

TECHNOLOGICAL CLUSTERS AND DRIVERS OF INNOVATION

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Abstract

A body of knowledge has evolved around the agglomeration of firms and economic growth. There has also been increasing interest, by many researchers in this area, to understand the effect of technological clusters on innovation. Some researchers have shown that geographical localization of knowledge spillovers contribute to the increased rate of innovation. This paper presents preliminary results from a survey of inventors in the telecom industry, examining the factors that influence innovation within and outside a technological cluster. The authors assess the strength of various influences that link inventors to the source of explicit and tacit knowledge at individual, organization and cluster levels.

Introduction

Competing firms often show a tendency to cluster in the same geographic area. For instance, in Europe, watchmakers clustered in Switzerland and fashion designers in Paris. In the United States, well-known clusters include Detroit for automotives, Hollywood for motion pictures, New York City for financial services, and Silicon Valley for electronics.

A body of knowledge has evolved around the agglomeration of firms and economic growth. Also, there has been increasing interests by many researchers to understand the causes of such growth. In the view of some researchers, clustering creates externalities that could fuel the economic growth. Led by Marshall in 1920 and studied more recently by David and Rosenbloom (1990), Krugman (1991) and Kelly and Hageman (1999), researchers have identified three advantages for locating in a cluster. The first advantage is the intensity of a labor pool due to the geographical concentration of firms in the same industry or in closely related ones. The second advantage is the availability of related materials and other inputs at lower cost. These inputs include tangibles, like raw material and supplies, and intangibles like consultations and collaboration. The third advantage is the intensity of knowledge exchange that can lead to knowledge spillovers between nearby firms and institutions in the clusters. Dobkins (1996), Paci and Usai (1999), and Hansen (2002) also studied location externalities and potential impact on innovation. While the first two advantages of clustering have an indirect effect on the innovation output of a cluster, the third one has a direct effect on the innovation process of people and firms located in a cluster. von Hippel

(1988) stated that direct contact with competitors, suppliers and customers is a good source of ideas for innovation. Freeman (1991), and Debresson and Amesse (1991), studied networks of innovators and found that they usually tend to be localized. Feldman (1994) points out how geographical proximity provides the knowledge inputs that contribute to a technological infrastructure supporting innovative activities. Audretsch and Feldman (1996) examined the link between industrial activities and geographic concentration. Baptista and Swann (1998) used regional employment to measure the strength of a cluster and test whether firms located in clusters within the same industry are more likely to innovate than other firms. They concluded that industries that are geographically concentrated and that rely upon sources of basic scientific knowledge in the cluster benefit most from the exchange of knowledge and should therefore grow at a more rapid pace. The spatial distribution of innovative activities has also been studied through detailed case studies by economic geographers like Saxenian (1985 & 1994) and Zucker *et al* (1998). Smith (1999) studied inter-state knowledge spillovers within the United States. Furman and Porter (2002) studied clusters' innovative performance and related the number of patents generated by a cluster to the R&D expenditures of the firms and universities in those clusters.

Prior research strongly supports the notion that firms in clusters have higher innovative output. However, not much is known about the mechanisms of this relationship and how knowledge is created in clusters. According to Hansen (2002) geographical studies have not directly addressed the relevant flows of information and knowledge externalities. Fritsch and Franke (2004) in their study of regional innovation conclude that the question of how spillovers come about remains unanswered. In this paper, we look at technological clusters and their effect on innovation. We start by reviewing the concept of technological clusters and their effect on knowledge creation. Then discuss the dynamics of knowledge exchange and spillovers. In the subsequent sections we depict the process of innovation through knowledge creation and discuss the drivers of innovation in technological clusters. In the end of the paper we present our study with some preliminary results and our conclusion.

Technological Clusters

A technological cluster is a geographical concentration of technology firms. Technological clusters often form around scientific research centers, such as universities or national labs. Many researchers have used this definition to study the economics and performance of clusters (Krugman, 1991; Porter, 1990). Clusters differ from one another, because of the type of technology, age, and culture. This variation creates problems for researchers who want to compare clusters' economics and performance (Porter, 1998, and Padmore and Gibson, 1998). Steinle and Schiele (2002) argue that industries respond to clustering differently depending on the inputs and outputs of their value-chains. Some studies of clusters have approached comparison and analysis at a national level (UK Department of Trade and Industry, 2001). In these studies, "cluster" refers to every technological concentration within the country.

The theory of endogenous economic growth (Romer 1990, 1994, and Grossman and Helpman 1994) is centered on the premise that accumulated knowledge will eventually find its way to productive applications, and hence leads to economic growth. This perspective has renewed interest of researchers to the role that geography plays in knowledge creation, knowledge exchange, and product or service development. Grossman and Helpman (1992) argue that knowledge exchange among the members of a cluster cause a cumulative process of knowledge creation, and if this process is affected by geography, that may explain why the rate of economic growth varies among regions. Glaeser et al. (1992) studied growth in cities and the effects of knowledge externalities that result from geographical concentration of industries. Eventually, clusters would decline and may be replaced by new ones formed around new technologies, Brezis and Krugman (1993) and Poudier and St. John (1996). We have witnessed some relocation of clusters as industries in the US have moved their manufacturing, software development and services to new clusters in Asia to take advantage of cheaper resources.

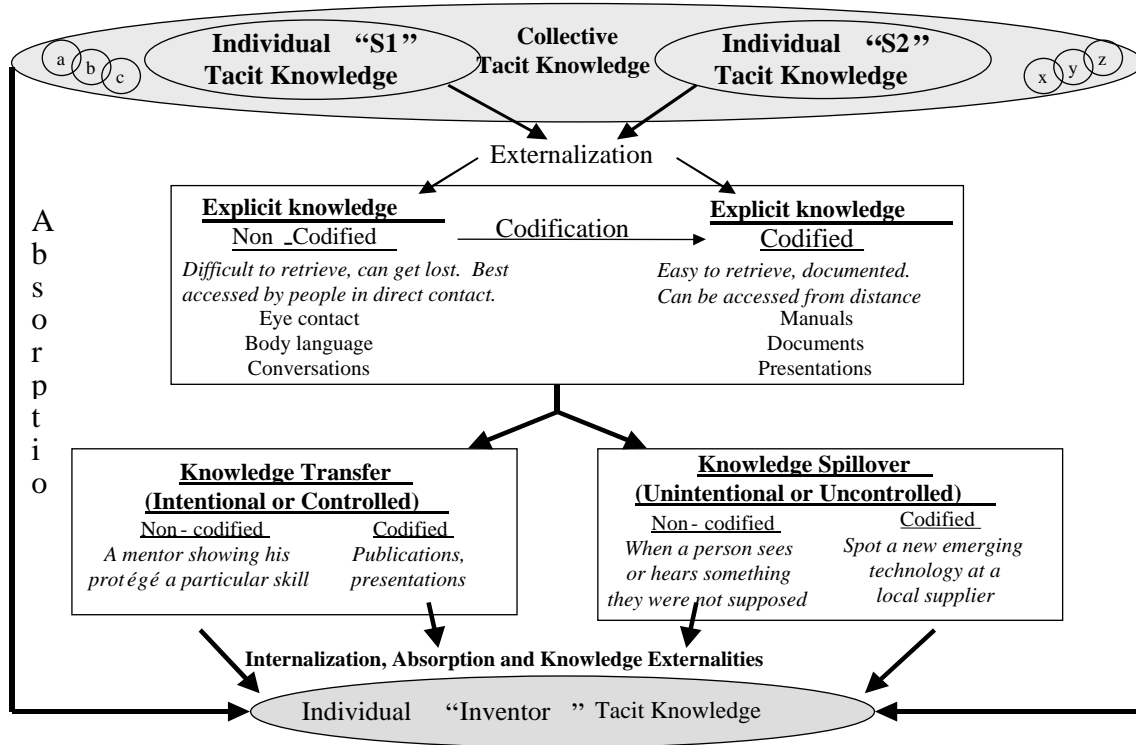
Knowledge Exchange and Spillovers

Knowledge is "the body of facts accumulated by mankind" (Webster Dictionary). It exists everywhere: in people's heads, in companies and in the surrounding environment. Knowledge is continuously being transmitted from one person (or entity) to another. Polanyi (1966) classified knowledge into two categories:

Tacit Knowledge. Polanyi described tacit knowledge as the knowledge that "indwells in a comprehensive cognizance of the human mind and body." Tacit knowledge is related to the context in which it is presented and the individual's own interpretation of it. Polanyi argued that this individual interpretation gives tacit knowledge a "personalized quality" that needs to be articulated by the individual in order to be communicated. Tacit knowledge could be held by individuals or held collectively by a group of people, and is not easily accessed by others. Individual tacit knowledge is knowledge that has not been articulated by its holder, which makes it inaccessible to other people, unless the person chooses to express this knowledge in some explicit form. Collective tacit knowledge is knowledge that is dispersed among a group and can be understood in its totality rather than in its bits and pieces. Such knowledge is difficult to access unless a person spends time in that environment and absorbs the knowledge through collective interactions (Cook and Brown, 1999). Both individual and collective tacit knowledge are essential for creation of new knowledge.

Explicit Knowledge. Once tacit knowledge is expressed and externalized it takes an explicit form and can be classified as explicit knowledge. Externalization can go through many iterations until the explicit knowledge becomes clear and easy to communicate. When tacit knowledge first becomes explicit, it usually takes a *non-codified* form, like when one uses body language and tone of voice to express feelings, or in the case where one blurts out thoughts about a particular idea, jumping from one point to another, or when a scientist jots down a formula on a paper napkin, or a group conducts brain storming of an issue on a flip chart. This knowledge while explicit can be unclear and misunderstood by someone not directly involved when expressed, and even lost if not recorded immediately. For this knowledge to become easier to communicate, it needs to be *codified*. This happens when someone repeats what he/she said in a more organized fashion and neatly writes down the thoughts in a memo or a document. The more explicitly the knowledge is iterated the clearer and easier to communicate it becomes, until it becomes standard information like in instruction guides, and manuals. Also, well-codified knowledge can be understood away from its origin and can be transferred over long distances and maintained over a long period of time.

Exhibit 1. Dynamics of Knowledge Exchange.



Knowledge Transfer and Spillover. When knowledge is explicit, it becomes transferable and available for others to access. Once tacit knowledge becomes explicit, the originator of such knowledge can lose control as to who receives that knowledge. We classify the dynamics of knowledge transmission into knowledge transfer and knowledge spillover according to the knowledge holder’s intent to share or not to share such knowledge. At every possible interaction between individuals or entities, there is a potential for knowledge exchange. If knowledge is exchanged with the intended people or organizations, it is considered a “knowledge transfer”. Any knowledge that is exchanged outside the intended boundary is considered a “knowledge spillover”.

According to the above classification tacit knowledge can originate from an individual or a group (collective tacit knowledge) and can take a non-codified explicit or codified explicit form when expressed. It can also become available through formal intentional transfer or through an unintentional spillover. However, what a person does with this available knowledge and how he/she uses the received knowledge could lead to the creation of new knowledge (Exhibit 1). The process of accessing and absorbing knowledge is called internalization and depends on each individual’s cognitive ability and the

organizations’ absorptive capacity (Cohen & Levinthal, (1990); Caloghirou, et al 2002). For example, two different people could stumble over the same piece of information, one person can link this information to other knowledge he/she has and make use of it in an innovative way, while the other person does not and overlooks the available knowledge. This cognitive ability affects the way knowledge is acquired and internalized, in the sense that people react differently to external factors, and given the same set of data, different people may reach different conclusions. Studies aiming to measure the effect of knowledge spillovers by counting innovation outputs, like patents and new products, overlook the role knowledge internalization and externalities play in the process. Some researchers have used the terms knowledge spillover and knowledge externality interchangeably (Acs et. al, 2002) and (Baptista and Swann, 1998). We argue that they are different and distinct. As we defined earlier, spillover is exchange of knowledge with unintended person or group of people beyond the intended boundaries. Knowledge externality on the other hand is the use of received knowledge in ways and for purposes different than was intended by the provider.

People share knowledge for different reasons: for example, to get feedback from other people, or to

receive acknowledgment of one's ideas. This acknowledgment could be materialistic or simply recognition between peers for the work done. Once the knowledge is shared there it can be used in different ways to benefit other people's work and could lead to other discoveries, regardless of whether it was transferred or spilled over. The amount and the direction of change the recipient of knowledge contributes to the previous knowledge is what leads to new ideas and inventions, and could lead to other innovations. Reverse engineering is an example of knowledge spillover that could lead to externalities if the knowledge gained is applied to develop a different product. When a company invests in research and development to introduce a new innovative product to market, the motivation is to profit from the innovation. However, there is an associated risk that a competitor might reverse engineer that product (a form of explicit knowledge) and make use of the externalized knowledge materialized in the new product. Companies guard against spillovers and unintended use for a period of time by patenting their inventions.

Innovation

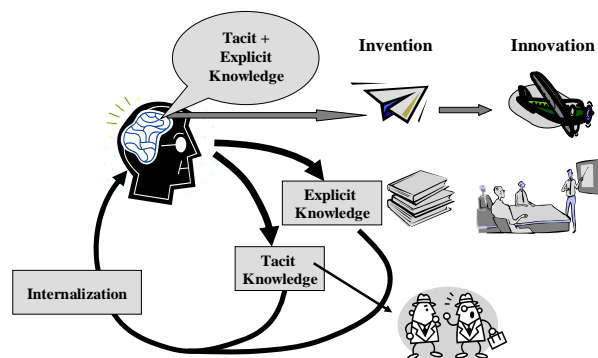
"Innovation is an iterative process initiated by perception of a new market and/or new service opportunity for a technology-based invention, which leads to the development, production, and market tasks striving for the commercial success of invention." OECD (1991)

The above definition of the innovation process points out to a clear distinction between *invention* and *innovation*. *Invention* is the process of discovering creating a new "thing", a new product or a process. This new "thing" is developed and successfully introduced into the market, it becomes an *innovation*. This description is consistent with Garcia and Calantone's (2002) view of innovation where they highlight two important distinctions. The first one is that innovation process includes both the technological development of an invention and the market introduction of that invention. They point out that a discovery that goes no further than the laboratory remains an invention, while a discovery that moves from the lab into production, and creates economic value (even if it is only cost savings) would be considered an innovation". The second distinction they make is that innovation is a repetitive process that includes many cycles of development. This implies that innovation doesn't only occur in basic and applied research, but also in other business functions like product development, manufacturing, marketing, distribution and product upgrading.

While business functions are carried out by companies, innovations can always be attributed to a

person's or a group of people's creativity and ability to solve problems. It is the knowledge creation process of a person or that of a group of people that leads to ideas or solutions that can become inventions and perhaps innovations. Exhibit 2 sketches the innovation process as an individual creates new knowledge by internalizing the surrounding tacit and explicit knowledge (Polanyi 1966). This process of knowledge creation is what leads to new ideas, and inventions that in turn can become innovations. It also shows that the process of knowledge creation is enhanced through interaction with other people and multiple iterations of tacit and explicit knowledge exchange. As Feldman (1994) points out, "interpreting and synthesizing information involves constant questioning and interpretation through a process of trial, feedback, and evaluation that is facilitated by face-to-face communication". The direct interaction between people where tacit knowledge is being exchanged is called "socialization" (Nonaka, 1994).

Exhibit 2. Transformation of Knowledge to Invention and Innovation.



While collective tacit knowledge is absorbed over time and through experience, for individual tacit knowledge to be transmitted a knowledge holder first needs to make that knowledge explicit (externalization). At that time, or later on, that person then makes a decision about whom this knowledge is to be shared with. That decision is about knowledge transfer. The externalized knowledge could also be shared with others unintentionally, or spilled over to others. It is important to note that there are situations where a person does not have control over this sharing process. Generally speaking, the more the knowledge

is codified, the less control a person has over who receives this knowledge, as others can facilitate the transfer. This does not mean that non-codified knowledge does not spillover; it does but may not happen as frequently and as easily as codified knowledge spillover. For example, it might happen that someone visiting another person's workplace watches this person do his/her job and learns from what was observed, just because he/she happened to be there. This learning also depends on the cognitive ability and the absorptive capacity of the recipient.

Technological Clusters and Drivers of Innovation

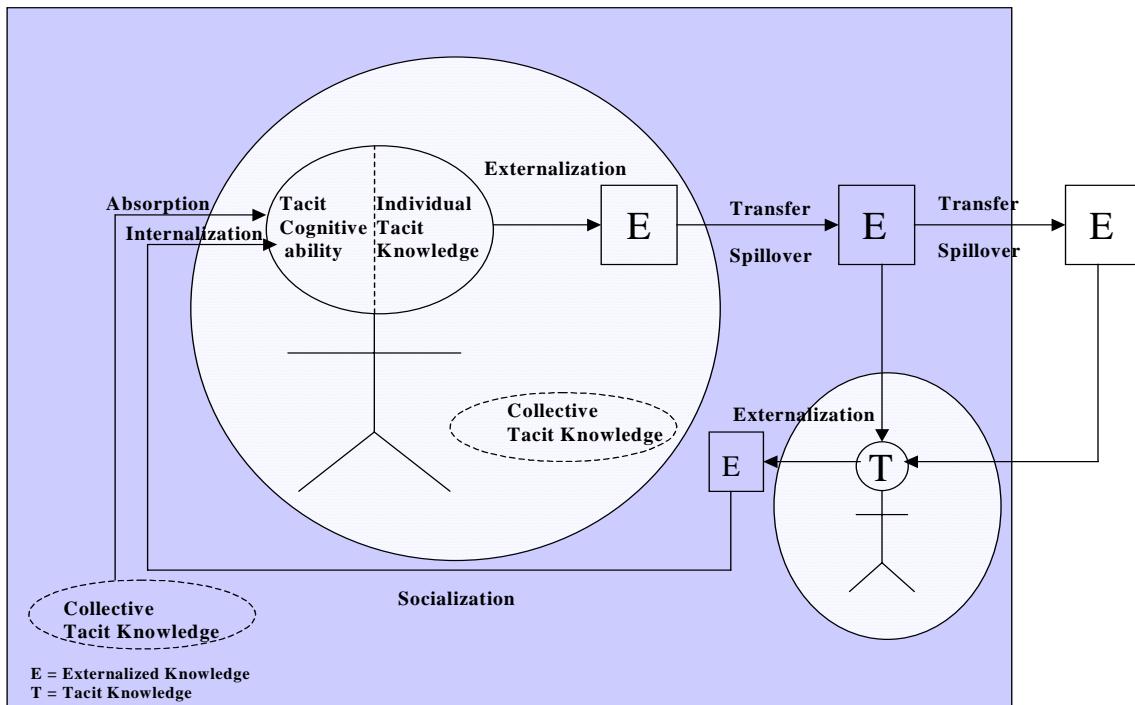
Inventions and innovations are the output of the knowledge creation process and embody tacit and explicit knowledge. According to Babtista and Swann (1998), "so long as much technological knowledge has a tacit nature and cannot be codified through plans, instructions or scientific articles, it seems reasonable to expect a greater geographic concentration of innovators". They argue that learning from new technologies can only happen through repeated use and informal personal contacts with the innovators, particularly when a technology is in the early stages of development. As previously discussed, this may be one of the reasons underlying formation of technological clusters. This argument also supports Pavitt's (1987) notion that informal, un-codified new technological knowledge should flow more easily locally than over great distances. Corno, *et al.* (1999) also referred to technological clusters and transfer of tacit knowledge when they studied industrial districts; they characterize as "complex networks between firms" where they analyze these systems from a geographic perspective they call "ba" (Japanese for place). Nonaka and Konno (1998) originally adapted the concept of "ba" to elaborate on their model of knowledge creation. According to them, "ba provides a platform for advancing individual and/or collective knowledge; it is the place where different subjects participate in the process of knowledge creation and the exchange of tacit knowledge." We believe that it is the increased intensity of knowledge exchange that drives knowledge creation and innovation in the technological clusters.

Exhibit 3 illustrates the exchange of knowledge between individuals in different companies within a cluster (socialization). An individual working for a company in a cluster externalizes his tacit knowledge. The externalized knowledge is communicated to the organization and can become part of the organization's body of knowledge. The firm may decide to protect this knowledge for competitive advantage. Organizations might choose to cooperate together, for

example in an alliance or as a joint venture, where knowledge is expected to be exchanged between the people of both companies, this is a type of knowledge transfer. However, when knowledge is exchanged between people informally beyond the company boundaries and without the intention of their companies to do so, we consider this a knowledge spillover. Geographical proximity allows for direct interaction with customers, suppliers, partners, competitors as well as educational and research institutions, which drives the innovation output of the cluster. This is not to say that knowledge transfer and spillover does not take place between people and companies outside clusters. It does, but at a lower rate and probably in a less efficient manner, especially for tacit and non-codified explicit knowledge exchange where direct interaction plays an important role. Also being in technological clusters enhances a persons' cognitive ability and allows an individual to *absorb* the collective tacit knowledge embedded in the cluster. For example, being in technological clusters permits an individual to better monitor state of the art and emerging technologies more closely and enables him/her to identify general problems and solutions in an industry. The enhanced absorptive capacity will also accelerate the knowledge creation process and hence greater innovative output. Technological clusters also provide for a working environment that appreciates and encourages new ideas, which can have an impact on a persons' creativity and further drive innovation.

Our Study

We are conducting a study to test how inventors rate the influences of being in a technological cluster for coming up with their inventions and comparing whether inventors within and outside of technological clusters rely differently on different forms and sources of knowledge and other key drivers of innovation. Focusing on the telecommunication industry, we will identify the telecommunication technology clusters in the United State based on the patent intensity over the past five years. Our goal is to survey recent inventors within and outside these clusters to assess the effect of various forms and sources of knowledge exchange on their particular inventions. Our survey questionnaire includes questions about the different types and sources of knowledge, knowledge creation stimulus and sources, knowledge creation situations and sources, knowledge spillovers and sources, and general questions about the inventors' organizations and geographic location. We are using a Likert scale of 1 to 5 to rate the influence and will use



a logistic regression model to test for the following hypotheses:

H1: Innovation in clusters is more likely to be influenced by the different types and dynamics of knowledge exchange than innovation in non-clusters

We expect inventors classified to be in clusters to rate the influence of individual and collective tacit knowledge and explicit forms of knowledge higher than inventors in non-clusters

H2: The level to which Tacit knowledge and Non-codified knowledge contribute to innovation is higher than Codified Explicit Knowledge in technological clusters

We expect inventors classified to be in clusters to rate the influence of tacit knowledge and non-codified explicit knowledge in relation to codified explicit knowledge higher than inventors in non-clusters.

H3: Inventors in clusters will rate the influence of knowledge coming from their geographical area aside from their company higher than inventors in non-clusters

This hypothesis focuses on measuring the clustering effect on innovation. We expect inventors in technological clusters to rate the influence of tacit and explicit knowledge sourced from their geographic

locations higher than those not in technological clusters.

H4: Company size will moderate the relationship between the effect different types and dynamics of knowledge have on innovation for people in and outside of clusters.

The test sample of the early surveys received tends to support *H3* and *H4*. Where there seems to be some significant difference between the way inventors in clusters rate how being in a cluster influenced the way they came up with their inventions, attributing that to the vast and diverse knowledge available in these areas, when compared to inventors in non clusters in *H4*. Our preliminary analysis also shows that company size does have a moderating effect on the clustering influence tested in *H3*. That is, inventors working for larger companies tend to highly rate the knowledge coming from their organization when compared to the knowledge coming from the surrounding geographic location even when that area is classified as a cluster, and also vice versa, inventors working for smaller companies tend to rely more heavily on the surrounding environment in obtaining knowledge related to their invention.

There also seems to be an interesting trend where inventors in clusters have a tendency to rate the influence of knowledge coming from their companies and the influence of their own working environment higher than inventors working for companies outside

of a cluster, we think the reason behind this could be that there might be an actual difference between the nature of the companies that operate in clusters, in terms of the way they accumulate and share knowledge internally, when compared to companies outside of clusters, given that they have more experience. Overall, respondents from both clusters and outside of clusters rated the effect of tacit knowledge of individuals and groups in the organization higher than influences of explicit knowledge.

For our initial analysis, we used the inventors' perception of whether they consider their geographic areas as clusters or not and used our judgment for the undecided ones. We are currently in the process of establishing the geographical clusters for telecommunications technologies using the number of patents generated per geographic area, over the last five years. We are still in the process of collecting survey data and the full results of the study will be published later.

Conclusions

There has been increasing interests by many researchers to understand the effect of technological clusters on innovation. This paper discusses the relationship of knowledge creation and knowledge exchange in technological clusters to innovation. The authors presented preliminary results from a survey of inventors in the telecom industry. The results show that individual and group tacit knowledge has the strongest influence on innovation. This study is a work in progress and the full result will be published later.

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