Unfortunately, the analysis will include only 19 countries due to a lack of data about efficiency.

As formerly done, all the logarithms with argument lower than one was forced to zero inside the model, because a negative value as indicator of patent families is not meaningful.

COUNTRY	K	X (source: OECD, 2001)	Y (source: OECD, 2001)	ln(k)
Canada	2,656472	1,74	60	0,976998996
United States	3,585767	2,5	74	1,276972454
Australia	2,472156	1,57	65	0,905090839
Japan	3,923958	2,77	83	1,367100866
Korea	3,442007	2,5	48	1,23605472
Austria	2,313808	1,56	34	0,838894749
Belgium	2,630146	1,74	54	0,967039487
Republic of Cekia	1,593424	1,01	23	0,465885079
Denmark	2,760322	1,84	57	1,015347403
Finland	3,319302	2,29	67	1,199754508
France	3,307014	2,31	60	1,196045547
Germany	3,246381	2,26	59	1,177540897
Greece	1,581214	0,49	23	0,458193213
Hungary	1,599646	0,73	26	0,469782553
Ireland	2,089124	1,34	40	0,73674482
Italy	1,636106	1	33	0,492319047
Netherlands	2,873874	1,99	46	1,055661025
Norway	2,670039	1,71	73	0,982093052
Portugal	1,587589	0,57	24	0,462216284
Spain	1,621432	0,81	30	0,483309576
Sweden	4,62717	3,46	77	1,531945402
Switzerland	3,73205	2,73	55	1,316957718
United Kingdom	2,890763	1,98	51	1,061520468

Tab. 3: Results of the model for knowledge generation centres in 1995

3.2 THE RESULTS

The model (2) supplied the following results:

γ = 1,447354656

η = 1,501882

λ = -6,56576

COUNTRY	Number of patent in "triadic" patent families for million population	Estimated number of patent in "triadic" patent families for million population
Canada	11,75	19,82225093
United States	42,43	57,23306284
Australia	8,21	12,40895167
Japan	68,5	46,31050199
Korea	6,94	8,755723789
Belgium	31,45	26,55969066
Republic of Cekia	0,26	1,278991784
Denmark	30,67	24,06625451
Finland	49,63	32,12328025
France	29,88	45,9620524
Germany	52,25	38,48673549
Ireland	5,43	9,386246335
Italy	9,72	6,62847436
Netherlands	46,53	40,15668286
Norway	18,18	26,22776791
Spain	2,2	1,292344977
Sweden	73,56	92,14339712
Switzerland	98,38	55,76987864
United Kingdom	22,23	19,91346678

Tab. 4: The results of the model on patent diffusion

The obtained values show that productive efficiency and the square of knowledge intensity represent equivalent factors in determining the number of patent families. The corrective factor is negative.

4 CONCLUSIONS

The knowledge and intangibles represents by now critical resources in the competition among enterprises. If knowledge is considered as technological innovation applicable at industrial level, both of product and of process, we are allowed to analyse the international trade of knowledge through the patent diffusion. The final invention has as input a knowledge effort or a knowledge investment that is directly proportional to R&D investments and the number of researchers in each country.

A mathematical model to estimate the knowledge investment was defined and calibrated, using a sample of 23 OECD countries.

A dependency of productive efficiency (measured as GDP per hour worked) was presumed and demonstrated with respect to the number of patents required for the same invention in UE area, USA and Japan. These areas are characterised by high income and high productivity, so looking particularly attractive for inventors.

Finally, a model for the number of patent families in this area was defined considering the dependency from the square of knowledge investments joined with the production efficiency. The obtained results show that the efficiency level positively affect the number of patented inventions, so contributing to the international trade of knowledge.

NOTES

[1] European Patent Office (EPO), US Patent and Trademark Office (USPTO) and Japanese Patent Office (JPO)

REFERENCES

Acs Z. J., Anselin L., Varga A., *Patents and Innovation Counts as a Measures of Regional Production of New Knowledge* – Reserch Policy – 2002

Arundel A., Kabla I., *What Percentage of Innovations are Patented? Empirical Estimates for European Firms* – Research Policy – 1997

Autant-Bernard C., *Science and Knowledge Flows : evidence from the France case* – Reserch Policy – 2001

Campisi D., Gastaldi M., Levialdi N., *R&D Investiments and Knowledge Stock Formation: a* Cross-*Country Study of Innovation and Growth* - 2001

Cefis E., Orsenigo L., *The Persistence of Innovative Activities. A Cross-country and Cross-Sector Comparative Analysis* – Reserch Policy – 2001

Eaton J., Kortum S., *Trade in Ideas. Patenting and Productivity in the OECD* – Journal of International Economics – 1996

Ernst H., *Patetent Applications and Subsequent Changes of Performance: evidence from time-series cross-section Analyses on the Firm Level* – Reserch Policy – 1999

OECD and Eurostat, *Manual on the Measurament of Human Resources Devoted to S&T – Canberra Manual*, 1995.

OECD Special Edition, *Science, Technology and Industry Outlook*, 2001

OECD, *Science, Technology and Industry Scoreboard*, 2001

OECD, *Science*, *Technology and Industry Outlook*, 2002

Porter M. , Stern S., *Innovation: Location Matters*, MIT Sloan Management Review – 2001

Rozhkov S., Ivantcheva L., *Scientometrical Indicators of National Science & Technology Policy based on Patent Statistic Data* – World Patetent Information – 1998

Stewart T. A., The Wealth of Knowledge, Doubleday - 2001

Zitt M., Barré R., Sigonneau A., Laville F., *Teritorial Concentration and Evolution of Science and Technology Activities in the European Union*: *a Descriptive Analysis* – Reserch Policy – 1999