Chapter 2.

Knowledge economy and the long-term growth – are there any relations?

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2.1. Economic growth and knowledge: the review of theoretical contributions

Last years have brought pretty much turmoil in economics caused first by so-called the "new-economy" phenomenon and later by the "knowledge-based economy" one.[1] Some of the new ideas emerged during the so-called "information revolution" have found to be only speculations the occurrence of which is quite usual during stock market bubbles (since the famous Dutch "tulip mania"), but some of them survived and seem to have solid theoretical grounds.

The "new economy" which is identified rather with information and communication technologies (ICTs) only, seems to have more limited impact on economic growth, as it was previously thought (especially at the end of 1990s – during the dot.com bubble). We can enumerate here e.g. the works of Solow with famous "Solow paradox" ("you can see computer age everywhere but in productivity statistics", 1987) and of Robert Gordon (1999) who showed that productivity growth in non-durable manufacturing decelerated in 1995-99 compared to 1972-95, and in durable manufacturing stripped of computers – even more. However, we have now clear empirical evidence of the strength of influence of ICTs on growth, thanks to the works of e.g. B. van Ark (or in case of Central and Eastern Europe – M. Piątkowski, e.g. Piatkowski, 2006).

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The knowledge-based economy (KBE), or briefly just "knowledge economy"[2], encompasses not only computers or ICTs but also education and innovation systems, as well as economic incentives and legal system – according to the World Banks' concept of KBE pillars. This idea is rooted in earlier works on economic growth theories, like those of Nelson and Winter (1982), Romer (1990), Grossman and Helpman (1991) or others within the stream of endogenous growth models which stated that knowledge is the main engine of growth. Many publications of OECD (1996, 1999, 2001, 2001a, 2002, 2003, 2005) or of the World Bank (1998; Dahlman and Aubert, 2001; Dahlman and Utz, 2005) have been devoted to such ideas. They started and strengthened a kind of fashion in economics for research on knowledge. Their applications have soon been found in management sciences and its new discipline called "knowledge management" (introduced by Nonaka and Takeguchi, 1995). Some even state that there is "economics of knowledge" (Foray, 2004).

Very soon, however, theoretical problems appeared and as Aghion and Howitt (1998) noted:

> *we do not have any generally accepted empirical measures of such key theoretical concepts as the stock of technological knowledge…* (p. 435),

and as they also noticed, it is not a problem of the wrong data but the lack of theory. This sentence is true also nowadays.

Before we start analysing the knowledge economy, we should define it starting from the notion of knowledge. Knowledge itself has been sufficiently well defined by e.g. Lundvall and Johnson (1994) (know-what, know-why, know-how, know-who). We can recall the "classic" KBE definition of OECD (1996), where KBEs are those, which:

> *are directly based on the production, distribution and use of knowledge and information*.

Later Dahlman (1998) added 'acquisition' to this specification.

We still lack some universally accepted system of knowledge measurement (and knowledge economy in consequence, as well; see Howitt, 1996), and some even question if knowledge can be measurable, at all (Steedman, 2003).[3] There are, of course, many definitions of knowledge and knowledge economy as well. However, in order to check knowledge-growth relations, the measures are neces-

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[2] The second phrase is a synonym; however, some economists call for usage of "knowledge-driven economy" as a term with more precise meaning.

[3] There are, however, a few theoretical contributions to growth models, which include knowledge as a factor of growth (see e.g. the most recent one: Welfe, 2006).

sary. We can distinguish between the following ways of knowledge economy measurement (for further details see Piech, 2004):

a) identification of the knowledge sector and measurement of its share in GDP – Machlup (1962), Porat and Rubin (1997), but also partly OECD (1998), which used contribution of knowledge industries and services in total value-added of firms;
b) share of knowledge activities in all sectors – the Machlup-Porat-OECD's approach should be rejected because knowledge spreads across all sectors and is not concentrated in some of them only; thus, Eliasson (1990) proposes counting working time devoted to knowledge-intensive activities; K. Smith (1995) followed this stream and counted R&D spendings, employment rates of graduates and the rate of new technologies application in all sectors as a proxy for intensity of knowledge;
c) productivity measures – through growth models identifying share of knowledge to GDP growth with Solow's residual (or its part);
d) econometric models – trials to model knowledge activities with the use of econometrics; however, so far the results remain limited to theoretical concepts;
e) multi-variable analysis – description of knowledge-economies with the use of dozens or even hundreds of indicators;
f) single index – the approach used by e.g. the World Bank Institute in its Knowledge Economy Indicator;
g) input measures: single and aggregate – while it is possible to measure some inputs into knowledge creation through single variable (R&D expenditures (GERD) are the most popular) or a composition of a few of them ("investment in knowledge" of OECD);
h) output measures – here we can enumerate approximation of "rates of return" or an overview of different indicators (e.g. number of patents, scientific articles, etc.), like in multi-variable presentations.

This paper is not an attempt to develop any new measurement system but uses the existing measures, considered by the author to be the best.

2.2. Economic growth and knowledge: the review of empirical contributions

Despite theoretical problems connected with measurement of knowledge and knowledge economy, we can find results showing that knowledge can be very important for growth. Knowledge is often associated with a TFP measure. According to Denison and Chung (1976), knowledge contributed to 22.4% of Japanese growth in 1953-71 and 29.8% of the U.S. growth in 1948-69. Other estimations – also based on a TFP approach – run later by Shinohara (1986) indicated that knowledge contributed to the growth of Japan in 45% in 1960-70 and in 41.5% in 1970-80.

In order to estimate the impact of knowledge on growth, estimates of total factor productivity are usually made. They are often based on a modified Cobb-Douglas production function:

$$Q = \alpha R^{\theta} K^{b} L^{1-b},$$

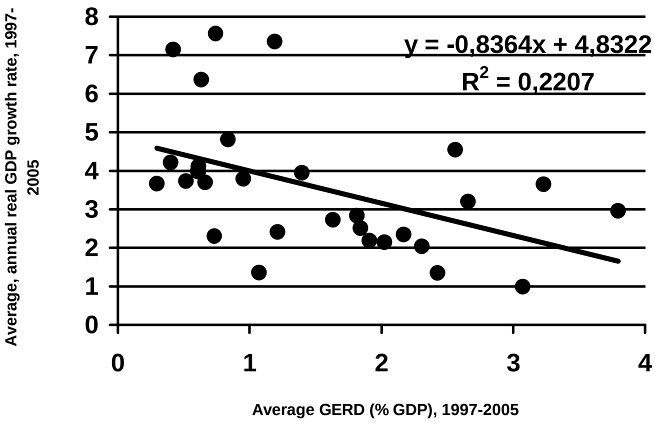
where:

Q – product,
R – stock of knowledge,
K – capital,
L – labour.

R is not directly measured and thus its increase related to product is approximated by annual expenditures on research and development (R&D) related to market value added of industry or a firm.

The results of different studies gathered by Flath (2000, p. 336) conducted with the use of "rates of return" estimates show that one dollar spent on R&D generated from 22 to 52 cents in Japan (in 50 analysed industries) and from 11 to 31 cents in the U.S. (in 193 analysed industries).[4]

Figure 2.1. Average rates of economic growth and GERD, 1997-2005



Note: UE-27 countries (except Luxembourg and Malta) and Turkey, Iceland, Norway, United States, Japan. There were some gaps in data series (the maximum of three lacking data was allowed for a particular country). The sample limited to UE27 countries did not change much the above results.
Source: Eurostat (2007).

[4] R&D expenditures in Japan were characterised by higher return rates than in the U.S., because of more frequent imitation of products in Japan.

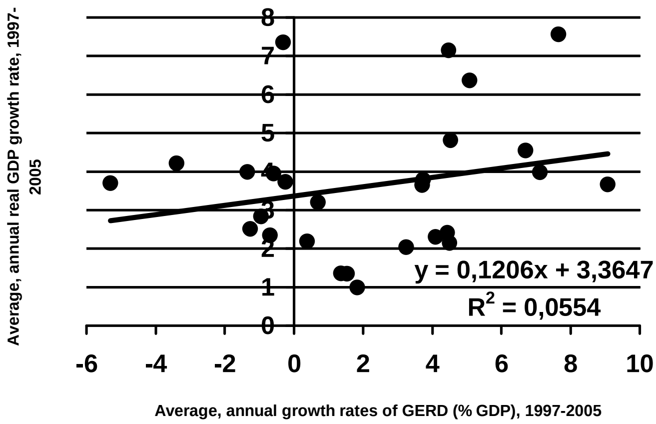
It is believed that gross expenditures on research and development (GERD) increase the pace of the long-term economic growth. However, Figures 2.1 and 2.2 show very weak evidence of it.

The first one compares average gross expenditures on research and developpment (GERD) related to GDP of the period 1997-2005 with the average annual growth rates of GDP of the same period. The trend line is surprisingly negative but still the correlation coefficient is very weak.

The aim of the figure 2.2 was to check if the pace of growth of GERD is correlated with the pace of economic growth (of GDP). Similarily to the previous excersise, the same time period was taken into account. This time, though the trend line is positive, correlation does not exist (in other words – it is statistically insignificant).

Further studies (not presented here graphically) show that there is stronger (statistically significant) correlation while comparing economic growth rates with the level of GDP per capita. These results are confirmed by e.g. Zienkowski (2003) who found that there is a relation (measured by correlation coefficients) between outlays on R&D related to GDP and the level of GDP per capita.

Figure 2.2. Average rates of economic growth and of GERD changes, 1997-2005



Note: UE-27 countries (except Greece, Luxembourg, Malta and Sweden) and Turkey, Iceland, United States, Japan. There were some gaps in data series (the maximum of three lacking data was allowed for a particular country). The sample limited to UE27 countries did not change much the above results.
Source: Eurostat (2007) and own counts based on it.

One of the fundamental recommendations of the Lisbon agenda was to increase R&D spending from 2% to 3% of GDP in EU until 2010. It is believed that this will give a boost to the EU economy and decrease a constantly-widening development gap between EU and the U.S. Partly as a result of these attempts, R&D spending have grown faster in the EU (3.3% a year) than in the United States and Japan (2.7%) since 1995 (OECD 2005). Figures 2.1 and 2.2 show, however, that R&D-growth relations are not so obvious. Moreover, the examples of Ireland and Slovakia during the last years show that it is possible to achieve high growth rates even with falling expenditures on R&D (GERD). Thus, factors other than R&D are important for the fast long-term growth as well.

The knowledge economy is not only the R&D sector; knowledge is mostly created there but is stored and commercialised also in other sectors. Thus, innovation systems are needed to enable profits from an increase in the stock of knowledge as well as information infrastructure to support the exchange of new knowledge. A basis for R&D is education system, which also plays an important role in absorption of innovations. All of these elements are required for coherent strategies to build knowledge economies. Their implementation resulted in fast progress of e.g. Korea, Malaysia, Finland, China, or Chile (WBI, 2005).

According to OECD, not only R&D expenditures are important for growth. It uses another approach (presented further in this text) and another measure: "investment in knowledge", which includes – apart from expenditures on R&D and higher education – also expenditures on software – a crucial factor "driving" growth of this measure in most OECD countries; OECD, 2005). Such investments are the highest in the U.S. (6.6% of GDP) and Japan (5.0%), while EU is lagging behind (3.8%). In most OECD countries, increase in "investment in knowledge" was mostly caused by growing expenditures on software (OECD, 2005).

2.3. Economic growth and knowledge economy: empirical study

This research is aimed at checking if there are relations between economic growth and the development of knowledge economy (initial results presented in Piech, 2006). It will be based first on stating if there is any statistical similarity between corresponding data series (measured by linear correlation coefficient) and, if so, which elements of so-called knowledge economy determine economic growth (regression analysis).

The whole study is based on the approach created and used by the World Bank Institute. There are a few other possible approaches (see Piech, 2004), however, this one is the most advanced one from methodological point of view (e.g., it uses normalised data) as well as concerning geographical coverage (128 countries). Thus, we will use a different way of studying the growth-knowledge relation: not based on growth models but on similarities between the pace of economic growth and the development of knowledge economy.

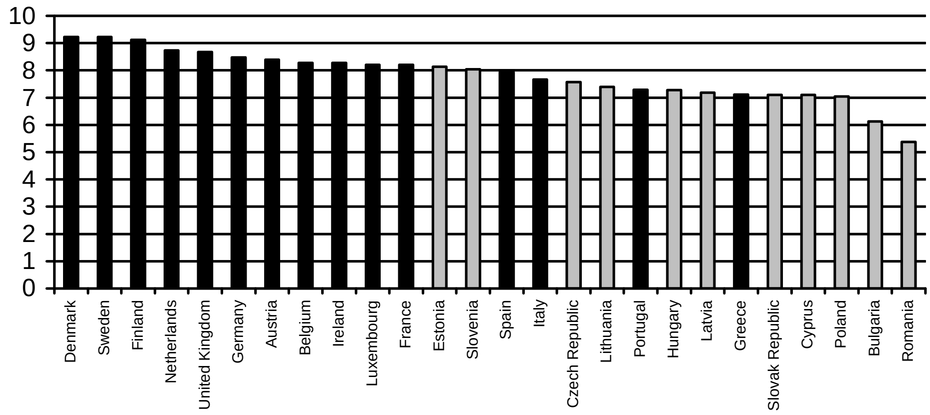
The World Bank Institute (WBI) developed the Knowledge Economy Indicator (KEI) as well as Knowledge Indicator (KI). They enable quite clear international comparisons for a wide variety of countries (both of them are normalised within the range <0, 10>; the higher the value, the more advanced the country is in KBE development). KEI follows WBI's concept of four pillars of KBE and consists of 12 variables categorized into four groups (three variables in each):

1. economic incentive and institutional regime (*Econ*): tariff and nontariff barriers, regulatory quality, rule of law;
2. education and human resources (*Edu*): adult literacy rate, secondary enrolment, tertiary enrolment;
3. innovation system (*Innov*): researchers in R&D, patent applications granted by the US Patent and Trademark Office (per million pop.), scientific and technical journal articles;
4. information and communication technology (*Inf*): no. of telephones (per 1,000 people), no. of computers (per 1,000 people), no. of internet users (per 10,000 people).

KI contains the data from the last three groups only.

The world leaders in the field of knowledge economy development at the end of 2006 were (figure 2.3): Denmark, Sweden, Finland, Iceland, Norway, the U.S. Japan was as far as on 14th place.

Figure 2.3. Knowledge Economy Index, 2006, EU members (except Malta)

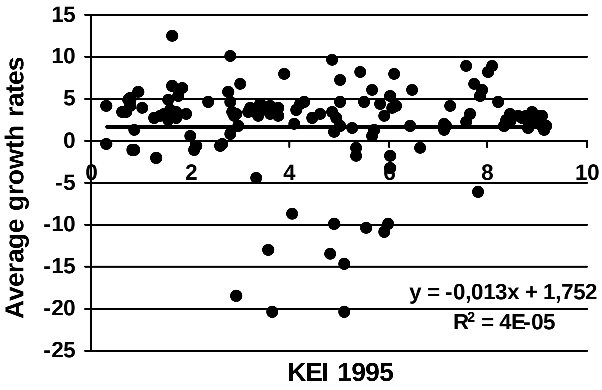


Note: shaded bars indicate new EU member states.
Source: WBI (2006).

The basis for data on growth was 10-year average of annual rates of real GDP growth - to avoid problems with short-term fluctuations (business cycles etc.).

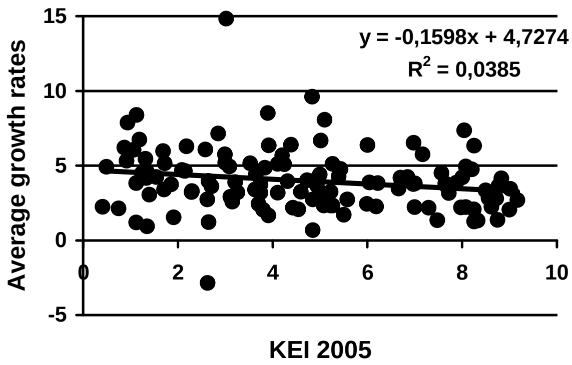
KEI data are available only for two years: 1995 and 2005. Thus, below I present an average pace of real GDP growth in 1985-95 with KEI for 1995 (figure 2.4) and average GDP in 1996-2005 with KEI for 2005 (figure 2.5).

Figure 2.4. Average GDP growth in 1986-95 and KEI for 1995



Source: WBI (2005) and own counts based on IMF (2005).

Figure 2.5. Average GDP growth in 1996-2005 and KEI for 2005

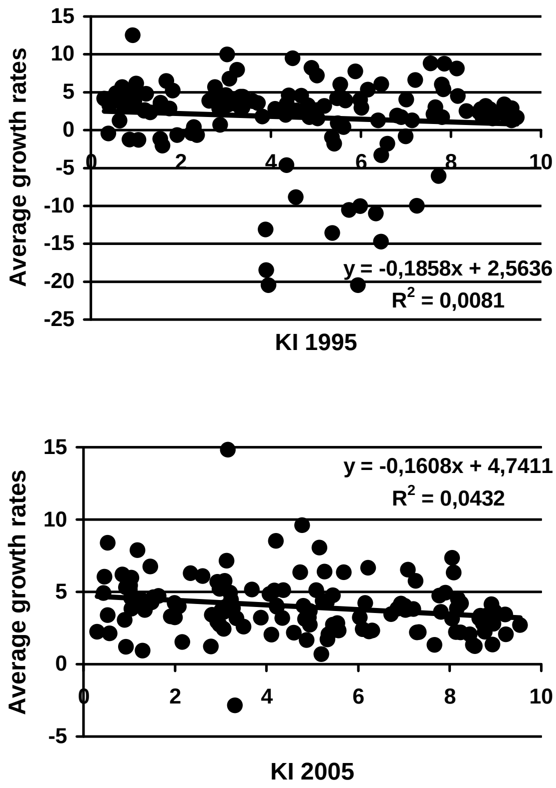


Source: WBI (2005) and own counts based on IMF (2005).

We see that there are no- or only week relations in the analysed sample of 128 countries. Correlation coefficient is not significantly (5% level is used) different from zero (-0.006) in the first case and significant but weak in the second one (-0.196). The second result is different than we could have expected (negative sign).

In the following paragraphs, we have conducted further exercises trying to catch the growth-knowledge economy relations. First, I checked if the KEI is not too broad an indicator and narrowed it to KI (figure 2.6).

Figure 2.6. Average growth in 1986-95 with KEI 1995 and growth in 1996-2005 with KEI 2005

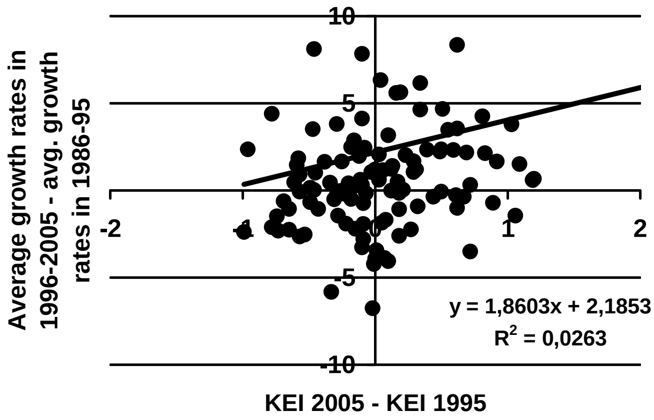


Source: WBI (2005) and own counts based on IMF (2005).

The results, however, are similar to the previous ones. While there is no correlation, we can say that both Knowledge Economy Index and Knowledge Index of the WBI did not determine 10-year average growth rates in the analysed sample of 128 countries.

Below we checked if there is a relation between the change of KEI between 1995 and 2005 and the change of average growth rates in the period 1986-95 and 1996-2005.

Figure 2.7. Change of KEI in period 1995-2005 and change of 10-year average growth rates, 128 countries



Source: own counts based on WBI (2005) and IMF (2005).

The results are similar again, i.e. there is no relation between change of Knowledge Economy Index and change of average long-term growth rates (usage of KI (not presented above) instead of KEI did not change this conclusion).

Having quite large sample of countries, we can eliminate those of them, which were characterised by phenomena that significantly influenced their growth, but are very unlikely to happen again. These are first the transition countries – their growth especially during the first half of 1990s was usually slower (or even negative). The other countries were Eritrea (creation of country in 1993) and Qatar (reduced oil earnings). As a result, 102 countries were left. Similarly, we used change of KEI during 10 years. The results (not presented graphically) of correlation were slightly higher: 0.207 in comparison to 0.162 in the previous case, however still too low to obtain clear answers. Hence, we decided for further limitation of the sample.

We have tested the hypothesis if knowledge economy development increases growth rates not in all countries, but only in those, which reached some higher level of economic development. We have chosen a sample of 26 OECD countries (excluding transition ones – see above for explanations). The correlation coefficient obtained accounted for only 0.045. Thus, there is also no relation between increase of average economic growth and increase of KEI (similar counts for KI only also did not provide significant results; correlation was equal to -0.194).

Interesting can be, which elements of KEI (or KI) had the largest impact on economic growth. Hence, we split KEI into four groups and if necessary, eliminate most non-significant KBE pillars. We run regression analysis with OLE for the sample of 26 OECD countries and obtained the following:

$$\Delta GDP = 0.55 + 0.71 Econ - 0.25 Innov + 1.31 Edu - 1.26 Inf$$
$$\quad\quad 0.46 \quad 0.57 \quad 0.82 \quad 0.55 \quad 1.02$$

where:

ΔGDP is a change of 10-year average rates of real GDP growth between the period 1986-95 and the period 1996-2005, and

Econ, *Innov*, *Edu*, *Inf* – changes of respective KBE pillars within 10 years (between 1995 and 2005).

Quality of model: $R^2 = 0.35, \overline{R}^2 = 0.22$[5], passed *F*-statistic test (5% level), however *Innov* variable was unacceptable (very high standard error and not passed t-statistic test). Thus, we have run the next regression without *Innov*. The model obtained was of similar quality $R^2 = 0.35, \overline{R}^2 = 0.26$ however this time two variables were unacceptable (*Econ* and *Edu*) and a sign of *Inf* was negative, what is contrary to the theory (that improvement in information infrastructure lead to increase of GDP). Thus, the trial to indicate, which KBE pillars are crucial for increase of the pace of economic growth, brought no conclusive results.

Finally, we have limited the sample to only such countries, which are the most advanced in KEI. We have chosen only 10 countries with the highest KEI in 2005, namely Sweden, Finland, Denmark, Iceland, Australia, Switzerland, UK, Netherlands, New Zealand, and Norway (figure 2.8). Interesting in this sample is that the growth of KEI was only in the case of Iceland (in other cases KEI has decreased – see figure 2.7).

The correlation coefficient accounted for 0.666 and was statistically significant, however very weak due to its value given small number of observations. Moreover, addition of other countries to the sample or its limitation results in smaller value of correlation coefficient (statistically insignificant).

2.4. Economic growth and investment in knowledge: empirical research

Below we will base on another approach, proposed by OECD. We will use 'investment in knowledge' (instead of KEI or KI), as a measure, trying to check if really "such investment is crucial for economic growth" (OECD 2005)?

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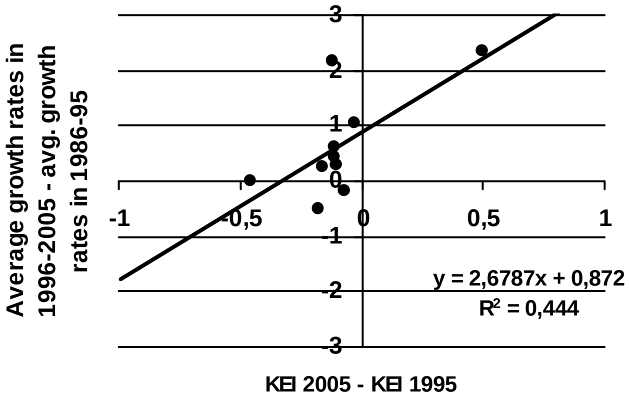
[5] Similar counts were conducted for the sample of 102 countries; however $\overline{R}^2 = 0.09$, thus the model was not presented.

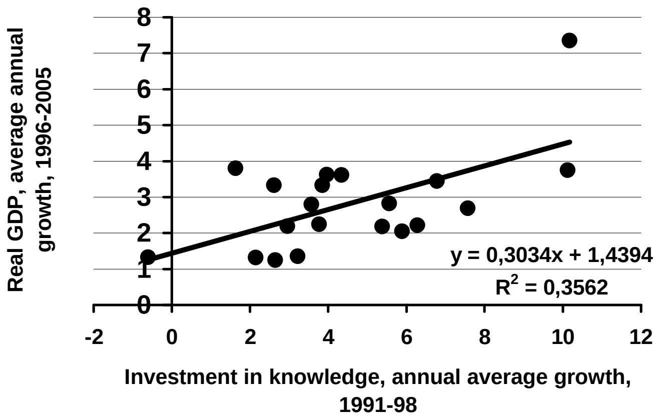
Figure 2.8. Increase of KEI in period 1995-2005 and increase of average growth rates, 10 most advanced in KEI countries



Source: own counts based on WBI (2005) and IMF (2005).

'Investment in knowledge' is a sum of expenditures on R&D, software and higher education – all related to GDP. Below we present data on 'investment in knowledge' with average (10-year) pace of economic growth for 19 OECD countries (data for broader sample or longer time series – unavailable). First, there were collected data on average annual growth rates of investment in knowledge in 1991-98 with average growth rates in 1996-2005 (figure 2.9).

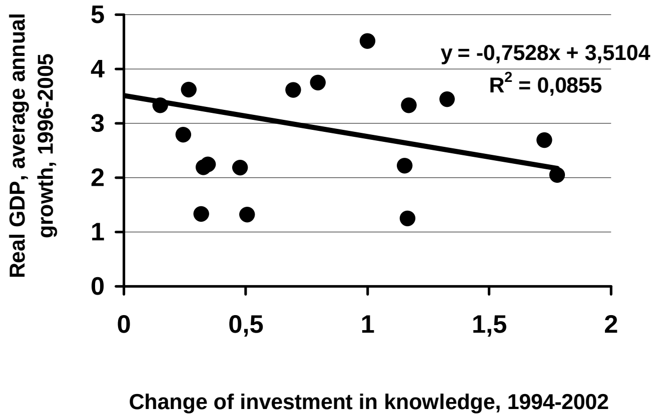
Figure 2.9. Average pace of growth and average growth rates of investment in knowledge



Note: Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, UK, US.
Source: OECD (2001) and own counts based on IMF (2005).

Results show weak correlation between these two variables. We can say that an increase in annual average growth rate of investment in knowledge might increase average growth rates of GDP in further years.

Figure 2.10. Average pace of growth and growth of investment in knowledge in 1994-2002



Note: the sample consists of Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden, UK, US.
Source: OECD (2005) and own counts based on IMF (2005).

I also checked relations between a change of 'investment in knowledge' between 1994 and 2002 to GDP ratio with an average annual growth rate of GDP in 1996-2005 (figure 2.10) and next – with a change in average annual growth rates between 1986-1995 and 1996-2005 (not presented graphically due to similar results). In both cases, there were no relations between the variables.

The results are different from conclusions of OECD (2005) on the above sample (including Korea), which shows that contribution of investment in knowledge to the growth as a percentage of GDP in 1994-2002 was ranging from -0.2 in the case of Ireland to 1.8 in Denmark. This was, however, a direct contribution to GDP (change of share of expenditures on three components of 'investment in knowledge' in GDP over time).

2.5. Conclusions

Despite a common belief in the key role of knowledge in economic growth, the matter of quantitative proof is problematic. The problems refer to the lack of a theory defining how knowledge economy should be measured. Without it, we have to use indicators, which approximate knowledge economy or expenditures on knowledge. In the first case we use Knowledge Economy Indicator developed by the World Bank Institute and in the second one – 'investment in knowledge' provided by OECD. However, in the first case we could not find evidence on relations with a long-term pace of economic growth and in the second case – the correlation exists but is weak. Moreover, no correlation was found between the speed of building knowledge economy (approximated by change of KEI over 10 years) and a long-term pace of growth.

Assuming that economic theories and common opinions supported by many reports of international institutions on existence of knowledge economy – growth relations are right, the conclusion should be that the existing measures of knowledge economy are not good enough. Further progress in methodology of measurement of knowledge economy is necessary in order to prove the existence of the knowledge – pace of growth relations. The existing indicators do not allow for confirmation of them.

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