INSTITUTE FOR
INNOVATION AND
TECHNOLOGY


# An IQ Test for Countries

## iit Innovation Capability Indicator

Ernst A. Hartmann, Sebastian von Engelhardt, Nadine Birner

## Imprint

**Published by**
Prof Volker Wittpahl
Institute for Innovation and Technology (iit)
Part of VDI/VDE Innovation + Technology GmbH

Steinplatz 1
10623 Berlin / Germany
Tel.: +49 30 310078-5507
Fax: +49 30 310078-104
E-mail: info@iit-berlin.de

www.iit-berlin.de/en

**Authors**
Ernst A. Hartmann
Sebastian von Engelhardt
Nadine Birner

**Layout**
A.-S. Piehl, VDI/VDE Innovation + Technik GmbH

**Image credit**
Monika Molin (image design for title page)

Berlin, May 2018

# Contents

# Introduction

There is no need to convince anyone that in developed economies, the capacity to innovate is one of the most important prerequisites for competitiveness and prosperity. This makes it all the more surprising that there are not yet any widely-used methods for measuring and assessing innovation capability. With the use of categories such as 'enablers' or 'absorptive capacity', established innovation indicators do cover some ground that relates to aspects of innovation capability. However, the construct of 'innovation capability' is not adequately reflected by these categories because they are either too narrow or too broad. There is often insufficient clarity in the distinction between 'innovation' and 'innovation capability'.

The intelligence of an individual person is a prerequisite for cognitive performance at school, in training settings and in the workplace. Similarly, an economy's 'collective intelligence' is what enables it to innovate – its innovation capability. The Institute for Innovation and Technology (iit) in Berlin has developed the iit Innovation Capability Indicator, which is an instrument for comprehensively depicting the innovation capability of economies (Hartmann et al. 2014), regions, sectors and companies.

### Why develop a new indicator?

Innovation is about creating new things, i.e. new products and processes. Without ideas, knowledge and skills, no innovations can be introduced. Only those with the ability to create new things will be able to be constantly innovative. As such, the ability to innovate is one of the most crucial abilities required for competing in the 21st century marketplace.

The focus on innovation capability results in a perspective that differs from conventional innovation indicators, which are based on the well-established input-throughput-output model. In the input-throughput-output model, the innovative process is depicted as a kind of production function. The input (e.g. research and development expenditure) goes through the 'production process' – via the throughput stage (e.g. patents) – and becomes an output (e.g. new products). It is common knowledge, however, that different countries have different 'innovation production functions'. The effect of 1,000 new engineers in France will not be the same as the effect of 1,000 new engineers in Greece. For this reason, conventional innovation indicators not only account for input factors but also for throughput factors and output factors.

Nevertheless, the innovation capability – the ability to use inputs to generate throughputs and outputs – is not specified or depicted by these indicators. Innovation capability, however, is the very factor that determines the efficiency of a country's 'innovation production function'. The European Commission's 'European Innovation Scoreboard' (EIS)[1] and the innovation indicator developed by Germany's academy for technological knowledge (acatech) in partnership with the Federation of German Industries (BDI)[2] are two examples of well-known innovation indicators. The EIS includes the sub-indicator 'enablers', which touches on aspects of innovation capability. From an innovation capability perspective, however, this sub-indicator is too broad in some ways. For example, it includes data about public spending on research and development, which is more pertinent to general resources and framework conditions. In other ways, the 'enablers' sub-indicator is too narrow. Higher education is the only aspect of human capital that is considered. This means that vocational training, which is proven to make an important contribution, is not included. On the other hand, the BDI/acatech indicator combines the conventional input-throughput-output model with an emphasis on the subsystems within the innovation system: the state, education, research, the private sector and wider society. The indicators in these subsystems range from very basic conditions such as the risk affinity/aversion of the population, right through to the indirect consequences of the innovation process, such as GDP growth. It is extremely difficult to distil innovation capability from these indicators. Furthermore, the way that requirements, innovative performance itself and its consequences are blended in these kinds of composite indicators causes serious methodological problems given the basic logic of the input-output model and of the innovation efficiency approach.

The iit Innovation Capability Indicator, however, makes it possible to perform a clear and rigorous analysis of innovation capability. Furthermore, the innovation capability it measures can be contrasted with clearly defined metrics of innovative performance including product and process innovations – the EIS sub-indicator 'outputs', for instance.

1 European Innovation Scoreboard: http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en
2 Innovation Indicator 2017 by Germany's academy for technological knowledge (acatech) in partnership with the Federation of German Industries (BDI): www.innovationsindikator.de

# iit Innovation Capability Indicator: An IQ Test for Countries

'Innovation capability' is defined as the capacity of a group, organisation, network or society to continuously generate innovations (Trantow et al. 2011). Following this definition, innovation capability is determined by the stock of knowledge available and the ability to combine useful knowledge. Thus an economy's capacity to innovate and to translate these innovations into competitive products, processes and services is not only determined by the quality and diversity of the knowledge it possesses but also by its ability to combine the different stocks of knowledge that are available.

As such, according to the definition used by the iit (Hartmann et al. 2014), the innovation capability of countries is not only determined by the quality of the education and training of the workforce in the country and the diversity of useful knowledge that makes it possible to manufacture complex products. It is also determined by the ability of organisations to combine various internal and external stocks of knowledge (see Figure 1).

## Indicator concept

Since (economic) innovations are primarily introduced by companies and entrepreneurs, the theoretical approach of the iit Innovation Capability Indicator starts with the company level. In order to be able to compare different countries, the company level data is then aggregated to the national level.

In theoretical terms, the iit Innovation Capability Indicator draws on the approaches of Cohen and Levinthal (1990), Stewart (1998) and on a development of Stewart's concept by Alwert (2006), which describes human, structural and relational capital as being determinants of a company's innovation capability. The iit has built on this concept and added the idea of complexity capital, which draws on the theoretical considerations of the 'Atlas of Economic Complexity' (Hausmann et al. 2013). As a result, the iit Innovation Capability Indicator covers four areas of capital, which together determine the capacity for innovation:

- Human capital: The education, training and lifelong learning of the workforce
- Complexity capital: The diversity of useful knowledge, which makes it possible to manufacture complex products
- Structural capital: The ability to combine knowledge from within the company
- Relational capital: The ability to combine knowledge from outside the organisation

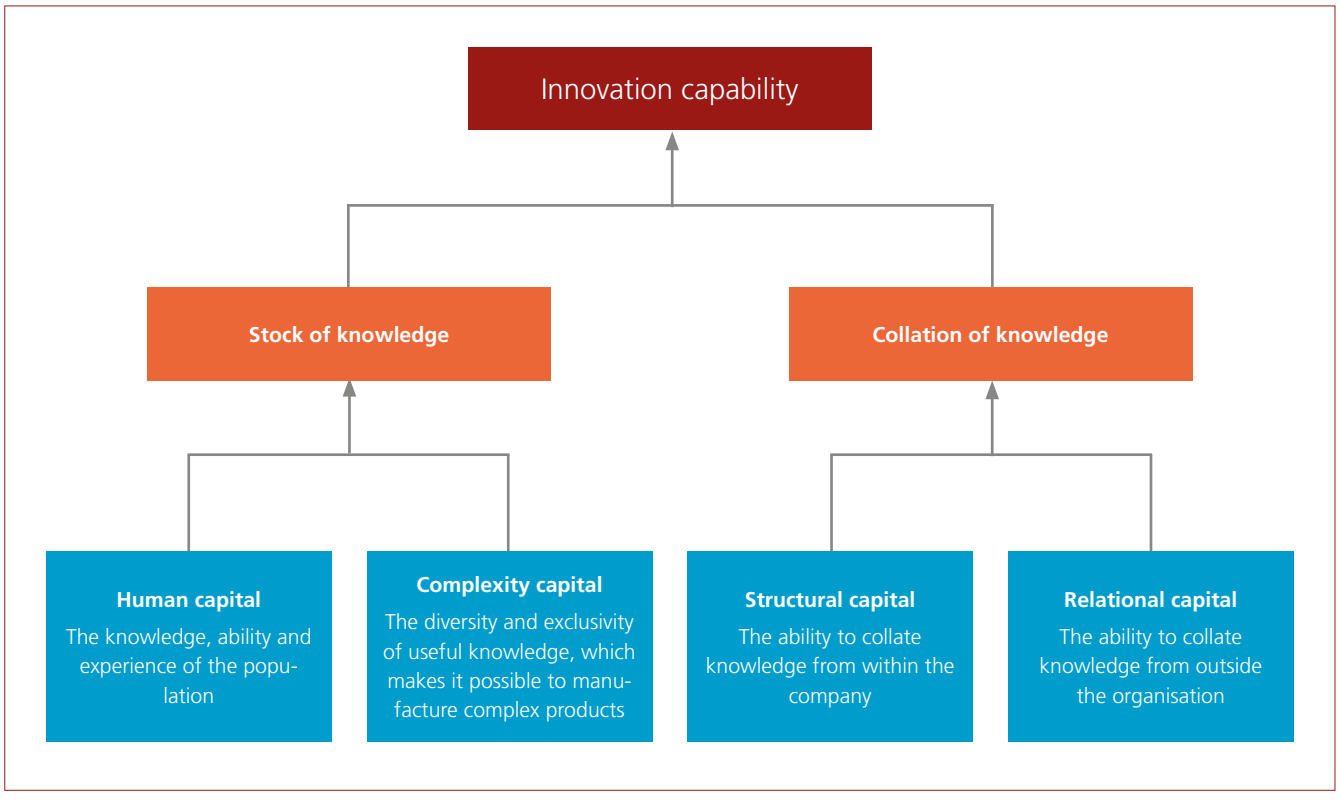


Figure 1: Innovation capability as the ability to use knowledge

*Human capital* is determined by the knowledge, abilities, skills, competencies and experience of the employees. Human capital is a key determinant for innovation capacity because without well-educated employees, there can be no innovation.

Nevertheless, innovation requires more than just a highly-qualified workforce. For the design and manufacture of innovative, complex products, it is necessary for wide-ranging expertise and diverse stocks of knowledge to interact and be combined. Innovation research has shown that both the intensity of knowledge (level of qualification etc.) and the diversity of useful knowledge are important for innovation capability (Tavassoli and Carbonara 2014; Beaudry and Schiffauerova 2009; Audretsch and Feldman 2004; Audretsch and Vivarelli 1996). Hence the heterogeneity of knowledge is a key determinant for the innovation capability of industrial districts (Carbonara and Tavassoli 2013). The diversity of the useful knowledge that is available is denoted by the term *complexity capital*.

Nonetheless, the diversified knowledge of a highly qualified, specialised workforce can only be utilised if these competencies are brought together. In the iit Innovation Capability Indicator, the ability to combine knowledge from within and outside of an organisation is depicted using the concepts of *structural capital* and *relational capital*.

*Structural capital* denotes internal structures and processes that combine the knowledge dispersed throughout an organisation and by doing so contribute to the company's innovation capability. Such structures include R&D[3] units and organisational structures that promote learning throughout the whole company (Hartmann and Garibaldo 2011).

*Relational capital* denotes the network of relationships that the company has with external players. This includes any of the company's relationships with external groups – such as partners in the private sector, the scientific and education sectors, politics and government – that are of relevance to knowledge creation and knowledge transfer in the innovation process.

## Data set and indicator calculations

The iit Innovation Capability Indicator uses various sets of data from areas relating to human capital, complexity capital, structural capital and relational capital. In order to measure human capital, the iit Innovation Capability Indicator relies on data about tertiary education and training – including informal learning – from European Union statistics on education and innovation. The data about tertiary education includes the share of new PhD students and the share of the population aged 30 to 34 who have a degree qualification. The data source for this is the Innovation Union Scoreboard.

The data on training and informal learning was taken from the Adult Education Survey and the Continuing Vocational Training Survey. Data about initial vocational training would also be important for measuring human capital. Not least because Germany is uniquely positioned on account of its dual vocational training system. Indeed, the OECD studies of vocational education attest that Germany has an exceptionally well-developed vocational training system (Fazekas and Field 2013). Nevertheless, since vocational training systems differ fundamentally from country to country, the standardised international empirics of educational systems do not include vocational training.

The source of the data for complexity capital is the Economic Complexity Index, which is based on a concept developed by researchers from MIT and Harvard University (Hausmann et al. 2013).

The way the Economic Complexity Index is structured is reminiscent of an IQ test. To test people's intelligence, we ask them to solve tasks that we presume will require intelligence. An obvious measure of intelligence is the difficulty of a task that a person is only just able to solve. Conversely, the difficulty of a task can be measured by the proportion of people who are able to solve it. As such, the people are measured by the tasks and the tasks are measured by the people. The complexity index uses a similar approach at an economy-wide level. 'Clever' countries are able to produce and successfully export 'difficult' things that not many other countries are able to produce. Conversely, products that are not produced by many countries are denoted as 'difficult'. It is the view of the authors that the specific ability to combine a diverse range of specialised components in new ways – again and again – is what makes economies 'complex' and 'clever' in these terms.

In terms of structural capital, the iit Innovation Capability Indicator uses data about workplace structures that promote learning and about the R&D workforce in the private sector. In essence, the extent to which an organisation promotes learning encompasses two strands. The first of these is participation – the extent to which and the ways in which employees can help shape their working conditions. The second is task complexity – how varied and demanding the tasks are and the intensity of learning involved. The source of data about these areas is the European Work Condition Survey. As a proxy for the size of R&D departments, data on R&D-employees was used. The data source for this is the Community Innovation Survey.

3 R&D' stands for 'research and development'

Depicting relational capital involves the use of data concerning R&D collaboration between companies and other companies, research institutes and higher education institutions. The data sources used for this include the European Union Scoreboard and the Community Innovation Survey.

The data for the areas of human capital, complexity capital, structural capital and relational capital was aggregated into the respective sub-indicator categories. These four sub-indicators then feed into the overall indicator. The relative weighting of the individual sub-indicators was determined by statistical analysis (regression analysis).

Innovation capability is the ability to innovate. A country with a higher innovation capability will also have a higher level of innovative performance than countries with low levels of innovation capability. As such, an indicator for innovation capability should be able to predict a country's actual innovative performance. For this reason, the relative weighting that was chosen for the individual sub-indicators corresponds to the combination that best predicts innovative performance. This was measured against the EIS output indicators.

# Summary and Outlook

The iit Innovation Capability Indicator is built on the insight that innovation capability is driven by knowledge, i.e. by the use of in-depth specialist knowledge (human capital), by the diversity of the knowledge available (complexity capital) and by the ability of companies to combine these different stocks of knowledge, both internally (structural capital) and across organisations (relational capital).

In this way, the iit Innovation Capability Indicator analyses aspects that are not captured by other indicators:

- It makes explicit, clear-cut reference to innovation capability as opposed to innovative performance.
- In the area of human capital, lifelong learning is factored in – which is not the case with any of the other indicator systems. This factor is very important, particularly in light of the demographic changes taking place, the resulting elongation of working lifetimes and the accelerated pace of technological change.
- By including complexity capital, the important role that knowledge diversity plays in innovation capability is also recognised.
- In terms of structural capital, clear emphasis is given to the importance of workplace structures that promote learning and of innovative working environments – no other indicator system includes these factors either. This eradicates one of the blind spots of innovation indicators.

In order to foster and strengthen 'industrial ecosystems', there is a need for targeted innovation policies that constantly monitor the whole range of components associated with innovation capability. These components include the training of very highly qualified people (post-doctoral level), life-long and informal learning, structures for R&D partnerships between the private sector and academia and structures within companies that promote learning and innovation. Here, a positive interplay between these components is likely to make more of an impact than the isolated optimisation of individual aspects.

If a differentiated analysis of an economy's innovation capability is performed, innovation policy can be tailored more accurately. After all, political measures that target crucial areas can only be suggested once the relative strengths and weaknesses of a country have been analysed across the four dimensions (human capital, complexity capital, structural capital and relational capital). These targeted measures then improve the country's innovation capability, which in turn strengthens its long-term innovative performance. For example, a country that is relatively weak in the areas of relational and human capital would require different measures to a country with pronounced weaknesses in the area of structural capital. For instance, analysis of the structural capital sub-indicators in the latter example might reveal that improvements are needed in the workplace structures that promote learning. In the former example – a country with weaknesses in the areas of relational and human capital – a differentiated analysis might show that new forms of collaboration could provide alternative ways of utilising potential that has previously been unused (or not used efficiently enough).

The iit Innovation Capability Indicator provides decision makers from politics and the private sector with a reliable instrument with which they can measure the ability of countries to turn ideas into new products and services. This specialised indicator makes it possible to translate the results of rigorous empirical analysis into real specific measures for economic, education and research policy that yield targeted improvements to the country's innovation capability.

# Reference List


- Alwert, K. (2006). Wissensbilanzen für mittelständische Organisationen. Stuttgart, Fraunhofer IRB Verlag.
- Audretsch, D. B. und Feldman, M. P. (2004). Knowledge spillovers and the geography of innovation. In: Henderson, J. V. und Thisse, J. (Hrsg.): Handbook of Urban and Regional Economics: Cities and Geography (Vol. 4), S. 2713–2739. Amsterdam, North Holland Publishing.
- Audretsch, D. B. und Vivarelli, M. (1996). Small firms and spillovers: Evidence from Italy. In: Small Business Economics, 8 (3), S. 249–258.
- Beaudry, C. und Schiffauerova, A. (2009). Who's right, Marshall or Jacobs? The localization versus urbanization debate. In: Research Policy, 38 (2), S. 318–337.
- Carbonara, N. und Tavassoli, S. (2013). The Role of Knowledge Heterogeneity on the Innovative Capability of Industrial Districts. In: Karlsson, C.; Johansson, B.; Stough, R. (Hrsg.): Entrepreneurial Knowledge, Technology and the Transformation of Regions. London/New York, Routledge.
- Cohen, W. M. und Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. In: Administrative Science Quarterly, 35(1), S. 128–152.
- Fazekas, M. und Field, S. (2013). A Skills beyond School Review of Germany. In: Organisation für Economic Co-Operation and Development (OECD) (Hrsg.): OECD Reviews of Vocational Education and Training. OECD Publishing.
- Hartmann, E. A.; Engelhardt, S. v.; Hering, M.; Wangler, L.; Birner, N. (2014). Der iit-Innovationsfähigkeitsindikator: Ein neuer Blick auf die Voraussetzungen von Innovationen. Arbeitspapier: iit perspektive Nr. 16. Institut für Innovation und Technik (iit) (Hrsg.). Verfügbar unter: www.iit-berlin.de/de/publikationen/der-iit-innovationsfaehigkeitsindikator, zuletzt zugegriffen am 01.02.2018.
- Hartmann, E. A. und Garibaldo, F. (2011). What´s going on out there? Designing work systems for learning in real life. In: Jeschke, S.; Isenhardt, I.; Hees, F; Trantow, S. (Hrsg.): Enabling Innovation: Innovative Capability – German and International Views. Berlin, Springer.
- Hausmann, R.; Hidalgo, C.; Bustos, S.; Coscia, M.; Simoes, A.; Yildirim, M. (2013). The Atlas of Economic Complexity: Mapping Paths to Prosperity. Cambridge/Massachusetts, MIT Press.
- Tavassoli, S. und Carbonara, N. (2014). The role of knowledge variety and intensity for regional innovation. In: Small Business Economics, 43(2), S. 493–509.
- Trantow, S., Hees, F., Jeschke, S. (2011). Innovative Capability – an Introduction to this Volume. In: Jeschke, S., Isenhardt, I., Hees, F., Trantow, S. (Hrsg.): Enabling Innovation: Innovative Capability – German and International Views. Berlin, Springer.
- Stewart, T. (1998). Intellectual Capital: The New Wealth of Nations. London.

## Institute for Innovation and Technology (iit)

The Institute for Innovation and Technology (iit) is a cross-sectoral facility within VDI/VDE Innovation + Technology GmbH. It offers consultancy in the areas of innovation-related policy and research. The iit also analyses, designs, assists with and evaluates policy programmes for research and innovation in areas where the private sector, science and politics intersect. This work builds on the expertise of more than 250 scientific assistants from all kinds of different disciplines.

For more information, see: www.iit-berlin.de/en

## Authors

Dr Ernst Hartmann

Dr Ernst Hartmann is the director of the Education, Science and Humanities department at VDI/VDE Innovation + Technology GmbH in Berlin. He lectures in the area of work and organisation psychology at RWTH Aachen University. His focus is on the subjects of innovation capability, transmissibility in the education system and on researching the effectiveness of policy in the areas of education, innovation and technology.

Dr Sebastian von Engelhardt

After studying economics, Dr Sebastian von Engelhardt went on to complete a PhD in 'The Economics of Innovative Change' at the DFG Research Training Group in Jena. He then worked on a post-doctoral research project in Jena and Berkeley. Sebastian von Engelhardt has been a scientific assistant at VDI/VDE Innovation + Technology GmbH since 2014, working in the Department for Education, Science and Humanities. The main focus of his work is on innovation capability and innovation indicators.

Nadine Birner

Nadine Birner trained as a market and social researcher. Since 2013, she has been working at VDI/VDE Innovation + Technology GmbH in the department of Education, Science and Humanities. Nadine Birner's responsibilities for the Innovation Capability Indicator project include research, processing and standardisation. She is also responsible for the aggregation of sub-indicators.