

High technology revisited: definition and position

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Abstract - This paper proposes a new approach to defining high technology by distinguishing two different aspects. First, complexity, which is a more or less a 'static' view on high technology and is applied to both the final product as well as the production process. Second, the newness, relates to a requirement to continually update the products or processes.

I. INTRODUCTION

Studies on economic development often focus on the role of technology, see e.g. [1, 2, 3]. For example, Varga [4] emphasizes the importance of high technology for regional development. Many states and/or regions have therefore plans for Technology Based Economic Development (TBED). The State Science & Technology Institute (SSTI) frequently publishes about TBED initiatives in different regions in the U.S. [5]. In many of these instances, the emphasis is on high-technology development. As an example, in 2003, the City of Spokane (Washington) and a group of local organizers designed a strategic plan to help the city and the Inland Northwest achieve an Innovation Economy [6]. The plan for Spokane's Innovation Economy equates technological leadership and innovation with the creation of high-wage jobs [6]. The U.S. congress states that "State and local government leaders are attracted to high-technology industries because of this sector's rapid expansion and its presumed job-creating potential"[7]. High technology is therefore considered important for national and regional economic development and is sometimes equated with high wage jobs.

Varga [4, p.1] provides Silicon Valley, Route 128 and the Cambridge Phenomenon as high technology centers that illustrate the existence of knowledge based economic development. Varga, therefore equates high technology with knowledge intensity and innovation.

Porter et al. [8] developed measures to assess the high technology competitiveness of countries. They developed three output indicators. High technology standing measures the current high technology production and export capability. High technology emphasis addresses the degree to which a country's exports concentrate on high technology. Lastly, they look at the rate of change of high technology standing. Porter et al. [8, p. 4] state that there is no consensus on the definition of high technology and they follow the U.S. Department of Commerce in categorizing by industry. The U.S. Department of Commerce definition of high technology, i.e. technology intensive, is based on U.S. R&D expenditures in a sector.

The compelling question is whether high technology can be equated with knowledge intensity and/or high wage jobs. This is for example illustrated by the aircraft industry which is commonly thought of as a high technology industry because it has a relatively large percentage of R&D. For instance the R&D expenditure in percentage of turnover in 2000 for the aircraft and systems sector of the European aerospace industry was 15.2% [9, p. 37]. However, much of aircraft manufacturing involves relatively simple assembly jobs which are not equated with high wages. This makes the question, what is high technology, relevant.

II. HIGH TECHNOLOGY

Many high technology definitions can be found, often by specifying a number of characteristics. Joseph [10] identified some of the problems with identifying high technology. He notes that there is a large diversity of definitions of high technology and that the definition varies depending on the context that is being used. We provide for that reason a short overview of a number of different techniques to define high technology.

Industry-based

Industry-based definitions of high technology are the most frequently encountered. Examples are the definitions by governments such as the Department of Commerce in the US, who defines high technology by industry (SIC codes). Malecki [11, p. 345] equates high technology industries with industries that are associated with innovation. Malecki [11, p. 348] mentions two commonly used indicators for defining high technology industries. First, the research and development intensity, or the percentage of sales expended on R&D. Second, technical workers as a percentage of the workforce. Once an industry is classified as high technology, all companies in such an industry are considered high technology. Tether and Storey [12] provide another example of industry definitions based on the proportionally heavy investment in scientific and technological activities compared to other industries.

Firm-based

Bullock [13] uses a company based definition of high technology. Bullock equates high technology companies with small research-based companies. This type of definition is

similar to the industry definitions mentioned earlier, except that it is measured at the company level instead of for an entire industry. Mohrman and von Glinow [14] have another viewpoint. They describe high technology organizations as organizations where all aspects of the environment are changing rapidly [14, p. 281]. In other words, a high technology company is defined by its environment. High technology organizations, must adapt frequently and quickly to this changing environment. Schoonhoven and Jelinek [15] provide another example of this viewpoint.

Product-based

Hansen and Serin [16] provide a definition of high technology products. They define high technology products by technology content, i.e. content of R&D in the products [16, p. 180]. This definition resembles the industry-based definitions. In other words, it is based on the knowledge intensity of the product which is measured by looking at the amount of R&D invested in creating the product.

Life-cycle based

In a study on managing product definition in high technology industries Bacon et al. [17] equate high technology industries with industries that have short development cycles. The viewpoint here is that some industries exist which have a need to continuously, and quickly, update their products. This can also be described as an industry's clockspeed, i.e. a measure of the dynamic nature of the industry [18]. A high industry clockspeed is regarded as high technology because products of competitors who are not keeping up with the latest industry developments quickly become obsolete.

Conclusion

The literature provides a number of different definitions of high technology. In many instances high technology is defined in the context of industries or sectors, in other instances it is defined in the context of individual companies, products or rapid life cycles. The classifications of industries according to SIC code is used to indicate which industries are considered high technology but this classification is much too general to have a practical meaning. One of the problems with this range of definitions for high technology is that if high technology is indeed important for economic growth, it should be clear what is actually meant with high technology and how such high technology impacts economic growth. This is not the case, i.e. the definitions do not provide consistency in what is considered high technology. Furthermore, most of these definitions are related to either the creation of the product, i.e. the amount of knowledge or R&D required, or to the pace of product development, i.e. how quickly products become obsolete. Not much attention is focused on the production of products. Malecki [11] looks at the percentage of workers within an organization that are related to technical jobs, but even this, doesn't provide a focus on the production process. Therefore, studies that discuss high technology typically use a range of definitions which do not show consistent results in what should be considered high technology or not. To obtain more insight,

in the next section we will explore the definitions of technology.

III. TECHNOLOGY

If discussions on high technology indicate technology or knowledge intensiveness, then one would expect low technology definitions to be related to a low degree or intensity of technology/knowledge. Also, technology definitions, would illustrate a similar dimension, i.e. knowledge intensity.

In reviewing the literature, this knowledge intensity dimension is not apparent in technology definitions. For example in the strategic management literature technology is seen as an instrument, management of the technology and technology investments should contribute to the value of the enterprise, see [19, 20]. In the production management literature, technology is classified by production process characteristics such as unit or mass production [21, 22]. In the marketing literature technology is viewed in relationship with a technology life cycle. This gives insight on when and how to sell technology [23, 24]. None of these specifically mention a knowledge component of technology, nor a classification of technology by the length of the product life cycle.

In the specific context of economic development, technology is generally described as being embodied in three components: software, hardware and humanware, see [25]. Others include a management component, see [26, 27]. Sharif [2] provides a detailed structure on the linkages between firm level-, industry level-, sectoral level-, and national level technology. Sharif [2] recognizes four components of technology: technoware, humanware, inforware and orgaware. Ultimately, a nation's technology capability depends on the technology content at the firm level which is related to the sophistication for each of the components. The Technology Atlas Team [27] and Sharif [2] provide a sophistication classification for each of the components divided into seven levels of increasing sophistication.

Technoware: (1) manual levels, (2) powered facilities, (3) general purpose facilities, (4) special purpose facilities, (5) automatic facilities, (6) computerized facilities and (7) integrated facilities.

Humanware: (1) operating abilities, (2) setting-up abilities, (3) repairing abilities, (4) reproducing abilities, (5) adapting abilities, (6) improving abilities and (7) innovating abilities.

Inforware: (1) familiarizing facts, (2) describing facts, (3) specifying facts, (4) utilizing facts, (5) comprehending facts, (6) generalizing facts and (7) assessing facts.

Orgaware: (1) striving frameworks, (2) tie-up frameworks, (3) venturing frameworks, (4) protecting frameworks, (5) stabilizing frameworks, (6) prospecting frameworks and (7) leading frameworks.

Ramanathan [28] and Bowonder and Miyake [29] provide an example of how such technology measurement can take place respectively at the firm level and at the industry level. Looking at the technology then, which is implicitly defined as the process of producing goods in these studies, one can discriminate between different levels of production process (or

production process organization) sophistication which can be equated with low or high production technologies.

IV. DEFINING HIGH TECHNOLOGY

Based on the literature survey above, it can be concluded that the definition of high technology is ambiguous, i.e. there is no consistent definition of high technology. In this paper, we propose a new approach to defining high technology. Our approach is intended to solve some of the inconsistency issues with current definitions and to provide a definition that takes the different aspects of high technology into account. One consistent definition is valuable because it reduces the ambiguity of high technology. We recognize two aspects of high technology. One, termed complexity is more or less a 'static' view on high technology. The second, termed newness, provides a dynamic element.

The level of complexity relates to the complexity of a product or the complexity of the process by which this product is produced. The product complexity relates to the complexity of the design of the product. For example, an aircraft is a complicated product, whereas a bar of soap is a rather uncomplicated product. The process complexity relates to the complexity of the production process, i.e. number of steps in the process and how complicated these steps are. For example, aircraft manufacturing is a rather simple process whereas soap production requires sophisticated processes. The level of high technology depends therefore on both the product and process complexity. Both can be rated from relatively unsophisticated to relatively sophisticated leading to a 2 by 2 matrix. A sophisticated product usually has extensive R&D, i.e. the design of such products may require significant R&D although the production of such products is not necessarily complicated.

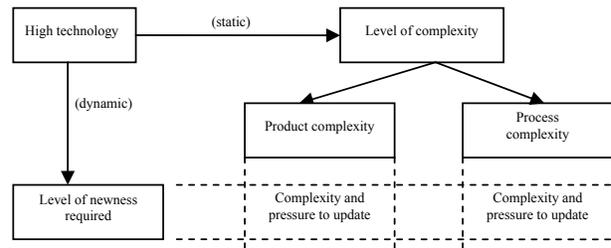
TABLE I
COMPLEXITY LEVELS

| | | Product complexity | |
|--------------------|------|--|---|
| | | Low | High |
| Process complexity | Low | Low tech product Low tech production (furniture) | High tech product Low tech production (aircraft) |
| | High | Low tech product High tech production (soap) | High tech product High tech production (bio-molecular device) |

The newness aspect relates to literature viewpoints that describe short product life cycles, in other words some companies or industries are faced with a requirement to continually update their products or processes. This is the dynamic element of high technology. The semi-conductor industry is an example of an industry with short product life cycles.

Figure 1 shows the combination of the complexity and newness.

Figure 1. Complexity and newness



V. THE TOTAL CONCEPT

The last section focused on the identification of three aspects of high technology: product complexity, production process complexity and short product life cycles. These three aspects can each be rated from low to high. This leads to Table 2.

If a scoring mechanism is used for each of the aspects, i.e. low = 1 and high = 2, then by multiplying the scores we get four categories of technology as shown in Table 3.

Table 3 provides an indication for what can be considered different classes of technology ranging from low technology to high technology. To be able to 'measure' the actual classification of a technology, it is possible to use the existing literature for each of the different aspects of technology.

For process complexity, we can use the technology components developed by the Technology Atlas Team [27, p. 25] and Sharif [2, p. 220]. These measurements include a level of sophistication which can be equated with a level of production process complexity. Tapping into the existing levels of sophistication, one can determine the level of process complexity, for example analogous to Ramanathan [28]. One then only needs to determine the distinction between what would be considered a low complexity value and a high complexity value.

A similar approach can be followed for determining the product complexity by using the existing thoughts on industry levels of high technology, i.e. the degree to which R&D plays a role. In this case a similar guideline can be used as currently exists for determining whether an industry should be considered high technology or not, i.e. whether R&D investments are more than a couple percent of the revenues.

With regard to the product development rate, the approach mentioned by Carrillo [18] can be used, i.e. the industry's clockspeed. This measures the rate of new product introduction or intervals between new product generations.

TABLE 2.
DEGREES OF TECHNOLOGY

| | | | | |
|--------------------------|--------------------|------|--------------------|-----------------|
| | Process complexity | | | |
| | Low | | High | |
| | Product complexity | | Product complexity | |
| Product development rate | Low | High | Low | High |
| Low | LOW TECHNOLOGY | | | |
| High | | | | HIGH TECHNOLOGY |

TABLE 3
TECHNOLOGY CLASSIFICATION

| | Process complexity | Product complexity | Product development rate |
|---------------------|--------------------|--------------------|--------------------------|
| Low technology | Low | Low | Low |
| Low-med technology | High | Low | Low |
| | Low | High | Low |
| Med-high technology | Low | Low | High |
| | High | High | Low |
| High technology | High | Low | High |
| | Low | High | High |

A combination of these three measures provides a more consistent approach to what should be considered high technology and therefore serves to remove the ambiguity that currently exists with the term high technology.

VI. CONCLUSIONS

High technology is considered important for economic development. This applies to the national level as well as at the regional level. In many instances high technology is equated with economic growth and high wage jobs. If high technology is important for economic growth, then it should be clear what high technology stands for. However, this turns out not to be the case. Many different definitions of high technology can be found, based on the context in which the definition is used.

This paper proposed a new approach to defining high technology by distinguishing two different aspects. First, complexity, which is a more or less a 'static' view on high technology and is applied to both the final product as well as the production process. Second, the newness, which relates to a requirement to continually update the products or processes. This is the more dynamic element. The combination of the two types of complexity and the rate of change in an industry provide a more consistent definition of high technology. The paper furthermore gives some indications on how to measure the different types of complexity and newness, by using existing thoughts on each of these aspects. The relevance of such a more precise positioning of the term high technology is that it facilitates

the exact determination of what should be considered a high or low value for each of the three aspects, it provides a more detailed definition of high technology, and this new definition can provide a more meaningful link between high technology and economic development, i.e. what types of technology are most important?

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