Effects of radical Innovations on regional Specialization.

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October 2004

Abstract

This Paper deals with the adoption of innovations by industries and regions.

The first part of this work defines the space and the time dimensions of adoption. The space dimension tracks the geographical diffusion from the originating region towards early and late adopters. The time dimension measures phases of adoption across applications and industries.

A particular group of innovations (radical innovations) are adopted by a large number of industries, thus generating major technology shifts affecting the entire economy. In this particular case, adoption phases mirror the sequential diffusion of innovation through industries.

The second part of the paper suggests that Information - Communication Technology (ICT) belongs to the group of radical innovations causing major technology shifts in the semiconductor industry. It then outlines the relationship between expansion of semiconductor productive capacity and diffusion of ICT technology. Regions react to the technology in various ways, depending on the timing of adoption, as well as on their active or passive reaction to the rise of a new industry. Technical aspects of production, as well as access to know-how, market information, and adoption of best practices, are some of the factors generating qualitative differences between regions. Active adopters of the new technology seem to enjoy important advantages over passive adopters. They have a better opportunity to pick their position in the global division of labor which emerges as the new technology becomes dominant.

This work considers the case of Lombardia, arguing that, with regard to ICT, this region behaves as a passive adopter, despite the location on its territory of a large semiconductor plant. It then suggests that a space and time analysis of the adoption of innovation might bear implications for regional economic policy. It concludes that applying the space-time approach to major technology shifts could provide useful verification of this approach

KEYWORDS

Industrial and technological districts, regional competitive advantage, innovation, technological shifts, international division of labor, global production networks, information technology.

1. **Introduction**

This paper deals with the adoption of innovations by industries and regions. In particular, it deals with innovations that permeate so vast a number of industries, that a major shift in the technology paradigm occurs. A key thesis of the paper is that, in the case of a *major technology shift*, the timing when regions start the adoption process determines their competitive position in the new paradigm.

The innovation adoption process is usually described by an s-shaped curve, tracking the pattern of demand for new technology along a time dimension. If a space dimension is added, the adoption cycle of a new technology might be described also from the point of view of different regions, playing a more or less active role in the process. This paper introduces a *space-time matrix*, to describe the pattern of diffusion of a major technology shift through both dimensions.

Different regions may be positioned on the space-time matrix depending on their entry-point in the technology adoption process. This paper describes three such regions: *Originating Clusters* are regions that identify the first commercial applications for a new technology; *Active Followers* are regions that adopt the new technology during the production ramp-up, and may therefore find their own space in the emerging supply chain of the new industry; *Passive Adopters* are regions that (for any reason) postpone adoption until the technology is mature. Although they may become sophisticated users, they are not likely to contribute to an already established supply chain.

This paper argues that a similar classification might emerge during any major technology shift. However, there is no reason to believe that the position of individual Regions shall be the same each time. In particular, the competitive position of regions could be modified by a major technology shift if, for instance, the old and the new technology paradigms employ different proportions of input factors, or if the introduction of new technology modifies their relative prices. Both are likely causes for a switch in regional ranking.

However this paper is confined to a more immediate explanation: that a major technology shift provides early adopting regions with a front-runner advantage, because of the internal dynamics of the adoption process. That is why timing of adoption is relevant.

The second part of the paper analyzes the adoption cycle of the semiconductor industry. In the first phase of *early application* (roughly form the invention of transistors to the mid Eighties) semiconductors are employed almost exclusively for data processing and industrial automation. In the second phase of *production expansion* (mid-Eighties to mid-Nineties) the so called “Intel-Microsoft cycle” takes off. During this phase the Personal Computer and other consumer applications become ubiquitous; growth of demand induces an expansion of production capacity from the Originating Clusters towards the Active Followers. Expansion takes place through a process of *copy exact*, which transfers to Active Followers not only up-to-date technical know-how and business practices, but also some of the contacts and competencies necessary to predict future trends and market applications.

The third phase of *widespread adoption* is characterized by convergence of information and communication networks; the explosive growth of Internet and mobile communication are the most visible signs of an *inflection point* leading to adoption of the Information Communication Technology (ICT) paradigm. Semiconductors are the pivotal industry for this major technology shift, affecting the value chain of a multitude of industries. Since the competitiveness of entire industrial sectors becomes dependent upon the adoption of the new paradigm, new and very large markets become available to companies producing or applying semiconductor technology.

Regions that were already part of the industry value chain before the inflection point (such as Originating Clusters and Active Followers) are now in the best position to exploit their own resources and know-how, and to establish competitive positions in the new international division of labor. Since they are the first to spot new applications, and they already possess the required network connections and production inputs, Regions in the Active Follower category can chose the market niches that best match their (existing or newly acquired) comparative advantages.

The third part of the paper considers Lombardia, a region defined as a Passive Adopter. An explanation is provided as to why this category has been applied despite the fact that Lombardia hosts two manufacturing facilities of a French-Italian National Champion (STMicro). Reasons are given as to why Lombardia fits the definition. And policy initiatives are identified, that might allow Lombardia to modify its own position inside the space-time matrix.

The following conclusions seem to be relevant to policy making:

- Regional policy making cannot rely on local industry to recognize the development path of new technologies, particularly in the case of major technology shifts. Instead, policy making should rely on a network of global intelligence on technology life cycles, aiming primarily at the Originating Clusters.
- The leading competencies of existing local industries should be continuously monitored against the background of newest technology cycles, in order to identify competitive market niches.
- Depending on the position occupied on the space-time matrix, a Regional Economy should decide between promoting the conditions to become a recipient of copy-exact investments, and developing the competencies leading to niche applications.

In sum, market forces do not necessarily lead to an optimum position of each Region in the new technology paradigm, because a) dominant industries in a mature economy have little interest or incentive to evaluate the impact of a major technology shift; b) as a result, only marginal resources will be employed in exploring and exploiting the new technology; c) there is asymmetric information among Regions: Active Followers have better visibility of business models and market opportunities, than Passive Adopters.

2. **Space and Time Dimensions of Innovation and Major Technology Shifts**

This section of the paper deals with innovations, and in particular with “radical” innovations, leading to major technology shifts, which affect more than one industry. The generation and adoption of innovations is displayed along a two-dimensional plane of time and space. The plan is divided among discrete phases, with inflection points separating one phase from the other. The plan is also divided among regions playing different roles at each phase of adoption. This exercise aims at providing a general framework to illustrate the interaction of phases and regions during a major technology shift.

Innovation might be defined as the combination of invention and adoption. The result of an inventive process is the generation of new ideas, new scientific or technological concepts. An invention is adopted by industries or individuals, when its application to an existing activity leads to either or both:

- process innovation: less resources are necessary to produce the same output;
- product innovation: a new combination of resources improves the characteristics of existing output.

This section argues that the combination of invention and adoption evolves through time. Both are characterized by cumulative effects, which in turn lead to technological path dependency (Arthur 1989).

Schumpeter (1943) considers the time dimension of the **phase of invention**. He describes the process of “creative destruction” as the cumulative combination of inventions, originating from a new idea. A recursive process is set in motion by the emergence of a new concept, and the cumulative effect of successive attempts generates a new technological trajectory for the market and the industry (Dosi, 1982).

Ryan and Gross (1943) plot a bell shaped curve to describe the various **phases of adoption** of a new technology. At first, “early users” test the innovation. They provide feedbacks to the inventors, leading to an incremental upgrading of the new product. Successful innovations survive this process and enter in the second phase of adoption. Early users’ positive reviews induce an “early majority” to adopt the new product. Demonstration effect and word of mouth have a cumulative effect till suddenly, orders increase exponentially.

In this frantic phase, it is critical for production to keep up with growing demand. The emergence of a new market standard is the reward for a technology that survives this phase. At the end of the cycle, also the most conservative segments of the market (late adopters) will be forced to adopt the new standard.

Similar nonlinear adoption cycles may be observed in many industries, and their influence on management practices and strategies belong to main stream business studies.

In the world of high tech, where emergence of new technologies and adoption of new products are frequent phenomena, such theories have a major impact. Many new products do not survive the early phases of the cycle, and the principle that “technology sells by itself” does not hold. In fact, good ideas often fail to reach the mainstream market. To understand why, it is necessary to go beyond the analysis of invention. Adoption becomes a key element to consider. New products embed a value proposition. This proposition articulates why the new technology is useful, and why it is important for a particular class of users to adopt it.

While a value proposition should hold throughout the various phases of adoption, Moore (1991) argues that “marketing strategy changes dramatically – indeed reverts itself - at every major inflection point in the Technology Adoption Life Cycle”. In the early phases of adoption the organizational imperative is to gain acceptance within at least one mainstream market segment, following very closely the reaction of the first group of adopters. Attention to the feedback of sophisticated early users is in sharp contrast with the “ship, ship, ship” mentality that becomes the imperative during the subsequent phases of production ramp-up, where a company’s goal is to establish itself as the new standard. Listening too carefully to existing customers might prevent the firm from achieving this result. Standardization, in turn, will lead to faster adoption even among the most skeptical users.

This is the crucial link where established corporations fail, as they are not able to abandon the traditional costumer base to embrace new markets (Christensen, 1997)Since adoption is so strategically driven, successful innovative firms need both technological and marketing core competencies.

Centers of Innovation in the Space Dimension

The economic environment required for the birth and the adoption of new technology is unique: Past and present literature on regional economics agree that ideas travel across a non-homogeneous space. Technology is adopted at uneven rates in different regions.

The Time dimension of Innovation

In his application of positive feedbacks to the study of regions, Krugman (1991) recommends that economists should focus only on two of the three sources of external economies identified by Marshall (1920) to explain diverging extent of economic development. The first is the presence of a large pool of specialized labor, and the consequent local division of labor; the second is the development of a network of specialized intermediate goods and service industries. The third factor is the emergence of a vibrant and local exchange of tacit knowledge, which leads to the circulation of knowledge spillovers among the firms and other organizations within an industry. Unfortunately, Krugman argues, “ideas do not leave paper trails” and therefore economists should concentrate only on the first two factors.

Jaffe et al. (1993) take up Krugman’s challenge, arguing that knowledge spillovers among the firms in an industry are particularly relevant and they actually “do leave paper trails”. By employing patent citations as a proxy for the flow of knowledge, Jaffe et al. (1993) were able to show that knowledge propagates from “a center” where new inventions are produced (and patented), to the proximities of the center, and over time to “the periphery” (where innovations are subsequently cited in new patents). This movement reminds the waves produced by a stone thrown in a pond.

A *center of innovation* is defined here as a region of dense know-how that creates new products, identifies new applications, and drives their market adoption. The literature on regional competitive advantages (see for example Porter and Stern, 2001), draws on the concept of external economies. It claims that physical contiguity of competent individuals is necessary in order for the innovative wave to travel across contiguous applications. That holds for both technical and marketing competencies.

By comparing the diffusion of innovation to the spread of a virus, Barabasi (2002) places space and time together in a powerful analogy. Social and professional networks act as powerful mechanisms to link the centers of innovation with the “early majority” of adopters. This network is characterized by the presence of “hubs” that are connected to a large number of users. As the innovation “infects” the hub, adoption of the new practice grows exponentially, like the spread of a disease.

The non-linear dynamics of new technology adoption suggest that large economies of scale and network effects may be present. Geographical contiguity and concentration contribute to this specific configuration. Centers, peripheries, and technological divides emerge throughout the technology adoption cycle. It will be argued here that those divides have significant implications for the economic development of regions, particularly for the case of innovations generating major technology shifts.

Major Technology Shifts

In this paper a major technology shift is defined as an innovation whose adoption leads to substantial product and process change in a large number of industries.

Most of these industries adopt the new technology as an input, but are not directly involved in the original innovative process.

As adoption of the major technology shift spreads, new markets emerge, and the competitive rules within mature industries change.Opportunities emerge for companies that become new market leaders by identifying original business practices and applying them to new industries.

As standardization of a new technology speeds up its adoption, so standardization of these business practices leads the new market leaders to fast growth.

The intensity of competition in different industries and regions ultimately regulates the timing of adoption. For instance, speed and spread of adoption are accelerated by market-share gains and by the pressure for standardization.

Active Followers and Passive Adopters

Reactions to major technology shifts differ not only among industries, but also among regions. One obvious distinction is that between regions that become active in the industry generating the innovation *(active followers)*, and regions that merely adopt the innovation in their existing industries (*passive adopters).*

When the originating industry establishes new production facilities, the technology shift propagates geographically beyond its original center. Active followers are regions hosting the new productive investments. (Figure 1) When innovation is adopted by other industries, its applications broaden. Passive adopters are regions whose industries adopt the innovation, and are thereby transformed.

This paper maintains that active followers will be more successful than passive adopters not only because they grow organically with the original industry, but also because they start new industries (or new industry segments) that will sell the innovation's new applications to the rest of the economy.

Production Expansion

The product cycle theory (Vernon, 1966) claims that when demand increases, a new spatial division of labor becomes possible. Some phases of production will be outsourced from the originating cluster to other "peripheral" regions characterized by access to low cost input factors ("vertical disintegration").

During this phase of production expansion, mature economies lack the institutional flexibility, and the sense of urgency to be recipients of productive investments by the new industry. It is assumed that welfare in these regions depends on existing industries, whose productivity has not yet been affected by the technology shift. Developing economies not only present characteristics that are opposite to those just described; they also have ample supply of low cost input factors and few competing investing alternatives. They therefore are more likely to host new productive investments. Once the new technology "crosses the chasm" of early adoption, time becomes more important than cost savings. The size of demand grows faster than the production capacity of the core regions. Gaining a large market share and achieving standardization and network effects are of strategic importance to firms, because market share will determine the selection of new standards. In this scenario it is conceivable that expansion of production to developing economies may take place before a process of vertical disintegration within the industry is technically available. This solution achieves some cost saving without delaying production ramp up. It is however at odd with the timing of decentralization suggested by Vernon's product cycle theory.

If every step of a non-mature production process is transferred simultaneously, and a vertically integrated production units is replicated exactly, the original know-how is reproduced in its entirety in some peripheral regions. Meanwhile, the industry keeps growing, following the life cycle of the new technology. The introduction of incremental process and product innovations is necessary to keep the peripheral plants current about progress made at the center. However, it also require a continuous and intense flow of information and knowledge among the firm's production units. The best business practices and working culture are also exported to the "active follower" regions, through an efficient communication network, in order to facilitate the updating of know-how.

In the case of a major technology shift, what also gets transferred is the awareness of (1) benefits that may follow adoption of that new technology and (2) variety of other industries or markets that might directly benefit from the new technology.

On the other hand, passive adopters are not affected by the new technology shift during the production ramp-up. Only when the new technology reveals its beneficial influence on other industries, established leadership positions in mature sectors are threaten; Only then developed regions realize the need for adoption.

Widespread Adoption

As technology matures, the production process becomes better codified and modular. This allows for a more rational distribution of tasks within the firm, and ultimately for a more efficient division of labor across firms and regions. A major restructuring of the industrial structure takes place (Baldwin and Clark, 2000). Original firms retain some production steps in house, while outsourcing other steps to third parties. Active followers are more likely candidates for outsourcing than passive adopters, because they already master know-how, culture and business practices of the new industry, and are well integrated in its network.

Furthermore, once the technology shift begins to affect new applications, new industries and market segments come to life. Because of their awareness about benefits and potential users, active followers are well positioned to exploit the opportunities created by increasing demand for new applications. In other words, when waves move further from the center, peripheral regions hosting satellite plants will make use of the know-how they possess in order to independently generate new applications.

Through the combined effect of vertical disintegration - present in most technology life cycles - and expansion of applications beyond the core industry - unique to major technology shifts - active adopters identify their niches within the new division of competencies. This is a self-reinforcing process, that might lead eventually to a very high degree of regional specialization.

On the other hand, passive adopters struggle to apply the new technology to their own traditional industries. At this point in the game, a "technological divide" has been created: overcoming that gap is necessary in order for passive adopters to preserve the competitiveness of their own industries. Since they lack the location advantages and expertise, passive adopters will be reluctant to imitate the path of growth set by active followers. As a result, they will become their preferred customers.

Figure 1 illustrates this scenario. The "phase" line describes three stages in a technology adoption curve, while the "region" line shows three regional economies.

FIGURE 1

PHASE **REGION**	EARLY APPLICATION	PRODUCTION EXPANSION	WIDESPREAD ADOPTION
ORIGINATING CLUSTER	-Concentration of specialized labor -Local production	-Innovation broadly adopted -Production expands to other regions	-Vertical disintegration -The next technology shift is originated
ACTIVE FOLLOWERS	Brain-drain	-Productive investments -Reverse brain-drain -Know-how transfer -Working culture -Best practices -Efficient communication network	-Innovation broadly adopted -Division of labor -Productivity increases -Specialization takes place -New applications and industries are created
PASSIVE ADOPTERS	Brain-drain	Brain-drain	-Innovation adoption begins -NO division of labor -NO productivity

CHASM

TURNING POINT

Inflection Point

The transition from Production Ramp-up to Widespread Adoption is not seamless; it is usually marked by an *inflection point*. At the firm level, the inflection point has been labeled by Moore as "the chasm" (Moore, 1991, 1995; Moore et al., 1998). He defines it as follows:

"… whenever truly innovative high-tech products are first brought to market, they will initially enjoy a warm welcome in an early market made up of technology enthusiasts and visionaries, but then will fall into a chasm, during which sales will falter and often plummet. If the products can successfully cross the chasm, they will gain acceptance with a mainstream market dominated by pragmatists and conservatives. Since for product-oriented enterprises virtually all high-tech wealth comes from this third phase of market development, crossing the chasm becomes an organizational imperative." (Moore, 1995, p.20)

Moore's description of the "chasm" holds for the adoption process of several innovations.. However, it is confined to the behavior of a single industry facing an innovation. Instead, in the case of a "major" shift, implications at the macro economic level should also be considered. In that case innovation spreads beyond a single industry, and becomes an enabling technology, allowing for a paradigm shift potentially affecting the entire economy.

The effects of a major technology shift on the entire economy have been studied by Perez (2002). In particular, Perez establishes a relationship between the technology adoption cycle and the financial investment cycle in the case of five major technological revolutions. For each one of these cases, she identifies a major discontinuity in the adoption process, which she terms "turning point". The turning point "represents the fundamental changes required to move the economy from a Frenzy mode, shaped by financial criteria, to a Synergy mode, solidly based on growing production capabilities. (…) This is, in fact, a time of indetermination, when the particular mode of growth that will shape the world of the next two or three decades is defined. Its characteristics will be within the range made viable by the potential of the (new) paradigm, but the choice within that wide range will depend on the interests, lucidity, relative power and effectiveness of the social forces participating in the process" (Perez 2002, p 52ff)

According to Perez, major technology shifts spread until they become the new dominant technology paradigm, thus replacing the previous paradigm as the engine of growth. A high rate of adoption is fuelled by financial investments that follow the same pattern at every major cycle. The initial phase of irruption is financed by means of risk-prone investments, which carry high return rates. The early success attracts massive financial resources, and these create excessive investment and "exuberant expectations". The excess supply of capital sustains a rapid deployment of the new technology in the "frenzy" phase, but leads inevitably to overheat the financial markets, and finally to a crash.

This paper suggests that, in the case of a major technology shift, Moore and Perez are describing the same event: (Moore from an industry perspective, Perez from a macroeconomic one)

a) A successful transition through the inflection point marks a qualitative change in the adoption process: it is the moment when a new technology ceases to be seen as an experiment, and becomes the dominant production paradigm

b) The decision to invest ceases to be made by "enthusiasts" in a "frenzy mode", to become the rational choice of "pragmatists" thinking along a "synergy mode"

c) That is also the time when uncertainties disappear; competing firms, institutions and regions "find out" about markets' new standards for the originating industry as well as the entire economy.

d) The turning point following the crash is a time of restructuring of market regulations and financial controls by government agencies, to make them compatible with the new technology paradigm. Speed and sustainability of the recovery will depend on the depth and effectiveness of these institutional changes.

In the case of regional economies confronting a major technology shift, active followers are better positioned than passive adopters in overcoming the inflection point. Active followers are ahead in the game, because they have already internalized know-how, business practices, working culture, and the network links required to make them successful in the next stage. On the contrary, passive adopters have missed the stage of production ramp-up. They now need to generate these competitive tools through a major shock involving creative disruption and internal re-composition. The duration and outcome of such process, according to Perez, are largely determined by social and policy (non market) variables.

The next Technology Shift

Nothing said so far challenges the assumption that the originating cluster might also dominate the next technological shift. On the contrary, going back to the core-periphery theory, conditions (or external economies) that lead to the rise of the new technological shift in the originating cluster are likely to persist. In this scenario, active followers may leverage the preferred relationship with the core region to position themselves in the division of labor for the new technological shift. However, these economies face the risk of stagnating on the flat section of the old technology life cycle, thus becoming passive adopters on the new one.

If the mature industries in the passive adopters regions fail to absorb the new technological shift, they will loose competitiveness and lead their economies to industrial decline. On the other hand, as new applications for the new technology will emerge, the leading industries of mature economies might be able to identify new niches of application for the enabling technology. If this happens, passive adopters may become the originating clusters for other important technological curves.

3. ICT as a major technology shift

This section applies the time and space framework to the interaction between Silicon Valley and other regions, throughout the critical phases of the Semiconductor and ICT (Information Communication Technology) life cycle. It suggests that ICT represents a *major technology shift* generated by the semiconductor innovation. It then describes the spread of such industry and technology, starting from Silicon Valley (*a center of innovation)*, towards peripheral regions in South East Asia, Israel and Ireland (the *active followers)*. Initially, *production ramp-up* beyond the original center takes place through a process of "copy exact". Subsequently, however, the combined effect of optimization in the international division of labor, and *widespread adoption* of the new technology by other regions (*the passive adopters),* enable peripheral regions to acquire specialized roles. The transition from production ramp-up to widespread adoption is marked by *inflection points.* ICT is a major technology shift because it allows for a higher level of specialization while reducing the benefit of vertical integration within the firm. Thanks to ICT, greater specialization and a more dispersed division of competencies become feasible and cost-competitive. At the same time, ICT allows for better coordination of the activities performed by multiple dispersed agents. It therefore provides for more efficient management of fragmented organizations. In the particular case of knowledge creation, the production of knowledge may benefit from local specialization, without suffering from the inefficiencies of decentralization. Finally, ICT lowers the unit cost of accessing remote information (Malone 2004).

This paper argues that the reinforcing effect also holds for regions. Advanced ICT regions are in a better place to strengthen their position in the knowledge economy. For example, recent studies on the relationship between Silicon Valley and its partner regions (Saxenian and Hsu, 2001; Saxenian, 2002) show the importance of "transnational technical communities" that provide the professional services needed for an international division of labor in a knowledge intensive sector such as ICT. These researches have shown that for professional services to become competent interfaces in the knowledge economy, ICT has to be coupled with preexisting business relationship and experience of both worlds that are involved in an interaction.

In sum, the adoption of ICT technology by a variety of industries results in a number of benefits: (i) it decreases transaction costs related to knowledge and information, (ii) it helps rationalizing the value chain of knowledge and information, (iii) it lowers the benefits of vertical integration for knowledge-intensive activities. For these reasons, ICT adoption might shift the production function of a large number of industries deriving value from knowledge transfer and transactions. However, Industries and Regions should restructure their organizations and modify business relations in order to realize the potential benefits.

Silicon Valley as a center of innovation

Silicon Valley is not an event of the last decade. Innovation and development of the Valley date back to the first applications of silicon, after the Second World War. It rode the waves of mainframe, PC and of the Internet industries.

Traditional literature on Silicon Valley explains the accelerating rate of ICT innovation through concentration and continuous attraction of brain-power within the confined region. On the other hand, empirical evidence suggests that the generalized adoption of technological and organizational innovations provide an equally important explanation for the outsourcing and the division of labor that eventually prevailed in ICT. In fact, Silicon Valley and its partnering regions (the *active followers)* began to share know-how, business practices and working culture during the early stages of the semiconductor ramp-up, long before the widespread adoption of the Internet. The early creation of a network of industrial relations represented the building blocks that allowed for a fast adoption of ICT, and the subsequent growth of *active followers.*

In this respect, brain drain played an essential role also during the ramp-up phase of ICT production capacity. It is not by accident if many of the foreign investments of Silicon Valley firms took place in precisely these regions that provided Silicon Valley with qualified labor in the previous decade. The build-up of production capacity in South East Asia was greatly facilitated by the fact that so many Silicon Valley engineers had migrated from that region in the previous decade, earlier as students in US colleges, and later as employees of US semiconductor firms.

Between 1990 and 2000about 200,000 engineers with scientific or technical degrees moved from India and China (including Taiwan, Singapore and Hong Kong) to Silicon Valley, in order to fill in about 340,000 newly created jobs (Saxenian and Hsu, 2001). At least 90,000 of them moved back to their original Countries between 2000 and 2003 (San Jose' Mercury News, November 9, 2003). Saxenian describes this phenomenon as "a bridge between Silicon Valley and Asia formed in equal parts by labor, knowledge and capital". (Saxenian and Hsu, 2001, p. 913)

Geography provides yet one more explanation of this phenomenon. During the 1980s, competition in semiconductors very often took the form of a direct challenge between American and Japanese firms. In those years, Japanese production technology was no second to Silicon Valley; both areas suffered from a high cost of input factors, and both sought relief by exporting production capacity to emerging economies. Those investments often took the form of a race for capital and labor resources in countries, (such as Taiwan, Singapore, Malaysia, Korea and the Philippines) which, until 1945, had been the traditional reserve of inexpensive input factors for the Japanese industry. To some extent, the determination of US companies to invest in South East Asia might be interpreted as part of a national strategy for the containment of growing Japanese industries.

The domestic governments of South-East Asia often exploited such rivalry, by playing the challengers one against the other. Cohen and Borrus (1997) suggest that the early transfer of technology and business practices by US firms towards the South East Asian economies was part of a deliberate strategy to contain Japanese competition in semiconductors.

The Rise of Copy EXACTLY

The process of quickly expanding production facilities beyond the core is known as "copy exact" in the semiconductor industry. The copy exact concept was formalized by Intel for the first time with an internal paper (McDonald, 1988) and subsequently presented to various conferences (Multani et al., 1994, McDonald, 1997) as follows:

"The Copy EXACTLY!" philosophy and systems were developed in order to minimize the time required for a technology to be transferred and to ensure product quality and yields are not compromised. The methodology has been improved and refined, and has become an important element in Intel's overall manufacturing strategy" (McDonald, 1998, p1).

In 2004 Intel had eleven fabrication facilities ("fabs" or "front end") and six assembly and test facilities ("back end") worldwide. However, establishment of overseas semiconductor fabs was limited to two foreign countries: Ireland and Israel. Fabs 10, 14 and 28 were built in Lexlip, Ireland in 1990 and 2004. Fab 8 was built in Jerusalem in 1985 and was followed in 1999 by Fab 18 in Qiryat Gat. Needless to say, all these were "copy exact" plants. All other overseas production sites of Intel are "back end" plants devoted to assembly and test (Costa Rica, Malaysia, the Philippines and China) or software (Bangalore, India). So strong was the copy exactly paradigm, that as late as 1999, Intel planned to follow again that principle in creating Internet service centers (Intel Data Service): "Intel planned to refine one data center, and then replicate the data center following Intel's Copy Exact process for building chip factories" (Burgelman, 2002, p 335). In that case however, the copy exact concept did not work, and the IDS project was abandoned.

In 1998, ten years after its initial adoption, Intel was still extracting benefits form the copy exact method: "Two new factories were successfully brought on line with the same yield results as the parent R&D line. Furthermore, all three lines were able to improve their yields together by implementing improvements simultaneously". (McDonald 1998) The copy exact method is intended to provide continuous, real-time transfer of know-how across regions.

Intel was not alone in using the "copy exact" paradigm. Other American and Asian semiconductor companies adopted it between 1985 and 1994, both in the US (ten States) and internationally. Here are a few examples:

Texas Instrument builds the first overseas operations in 1980 at Miho, Japan. TI Miho may represent an early example of copy exact, although the strategy was not yet explicit. When the international ramp-up of capacity was decided, TI built four copy exact factories in less than five years: Avezzano (Italy, 1989), TI Acer (Taiwan, 1989), KTI (Japan, 1990) and TI Singapore (1992).

Motorola has followed a similar pattern with regard to front-end facilities. Furthermore, two DRAM fabs, MOS6 in Sendai, Japan, and MOS9 in East Kilbride, Scotland were "copied exactly" from Toshiba. Interviews with Motorola management confirm that technology and hardware (test programs, testers, probers, and handlers) were directly transferred by the Japanese company to the American one. This example shows that copy-exact became common practice also with know-how derived from third-party sources.

It could be shown that, to a lesser extent, also smaller American semiconductor manufacturers, such as AMD, MICRON or ATMEL, have followed a similar path.

Companies outside the US were equally eager to follow the concept of copy exact, although not with the same international emphasis. Among the European semiconductor manufacturers, STMicro is probably the one that most closely followed the copy exact model. STMicro's front-end facilities are located in France, Italy, USA and Singapore. Back-end facilities are located in Morocco and Malta. As for their US colleagues, it was common practice at STMicro to share the same processes and equipment across all plants. In fact, in order to share processes, not only tools need to be the same, but also the complex facility infrastructure should be replicated as closely as possible.

Koreans conglomerates such as Samsung and Hyundai made large use of copy exact practices. They started by licensing "copy exct" products and processes from Japanese and US leading suppliers. During the ramp-up of DRAM memory production capacity, they both made repeated use of the copy exact principle. For example, Samsung went as far as building four identical DRAM factories, next to one another.

The Japanese semiconductor companies adopted different principles; they where much less eager to directly export vertically integrated process technology., They relied on partnerships instead: Toshiba for example established process and product licensing agreements with Motorola in 1987, with IBM and Siemens in 1992, and again with IBM in 1996 (Kawanishi 1997, p.90). Foreign direct investment was never implemented on a very large scale, , and only when sharp differences in input factor prices made international division of labor a mandatory practice.

To conclude, most "fabs" and several back-end facilities built in South East Asia between 1986 and (at least) 1995 were based on the copy exact formula. There were two reasons for that: first, demand increased so fast that adding production capacity was essential in order to maintain market positions. There was no time to rationalize production processes. Second, process control is critical to manage yield, and yield makes the difference between profit and loss. Processes are continuously modified because of improvements or because new generations of products hit the floor. Perfect execution of these modifications is critical to ensure fast ramp-up of the new generation, with minimal yield losses.

Effects of the Copy EXACTLY Model

The copy exact model was employed to expand production capacity not only in South East Asia, Israel and Ireland, but also in other European regions, such as Saxony and Bavaria(AMD and Infineon in Dresden, Hitachi in Muenich), Scotland (Motorola), Southern France (STMicro Grenoble, Motorola Marseille) and Southern Italy (TI Avezzano, TI Rieti, STMicro Catania). However, with the possible exceptions of Southern France, Saxo ny and Catania, these installations remained isolated, and failed to stimulate the growth of local "clusters" on a scale comparable to Taiwan, Singapore, Korea, Israel, or Ireland.

Similarly, on the back end, installations built in Malaysia, the Philippines, Indonesia have created local clusters of semiconductor industry, whereas analogous installations in central Italy (the "Tevere Valley") or Southern France have not yet met with comparable success.

Why copy exactly did work in emerging economies? Perhaps an easier question would be: "why copy exactly did not work in mature economies?" What was different between South East Asia and the low-income areas of large European nations?

The answer might be a combination of three sets of elements: a) The existence of externalities in some emerging economies: namely a dual labor market; government active support of structural change; selective foreign direct investments; and lack of competition by alternative investment opportunities. b) The direct influence of copy-exact: namely, creation of meta-bridges, transfer of complete know-how, and a new labor culture. c) The ability to extract benefits from successful copy-exact: Further growth resulting from rationalization in the international DOL; fast adoption of new productivity tools across the economy; no need for “shake-off” turning points; presence of continuous government support policies that encouraged widespread adoption of the new productivity tools.

In other words, the main obstacle in mature European economies was not the absence of a “copy exact” phase, (although, admittedly, it was of limited scope) but rather the lack of political resolve to pick up the opportunity and carry the copy exact experience to its natural conclusions.

The mature European economies lost the competitive battle against South East Asian Economies during a process that lasted over twenty years; it is clearly not possible to identify a single cause. However, one key element recurrent throughout the period is that South East Asia entered each phase of the game at an earlier stage, and with unfettered commitment to the new industry.

When US semiconductor companies decided to invest overseas, they looked for low-cost input factors, particularly labor and capital. In that, the European low income regions did offer similar financial incentives, tax holidays, and flexible labor markets as South East Asia. (Although labor might have been slightly more expensive and regulated.)

The difference was not in the conditions provided to the foreign investors themselves. It was rather in that, whereas South East Asian government offered similar conditions to all the local complementary enterprises stemming out of the copy exact plant, the European governments offered those conditions only to the main foreign investor. In Europe the rest of the economy was treated with no special regard. As a result, the “copy exact” transplants failed to generate a “lateral effect”. And finally, the National Governments they depended upon were involved in a variety of other industries (the “National Champions” in traditional industries) and had little patience to develop comprehensive strategies for new industries at a local regional level.

Widespread adoption

The first part of this paper suggested that, as the industry moves along the technology curve, both market and technological factors lead to a reset of the competitive strategies and the international division of labor. It was argued that active followers have better chances than passive adopters to acquire sustainable competitive advantages in the new division of labor. In the case of a major technology shift, active followers carry over their advantage to other mature industries that are impacted by the new enabling technology.

The case of the semiconductor industry in the age of convergence of information and communication technologies (ICT) may be an example of such dynamics. Towards the mid 1990s, the application of semiconductors expanded beyond the original computer market, leading to higher demand and market segmentation. The effect of this process on production organization took at least three different directions:

1. vertical disintegration both within the firms and across firms
2. outsourcing both within the original industry and across applications,
3. redefinition of the boundaries of markets and industries

Ultimately, new niches of specialization emerged among the “active follower” regions.

An example of vertical disintegration within the firm is the separation between design and wafer production. Dell and HP offer good examples of vertical disintegration within the firm. The separation between foundry and fabless offers an example of outsourcing of production at the semiconductor level. Companies such as Solectron and Celestica are examples of outsourcing for the development of ICT applications.

In the late 1990s, a major redefinition of markets and industries took place. In November 1994, IBM published a new organizational chart that replaced the traditional product oriented matrix with an application-based matrix. In 1997 the US Census Bureau modified the industry classification system in order to reflect the emergence of new markets and industries Product upgrades and changes in production organization were generated by widespread adoption of ICT. They provided an opportunity for active followers to leverage the local embedded factors, combine them with the acquired knowledge, and evolve towards the creation of specialized niches.

Niche specialization of “active follower” regions cannot be explained with a single factor. Multiple regional cases provide evidence that having been part of a “copy exact” phase does not necessarily lead automatically to participation in the industry’s new division of labor. According to Girratana et al (2004) the presence of multinational corporations and the creation of meta-bridges between these regions and the centers of innovation were not sufficient elements for scaling up the value chain. Interactions with factors such as local entrepreneurship, science and technology policies, local factors of production, or other more serendipitous elements are necessary to identify the appropriate niche within the industry that best fits the characteristics of the region.

Examples in cluster literature abound: According to O'Riain (1997 and 2000), the rapid turnover of managers between multinationals and local firms, and the density of local networks, were the factors behind Ireland's success. "Moving up the value chain" was made possible in the Taiwanese computer industry by a local entrepreneurial class (Hsu, 2000), that greatly benefited from the advantages of a quite developed informal economy (Cheng and Gereffi, 1994), and that was well connected to the hotbeds of ICT technology through a diaspora of technical savvy emigrants (Saxenian and Hsu, 2001). Finally, describing the case of software industry, Arora et al. (2004) show that scalability was a prime concern in the determination of which software projects should be outsourced to which region. Local cultural and organizational factors played a major role in the allocation of contracts and investments.

When ICT revealed its nature of enabling technology for many industries in the "old economy", integration with the center of innovation established during the copy exact phase allowed some of the peripheral countries to exploit their competitive advantage over passive adopters well beyond the early applications for integrated circuits.

The ICT inflection point

Somewhere between "copy exact" and widespread adoption a qualitative change takes place. This paper suggests that the ICT inflection point in the semiconductor industry did not occur at precisely the same time for active followers and passive adopters. If one had to pick precise moments in time, these would be 1996 for South East Asia and 2000 for the developed regions. The two dates correspond to the Asian currency crisis of 1996 and the Internet bubble burst of 2000. Starting with 2001, the US financial and corporate world has been shaken first by a deep recession, then by a sequence of corporate and financial scandals, and finally by a wave of changes in regulatory practices. The Asian currency crisis of 1996 represents the equivalent of a "shake off", in that it temporarily slowed employment and output growth in the seven fast expanding Asian economies (China, India Indonesia, Malaysia, the Philippines, South Korea and Thailand). In actuality, however, the nature of the 1996 currency crisis is different from that of the 2000 bubble burst. With regard to the South East Asian countries, "until 1996 these economies ran aggregate current account deficits. But after the Asian financial crisis these shifted into a large surplus." (Wolf, 2004) As the trade balance of these economies was already active before 1996, the shift in their current account was due solely to net capital flows becoming positive. In fact, starting with 1996, these Countries turned from being net recipients of foreign investment (equity + loans) to being net exporters. [1]

It may be argued that, in coincidence with the 1996 financial crisis, the fastest growing Asian economies switched from the "copy exact" phase, where the manufacturing activity was fuelled by foreign investments, to the "division of labor rationalization" phase, where domestic investments became prevalent in the creation of specialized products and services for the world economy[2]. The currency and financial crisis suffered by emerging Asian economies in 1996 was instrumental to call an end to the "copy exactly" phase of foreign investments, and marked the establishment of a new position within the new international value chain of the ICT economy. Further research is needed to explore the connections between dynamics, and to precisely define the timing of this inflection point.

On the other hand, the major recession suffered by the US economy as a result of the 2000 Internet bubble burst was instrumental to realize the potential labor savings brought about by the "major technology shift", to clean up the dead woods generated by over-investments, and to adjust infrastructure and institutions to the

[1] To be precise, aggregate equity flow was already positive since 1993, whereas aggregate private loans turned positive in 1996-7) (SOURCE: Institute for International Finance, Washington)

[2] There are of course more technical explanations for the reversal of the current account balance by South-East Asian economies: pegging local currencies to the US dollar, hedging against exchange rate risk, high domestic saving rates, and financing the US twin deficit are a few of them. All these arguments however are somehow contingent to specific situations, and do not undermine the long-term structural conclusion.

new technology and the shifted production function. As a result of the turning point, the benefits of ICT technology were finally apparent on a large scale, and productivity in the US economy started to rise. Alan Greenspan officially announced increasing labor productivity for the US economy in October 2002, by reporting the findings of a study showing a direct relationship between productivity and investments in ICT by major US corporations. (Oliner and Sichel, 2002)

A similar analysis, performed a year later in Europe, revealed a growing discrepancy between the two areas (Van Ark et al. 2003). According to the latter study, the absence of productivity increases in major European economies could be explained to some extent with the lower adoption of ICT technology by European corporations, and to some extent with the shallower recession, the higher rigidity of the European labor market, and the smaller “churning effect” in the labor market, especially across industries.

4. Lombardia and the development of ICT

This part constitutes an attempt to apply the space-time framework of ICT adoption to the regional case of Lombardia. The first section deals with the presence of a semiconductor industry in Lombardia. The second section considers which space-time box Lombardia occupies, outlines the factors required for a region to move from one to the contiguous one.. The third section argues that this exercise might produce policy implications, and offers some suggestions for future research.

It may be argued that Lombardia is a mixed case. On the one hand, it looks like an active follower; it hosts two STMicro semiconductor plants (a large one in Agrate and a small in Castelletto), as well as the MEMC silicon crystal plant in Novara[3], plus a half a dozen of fairly small equipment suppliers. On the other hand, the Region seems to fit the definition of a passive adopter; it has never received major "copy exact" productive investments, nor has it witnessed the spread of ICT applications based on vertical disintegration and diversification. The dual nature of Lombardia appears to escape the definitions outlined while presenting the time - space model.

The case of STMicro

STMicro was a late starter in semiconductors, albeit a successful one. As a late starter, STMicro chose to stay out of the "high end" markets of Microprocessors and DRAM memories, the personal computers' building blocks. STMicro concentrated instead on Analog and Mixed Signal products. Success hit STMICRO in 1993-94, when ICT applications started to expand beyond the original PC sector, and the industry entered a phase of widespread adoption. For example, between 1995 and 2004 compound growth of the Analog segment was twice that of the semiconductor industry as a whole.

Events leading to the presence of STMicro in Lombardia might cast some light on the issue. The company was formed by the governments of France and Italy through a series of mergers in 1987; Agrate happened to be the headquarters of one for the merged companies. At the outset, most of STMicro products were (and are) shipped to automotive, wireless communication, and the peripherals industry (printer, modem, mouse and the like). In 2004 still only 16 % of STMicro revenues are generated by broadly defined computer applications.

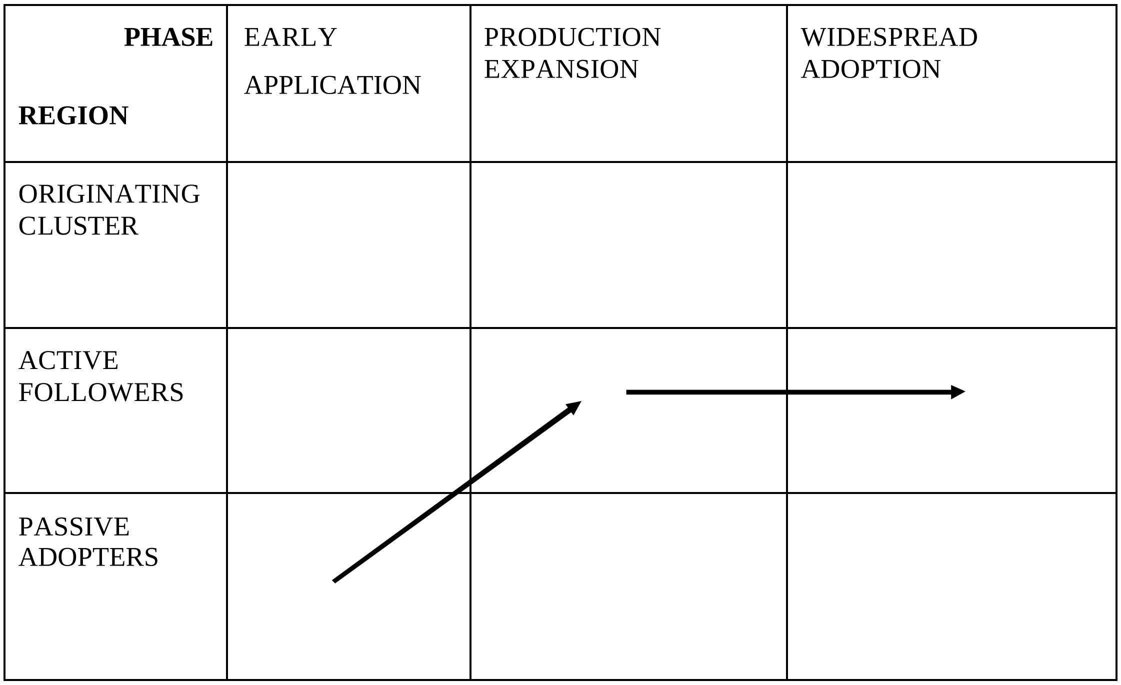
Concentration on some market niches and avoidance of others reflects a technology strategy. Analog and Mixed Signal products, the bread and butter of STMicro, are smaller niches than Memories and Microprocessors; they have not met the fierce technology-based competition prevailing in those markets. For that reason, at least until 2000, technology required to competitively manufacture and sell STMicro products was less sophisticated than that employed by Intel, Samsung or Toshiba to manufacture DRAMS and Microprocessors.

After 1993, as adoption of semiconductors expanded beyond computers, into automotive and wireless communications, demand for STMicro products grew. The company is now a primary player in semiconductors, with about 4% world market share. Pursuing applications outside of the mainstream market was definitely a rewarding strategy. Its success is due to the considerable growth of demand in new applications for semiconductors outside the historical computer industry, and to the continuous focus of STMicro on developing technologies that would complement those applications. With regard to semiconductors, STMicro may therefore be defined a late starter, who deliberately pursued dominant market positions in fast growing niches, outside of the industry mainstream applications.

Since the space-time framework describes the entrance of a specific unit of analysis in an industry, and it does not per se depicts any predictive implications it is possible to apply this framework also to describe the business strategy of a single company. STMicro exemplifies the case of a firm that has been able to move from the rank of passive adopter during the "early application" period, to a "copy exact" process during the phase of production expansion, and finally, to the position of active follower in new applications, during the phase of widespread adoption. (Fig. 2)

[3] Although Novara is in the bordering region of Piemonte, not in Lombardia

FIGURE 2: the journey of STMicro



This STMicro case bears policy implications because it shows that visionary decisions and accurate execution may propel a single company from the condition of "passive adopter" in one phase of the adoption cycle, to that of "active follower" in the next phase. A late-start company can indeed enter the market at a later stage, positioning itself as a leader for the subsequent phases of the adoption-cycle. When innovation expands to other industries new markets emerge, and new players may take advantage of the opportunity.

Moving from a firm-level to a regional level, the discussion of STMicro presented in the next pages will however raise two questions: The first one is: are large-scale government initiatives a viable solution for a region to recover from a position of late starter? The second question is: which goals should a region pursue, while attempting to move across the space-time framework?

The spillover effects of a late starter

The experience of STMicro in Lombardia may provide an answer to the first question. The copy exact phase was described as a way to expand production beyond the core, at a time when vertical disintegration is not yet available. As a result, all steps of a non-mature process will be replicated simultaneously in some peripheral regions. The spillover effects of a "copy exact" investment onto the recipient region are: transfer of updated know-how from the center to the periphery, brain return, diffusion of best practices and working culture. The permanent consequences of a copy exact phase for the new region include a steady stream of knowledge from the center of innovation, awareness of benefits and of new potential applications of the major shift. The combined information enables the new region to grow a specialized cluster during the subsequent phase of widespread adoption.

None of STMicro regional suppliers, with the possible exception of the French national gas company L' Air Liquide, were able to grow beyond their native regional markets, and acquire international status as mainstream suppliers to the ICT industry. In particular, the growth of local suppliers in Lombardia has been very limited in number as well as impact; almost all of them are struggling to expand their market share beyond the original customer. The specialized cluster did not materialize.

In terms of diffusion of business practices and working culture, results are hard to quantify. STMicro brought about some brain-return. The Company's CEO, Pasquale Pistorio, was in fact a Motorola executive in the US for 23 years. However, of the other 18 front line executives at STMicro, only 4 did work for major semiconductor manufacturers in the US or Japan. As a result, culture and business practices at STMicro were largely endogenous. In particular, the corporate culture of STMicro in Lombardia might bear similarities with that of large semiconductor companies such as Motorola or Texas Instruments. But it would be hard to find any vestige of Silicon Valley "spirit".

STMicro was for a long time a skittish member of the semiconductor global industry network. It is not surprising therefore that the Semicon culture did not spilled over from STMicro onto its network of contacts in Lombardia. Anecdotal evidence points to a rather different outcome, and even STMicro presents itself as an anti-Silicon Valley hero: The stated company mission is to "offer strategic independence to our partners worldwide" with the implicit understanding that partners would otherwise "strategically depend" on other semiconductor manufacturers.

Finally, there is little evidence that the journey of STMicro from late starter to leading niche player did stimulate the growth of a specialized cluster in Lombardia during the phase of widespread adoption. The cases of STMicro plants in Southern France (Rousset and Crolles) and Sicily (Catania) lead to partially different conclusions. This is largely because Regional Governments did provide incentives for other large and small companies to settle in the area. Furthermore, there was a dialogue between local administrations and the Company. However, in those locations too, suppliers and subcontractors are struggling to exit from under the shadow of STMicro, and become worldwide players in their own title. Even the most positive accounts of STMicro's presence in these peripheral regions concede that overdependence on the company's business strategy and specialization might at the end be a problem for the local development perspectives (Di Guardo and Schillaci, 2003).

The experience of STMicro suggests that a large late-start company is capable of moving to a position of active follower, provided it can ride the wave of widespread adoption. But this success remains its own. Only if coupled with active policies, a large settlement of new technology may be expected to produce entrepreneurial spillover in the surrounding region.

Moving inside the box

The former conclusion leads to a second question, namely: what policies would help a region to move from one stage to the next inside the space-time framework? The experience of STMicro in Lombardia shows that large-scale government initiatives may succeed in creating a national champion. But the presence of a national champion *per se* does not rescue a region from the status of passive adopter.

In other words, technological development should not be attributed to the particular phenomena emerging at each phase (Figure 2); one should rather consider the causes leading to their manifestation. In order to move from one phase to the next, a number of conditions have to be in place; the function of a considerate regional government should be the nurturing of such conditions.

Within the space-time table, two shifts have been deemed relevant for the case of Lombardia:

- Active Follower from Early Application (1) to Production Expansion … (2) and thereon to Widespread Adoption
- Passive Adopter to Active Follower (4) through a phase of Widespread Adoption (3)

Figure 3 summarizes the objectives of regional policy aimed at generating these shifts.

FIGURE 3: regional preconditions

PHASE / **REGION**	EARLY APPLICATION	PRODUCTION EXPANSION	WIDESPREAD ADOPTION
ORIGINATING CLUSTER			
ACTIVE FOLLOWERS	-regional openness - industry focus -competitive cost of factors - effective R&D infrastructure -proximity to final markets	1 - regional policies leverage on foreign investments for growth and diversification	2
PASSIVE ADOPTERS		3 -local knowledge basis and new technology shift complement each other in generating new applications	4 -regional policies stimulate the growth of clusters in new applications

It might be worth remembering that these are not recipes for "technological development" but strategies aimed at attaining a value-added position within the global division of labor emanating from a new technology shift. This paper points towards a general direction; discussion of the specific economic policies might be the subject of a different paper.

The position of Lombardia

An originating cluster, or center of innovation, was described as a region characterized by high concentration of know-how that creates new products, identifies new applications, and drives their market adoption.

Lombardia stands out as the most innovative region in Italy. In the period between 1969 and 1995, 50% of the US patents granted to an Italian inventor have been assigned to companies located in Lombardia. Among the US patents resulting from R&D activities of foreign companies in Italy, 57% were the result of research performed by inventors located in Lombardia. (Cantwell 2002)

Lombardia, however, does not belong to tier one innovation centers in Europe. A comparison based on the US patents granted, during the same time period, to inventors located in other European regions gives a rough idea of where Lombardia stands. German Landers such as Nordtrhein-Westfalen, Bayern, Baden-Wurttenberg, Oberbayern, or the Southwest of England have a concentration of patents at least 5 times larger. When the Eurostat NUTS (Nomenclature Territorial Units for Statistics) are considered, a region with Lombardia's patents would rank 14th in Germany, and 5th in the UK.

A study conducted on the evolution of pharmaceutical industry in Lombardy (Orsenigo 2002) leads to a similar conclusion, arguing that the location advantages of Lombardia disappeared as the industry underwent a consolidation process; during the 1990s, multinational corporations systematically shut down their R&D centers in Lombardy, with a regularity that cannot be deemed accidental.

Similarly, it might be easily shown that Lombardia firms did not have a role in the origination of ICT technology.

This paper suggests that in order to play the role of "active follower" for the next major technology shift, Lombardia should either:

? attract copy exactly foreign investments,

? or replicate domestically the effects of copy exactly.

In either case, the final goal should be to generate synergies leading to niche diversification in the phase of widespread adoption.

Preconditions for an active follower

The ultimate effect of a "copy exact" investment on active followers is to establish the receiving hub of an information network, specializing in the "mayor technology shift". The hub possesses knowledge to understand and process information, has enough influence to reverberate it to the surrounding regional economy, and is well enough connected to the originating cluster to keep current on new technologies and applications.

In the case of ICT, "copy exact" events have triggered the development of active followers. However, a region such as Lombardia did not possess the requisites that made it a likely candidate for a "copy exact" investment decision by a foreign corporation. That does not need to be the case for present major technology shifts, such as biotechnologies, Hydrogen, or the treatment of materials and material surfaces at very small scale. Hence one possibility would be to encourage the growth of preconditions leading to copy exact investments in those sectors by large international firms. But the case of pharmaceutical R&D installations seems to indicate that it might already be too late for some of these industries.

Furthermore, a case may be made here that those effects could be replicated even in the absence of a "copy exact" event. This will require active economic policy on various levels:

a) Creating an information network in the centers of innovation

b) selecting appropriate "technology shifts" as priority goals for regional technological growth

c) financing stimulus packages for domestic industries willing to embrace the technology shifts and make use of the information network

d) boosting the input factors

e) establish global feedback loops based on objective checks and balances, to periodically evaluate the direction of technology shifts and the performances of local companies

Point (e) is of critical importance: "complementarity among regions is a dynamic process because of continuous innovation and entrepreneurship, which, in turn, stimulates the restructuring of firms, industries, and regions" (Collaborative Economics, 2003)

5. Conclusion and further research

This paper was an attempt to describe the production ramp-up of a fundamental technology shift from one regional economy to the rest of the world, first through a mechanism of "copy exactly " and later through a rationalization in the division of labor.

It has been argued that "active followers" undergoing a process of "copy exactly" at an early stage have enjoyed a competitive advantage over "passive adopters" who simply received the innovation as users. This is because, together with the productive investment, active followers have also benefited from innovative know-how, a new working culture, an efficient network of communication, and information on future applications. As a result, they were able to sustain internal structural changes. When expansion of the new technology moves from the "copy exactly" phase to the phase of rational division of labor, active followers already possess most of the necessary requisites to successfully compete for the allocation of specialized tasks, as well as for new markets and applications, in the new regional division of labor.

The two -dimensional framework of space and time was introduced on the ground that innovation is the combined result of invention and adoption, and adoption cannot be understood without considering its regional dimension.

The second part of the paper has focused on the semiconductor industry as it was going through one major technology shift, namely the ICT revolution. This case showed that adoption by active followers comprises two steps, an early stage described as "copy exactly" and a later stage described as "rationalization in the division of labor".

The case of Lombardia was described as that of a "passive follower with a national champion". Among the most visible differences between an "active follower" and a "passive adopter" region there are:

- the extent of R&D investment and in the interaction between public and private research
- openness to knowledge and know-how from outside the region
- decisional structures in R&D (MALONE 2004)

The conclusion of the analysis of Lombardia concluded arguing that the effects of a copy exact event are reproducible through economic policy decisions.

Applying the space-time exercise to other regions, as well as extending this analysis to further cases of mayor technology shift might provide the ground for some generalization. In particular, two possible avenues for further research might be pursued (1 and 2), resulting in the verification of a normative suggestion (3)

1. An "active follower" is a region whose government has enacted economic policies and structural measures that favor the "copy exactly" process during the early stage of a technology adoption process (production ramp up). Such appear to be the cases of Ireland, Taiwan, Singapore, Korea and Israel (among others) in the case of semiconductors.
2. A "passive adopter" regional economy is the default outcome of a region that is not an originating cluster, nor has an active economic policy to foster its position in a specific technology shift.
3. In order to move from a position of passive adopter to a position of active follower, a region needs to either compete as a recipient of "copy exactly" investments during the early stages of the next major shift in technology, or procure itself (by means of active economic policies) the ensuing characteristics, which will position it as a player in the later stage of division of labor rationalization.

Failure to pursue the either of the goals stated in (3) will relegate a region at the periphery of the industry, and as a chronic passive adopter of the applications of the major technology shift.

In terms of policy implications, there is a need to understand whether the conclusions of this study may be relevant for future technology shifts, such as Hydrogen-fuelled transportation, the Biotechnology revolution, or Nanotechnology. To that effect, the single most critical question involves a comparison between the semiconductor /ICT case and new industries that are likely candidates to generate future technology shifts.

In other words, are the structural characters of those new industries and technologies sufficiently similar to those of semiconductors before the ICT revolution, to legitimize the use of a similar model for predictive purposes? In our opinion, the answer to this question will enable policy makers to determine whether the past experience of ICT might be used as guidance for policy decisions regarding future technology shifts.

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