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THE ROLE OF SCIENCE AND TECHNOLOGY PARKS IN FOSTERING TECHNOLOGICAL INNOVATION IN MANUFACTURING

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STPs and AIs fostering technology-driven projects

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The Role of Science and Technology Parks in Fostering Technological Innovation in Manufacturing

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Executive Summary

In recent years, manufacturing has returned to the forefront of policy making aimed at boosting national and regional economies. Terms such as “back to making stuff” and “the factory of the future” can be found in reports urging governments to boost local industry by developing policies to support modern manufacturing and the technology that is transforming it. While policies for the factory of the future are under discussion, specific programs to increase the productivity and level of innovation of SME manufacturers are also underway (National Academies, 2013).

Traditionally, manufacturing activities were excluded from Science and Technology Parks (STPs); manufacturing understood as large scale production of goods. This paper argues that STPs have an opportunity to play a leading role in fostering, and articulating the adoption of modern manufacturing practices and technologies, and that this should be done by taking into account the demand identified in their local areas of influence.

1. Why Manufacturing?

The question of whether manufacturing is still a driver of the global economy is raised in several reports. The share of global value added manufacturing has declined over the past 30 years, while the global value added by services has increased (WEF 2012). Nevertheless, the U.S. Department of Commerce indicates that manufacturing has a higher multiplier effect on the U.S. economy than any other sector, with USD 1.40 of additional value added in other sectors for every USD 1.00 in manufacturing value added (WEF 2012).

Manufacturing as a share of the economy has evolved differently in different countries, and while Germany has maintained a strong manufacturing industry over the years, Britain and the U.S. have gone through a period of deindustrialization, with the UK losing two thirds of its manufacturing work force in the past 40 years, and the U.S. one third in the 2000s alone. However, according to President Obama, the U.S. has recovered 620,000 jobs in the last four years (Obama, 2014). At the same time, some of the emerging economies, traditionally viewed as locations for low-cost labour, have developed their own manufacturing and innovation capacities, resulting in an increase in the production of advanced manufactured products.

Differences in manufacturing as a share of the economy are also found at the regional level. A recent study from the Regional Innovation Monitor Plus project developed for the European Commission (RIM Plus 2014) shows that in the EU28[1] more than one in six people are employed in industry and the Gross Value Added (GVA) generated by industry in the EU28 accounts for 19% of the total GVA. However, there are differences across EU regions. Of the 200 regions covered in the study, only 73 are defined as industrial regions[2]. Of these, 32 are considered technology advanced regions, i.e., they have high or moderate intensity of R&D investment[3], while 41 are considered low tech regions, i.e., they have low intensity of R&D investment.

The decline of manufacturing activities has prompted much concern in governments of developed economies. As a result, recent years have seen the return of manufacturing to the forefront of

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[1] UE28 refers to the current 28 member states of the European Union (http://europa.eu/about-eu/countries/member-countries/index_en.htm).

[2] Industrial regions are taken to be those with a strong focus on industry-related activities and employment, which registered for GVA by industry more than 25% and/or employment in industry 20% of total and above (RIM Plus, 2014).

[3] In the RIM Plus study the classification of high, moderate or low intensity of R&D investment is made on the basis of BERD and GERD expenditures as percentages of GDP (see RIM Plus, 2014 for more details).

policy making aimed at boosting the economy. Terms such as "back to making stuff" or "the factory of the future" can be found in reports urging governments to boost domestic industry by developing policies to support modern manufacturing and the technology that is transforming it (The Economist, 2012). Meanwhile, emerging economies are also actively developing their own manufacturing and innovation capacities; while still maintaining low-labour costs, but with modern manufacturing technologies.

In order to understand the role that Science and Technology Parks (STPs) might play in fostering technological innovation in manufacturing, the next section looks into what is involved in the manufacturing process nowadays, i.e., the role of services in the manufacturing value chain, the need to tackle the market failures hindering the competitiveness of current SME manufacturers, and the needs of the budding *personalized digital manufacturing*, also called the factory of the future.

2. On the Nature of Manufacturing

The nature of manufacturing has changed over time. Manufacturing is no longer just the process of turning raw materials into physical products: it is not just about production. In the wider set of activities that nowadays form part of the value chain of manufacturing, services play an increasing role. As an example, the percentage of British companies with more than 100 employees that derived value from services related to their products increased from 24% in 2007 to 39% in 2011 (Foresight, 2013).

Nowadays two kinds of manufacturing can be distinguished. The first, and still most common type, is centered on large capital-intensive factories (such as car plants), employing many hundreds of people, making long series of products and involving a large community of SME manufacturers and component providers. Boosting the productivity and innovation capacity of this community of SME manufacturers has been the core of many government policies in support of manufacturing. Long running programs such as MEP (U.S), MAS (U.K.), and IRAP (Canada) are good examples of programs aimed at tackling the market failures that hinder the competitiveness of these SMEs (National Academies, 2013).

The second type is the budding, smaller scale, more flexible, personalized digital manufacturing, also known as the factory of the future. Analyses of future megatrends[4] by recognized institutions such as the Copenhagen Institute for Future Studies or CSIRO indicate expected high growth in this area. The shift to personalized products and services is one of the megatrends for the next decades. Citizens and customers are cross-culturally different in their behaviour and their preferences for products. As a result, a growing number of companies have begun to adapt, not just their marketing, but also their products and manufacturing processes to the individual markets (Larsen G., 2006). Going one step further, the creative customer who wishes to create his or her own solution is the coming thing. Innovative personalization, using modern manufacturing technologies, such as additive manufacturing, aims to cater for customers' expectations for individual and unique products (Hajkowicz SA, Cook H, Littleboy A, 2012).

A more individualized production system, based on digital technology, 3D printing (also called additive manufacturing), and new materials will play a central role in the development of a new generation of SME manufacturers. This new generation is expected to cater for emerging markets as well as traditional ones. According to a market research report (Marketsandmarkets, 2013), the 3D Printing Market is expected to grow at a Compound Annual Growth Rate (CAGR) of 23% from 2013 to 2020, and reach USD 8.41 billion in 2020. Applications are being developed for the automotive, aerospace, consumer, healthcare, government and defence, industrial, and education and research sectors. The geographical analysis in the report covering America, Europe, Asia-Pacific, and the Rest of the World shows that America, currently, leads the market, although the European region is the fastest growing market, and according to the report it will surpass America in the near future.

[4] Megatrends are global, sustained and significant shifts in social, economic and environmental conditions that will very likely affect the future in all areas in the coming decades. The analysis of megatrends and their implications are used by companies and governments in their strategic decision making and planning.

Manufacturing thus requires the development of technological innovation to cater for the needs of current SME manufacturers as well as for those of the factory of the future. This is prompting a set of policy measures by governments in developed and emerging economies.

3. Policy Measures in Support of Manufacturing

Several countries are looking to the factory of the future to develop a new domestic highly skilled manufacturing industry in the coming decades. This movement is known in Germany as Industrie 4.0 or the fourth industrial revolution. Industrie 4.0 refers to the technological evolution from embedded systems to cyber-physical systems. Characteristics for industrial production in an Industrie 4.0 environment are the strong customization of products under the conditions of highly flexible (mass-) production, where the required automation technology is improved by the introduction of methods of self-optimization, self-configuration, self-diagnosis, cognition and intelligent support of workers. To support this initiative, the German government has allocated funding of up €200 M within the High-Tech Strategy 2020 Action Plan, approved in 2012 (Germany Trade & Invest, 2013). This funding is expected to finance collaborative projects between industry and academia, using their well-established technological networks including the Fraunhofer (for applied research) and Max Planck (for basic research) research centres, universities, clusters, trade associations, big manufacturing companies and suppliers.

Comparatively, recent strategies in the U.S. and the U.K. place a stronger emphasis on the development of (applied) research infrastructures to strengthen what is known as "industrial commons"[5]. In the U.S., recommendations from the President's Council of Advisors on Science and Technology (PCAST, 2012) include the development of a set of regional Manufacturing Innovation Institutes (MIIs) to bridge the gap between research and commercial application of advanced manufacturing technologies. Unlocking advanced manufacturing innovation at a regional level is viewed as critical to transforming U.S. global competitiveness in manufacturing by enabling unique public-private partnerships that leverage regional competencies. These institutes form a national infrastructure network, the National Network for Manufacturing Innovation (NNMI). The President asked Congress to authorize a one-time $1 billion investment—to be matched by private and other non-federal funds—to create an initial network of up to 15 MIIs, some of which have already been launched. Over a span of 10 years, he has proposed building the NNMI to a level of 45 MIIs (NNMI, 2014).

In the UK, industrial policy has regained importance in recent years. An integral part of this policy is the Catapult programme, set up by the Technology Strategy Board in 2010 to develop a network of Technology and Innovation centres called Catapults (TSB, 2013). The network of Catapults is a strategic long-term investment in the UK's innovation capability, aimed at driving economic activity and significantly increasing wealth creation by building a bridge between the research base and business. Each Catapult focuses on a specific area of technology and expertise which is understood to have great potential. The first technology chosen to develop a Catapult was High-Value Manufacturing. The High-Value Manufacturing (HVM) Catapult centre was opened in October 2011, bringing together a network of seven existing technology centres (TSB, 2013). According to results presented in October 2013, the HVM Catapult has already invested GBP 350M, GBP 134M of innovation activity with 38% contribution from industry, exceeding the 1/3 target, over GBP 2.00 of industry and collaborative funding from every GBP 1.00 of core, and more than 1,800 SME engagements (Elsy, 2013).

[5] Industrial commons (Pisano G. and Willy S., 2012): the collective operational capabilities that underpin new product and process development in the industry sector. It refers to the "R&D and manufacturing infrastructure, know-how, process-development skills, and engineering capabilities". Pisano and Willy call for a U.S. national economic strategy for manufacturing, with an emphasis not on "picking winners" among companies or even industries, but on providing support for basic process-oriented innovation that can be utilized by competing companies in several industries. Their argument has been used to support the U.S. Government policy for the development of the Manufacturing Innovation Institutes.

It would seem that the MIIs in the U.S. and the Catapults in the U.K. have been inspired by the German Fraunhofer network of applied research centres, changing course in both countries from a previously stronger university-led technology transfer strategy[6].

Emerging economies are also developing policies in support of advanced manufacturing. China, the world´s largest manufacturing economy, and currently considered one of the most competitive nations in the world, has evolved in the past 10-15 years from low-cost labour manufacturing to higher-end manufacturing. The development of its own manufacturing and innovation capacities is resulting in increased production of advanced manufactured products.

Manufacturing, and in particular High-End Equipment manufacturing, is treated as a strategic emerging industry in China´s 12th Five-Year Plan, covering 2011-2015. The objective is to drive equipment manufacturing from a production-oriented type to a service oriented type, and promote the development of equipment required for new strategic industries and infrastructure (FYP, 2011).

While policies for the factory of the future are under development, programs to increase the productivity and innovation level of SME manufacturers are also underway. Some governments have developed programs to support the provision of what is generally called Technology Extension Services-TES (also called Manufacturing Extension Services-MES), to increase the productivity and level of innovation of SME manufacturers. TES are common in developed economies such as Canada, Germany, Japan, the UK, and the U.S (National Academies, 2013), and are becoming more popular in emerging economies (ITIF, 2013). For example, the Manufacturing Extension Partnership (MEP) is a U.S. program which has sought to strengthen American manufacturing since the 1990s. Originally developed as a part of the U.S. response to the perceived declined in their position in relation to Japan as a leading manufacturer of high-technology goods, MEP has offered technical and business support to SME manufacturers for more than two decades. It has done so through a national network of manufacturing specialists with centres in 50 states. With a similar objective, since 1997, the Manufacturing Advisory Service (MAS) in the UK has provided manufacturing business support to help companies improve and grow. MAS is currently financed by the UK Department of Business Innovation and Skills (BIS) and operated by the Manufacturing Advisory Consortium (MAC) under contract to BIS. Finally, Canada´s Industrial Research Assistance Program (IRAP) is also a TES program, although slightly more geared towards encouraging R&D in SMEs. IRAP is a business R&D enhancement program that has provided funding, technical and business advice, and networking services to SMEs since 1962. The program operates through its own offices and also through partner organizations in five regions of Canada.

Emerging countries, which have benefitted from the offshoring of manufacturing companies and are developing manufacturing capacities of their own, have also started to put in place programs to support Technology Extension Services. In the Latin American and Caribbean (LAC) Countries, for example, Technology Extension Services are being developed around four main goals: increasing productivity, boosting innovation (i.e., creation of new products), facilitating supply chain management and integration, and spurring exports (ITIF, 2013). Brazil has developed the Technology Extension Network under the Brazilian System of Technology (SIBRATEC). This network provides access of SMEs to the State Networks of Technology Extension, to bridge gaps in technology management, projects, development, production and commercialization of goods and services.

To understand the role that Science and Technology Parks might play in the implementation of some of these policy measures in support of manufacturing, it is important to first understand the current manufacturing activity in STPs. The next section presents an analysis extracted from the report of the 2012 survey conducted by the International Association of Science Parks.

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[6] It is not the first time that the Fraunhofer model has inspired the development of a strong applied research infrastructure to revitalize the industrial sector. The research centres currently constituting Tecnalia and the IK4 Research Alliance in the Basque Country region were originally created, in the 1980s, following the Fraunhofer model. The Basque Country is one of the Technology Advanced regions of the UE28 (RIM Plus 2014).

4. Manufacturing Activity in STPs

Results of the latest available study (IASP, 2012) indicate that, although the majority of manufacturing employment can be attributed to the Advanced Engineering and Metals clusters, there are key elements of manufacturing in all clusters.

The study includes a sample of 119 science and technology parks, from 38 countries (Argentina, Australia, Austria, Brazil, Canada, China, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, India, Iran, Italy, Japan, Korea, Latvia, Lithuania, Malaysia, Mexico, Panama, Poland, Portugal, Qatar, Russia, Slovenia, South Africa, Spain, Sweden, Thailand, The Netherlands, Tunisia, Turkey, United Kingdom, United States of America and Venezuela).

As shown in figure 1, more than 41% of STPs do not permit manufacturing activities (only prototyping) with only 26.9% of STPs permitting their companies to carry out manufacturing activities.

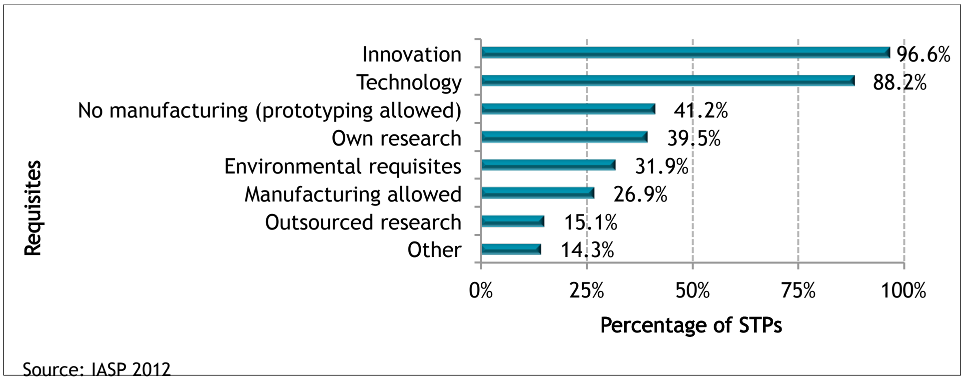

Figure 1: Requisites for tenants in STPs

Also, the largest percentage of STPs that permit manufacturing comes from those STPs created between 2002 and 2006 (57.1%). Before 2002, this percentage is significantly lower (see figure 2).

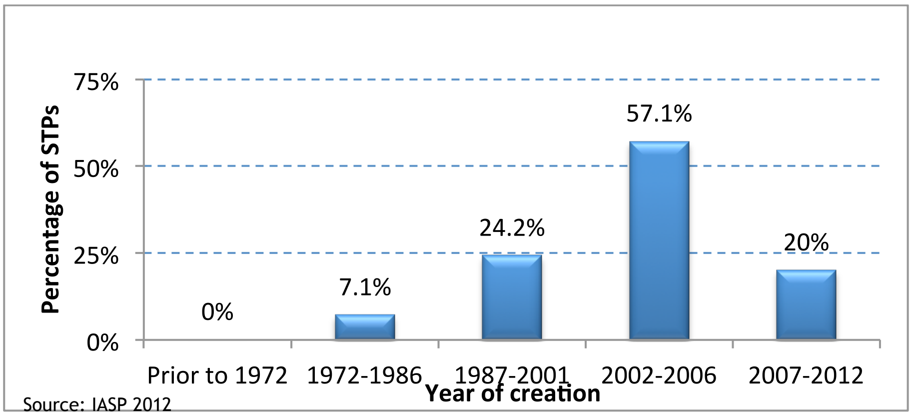

Figure 2: STPs that permit manufacturing (by year of creation)

STPs are also sometimes classified as Generalists or Specialists according to whether they admit companies from any sector or they specialize in one sector or a limited number of sectors. Semi-specialists are those STPs that encourage or give preference to certain sectors, but admit others. According to the IASP survey, nearly half of the STPs surveyed are generalists, with 18.4% being specialists (see figure 3).

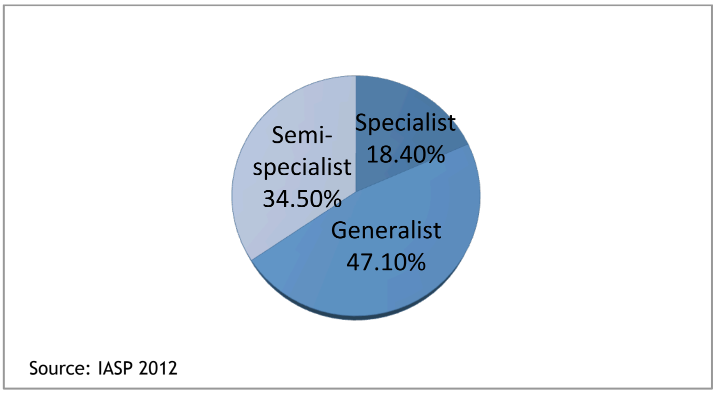

Figure 3: Specialisation of STPs

An example of STPs specializing in manufacturing is the Advanced Manufacturing Park (AMP) in the UK (AMP, 2014). This is a 40 Ha. manufacturing technology park in Rotherham, South Yorkshire (U.K.). The model for the AMP emerged from the decline that South Yorkshire had seen in its traditional industries of coal and steel over the last twenty years. Despite this decline, the region had retained established skills and expertise in the areas of advanced manufacturing, backed up by the materials research expertise from within the two Sheffield universities, and other independent research organisations. The setting up in 2004 of the AMRC (Advanced Manufacturing Research Centre) between the University of Sheffield and Boeing in AMP was a catalyst for the development of the Park.

AMP further specialises in materials and structures, covering metallic and composite materials, typically used in precision industries including; aerospace, automotive, sport, environmental, nuclear, and energy, oil and gas, defence and construction. Technology developed in the AMP is already being used in cutting edge projects, such as those of Formula One and the next generation of military and commercial aircraft, including the new Boeing 787 Dreamliner, and advanced 3D printed facial prosthetics.

Generalists or Semi-generalists STPs might allocate space for specialized sectors. Answers to the IASP survey show that just under half of the STPs do have some zones reserved for specific sectors.

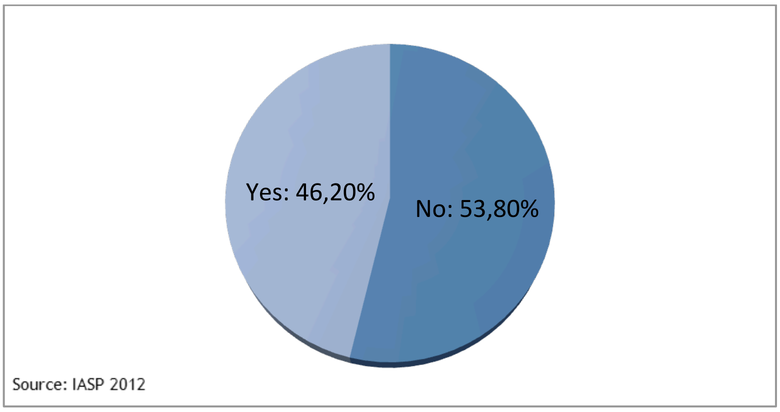

Figure 4: Specialised technology sector areas within STP

An example of an STP with a specialized area for manufacturing is Western University Research Park in Canada (Western AMP, 2014). The manufacturing sector of Southwestern Ontario, the driver of the region’s prosperity since Confederation, was seriously affected by the recession of 2008. Stakeholders across the region vowed to recover it; smarter and re-tooled for the 21st century. In 2010, the Western University, the City of London and Fanshawe College set up an innovative partnership with three levels of government to commission Western’s Advanced Manufacturing Park (Western AMP, 2014) – the first Canadian Research Park dedicated to the manufacturing sector. It is part of the Western University Research Park program, which started in 1989 with the Western Research Park, located adjacent to Western University. The Western Advanced Manufacturing Park is aimed at developing new technologies in the renewable energy and transportation sectors, focusing on smaller, lighter and more energy efficient parts, products and processes.

Having examined the needs related to technological innovation arising from modern manufacturing, the relevant policy measures being put in place to tackle them, and the current activity in this sector in STPs, the next section puts forward the argument that STPs have an opportunity to play a leading role in fostering technological innovation in manufacturing, and it points to new ways in which this could be done.

5. STPs as Manufacturing-Innovation Ecosystems

The Manufacturing for Growth Initiative, a follow up from the Davos 2012 review and discussion on the output of The Future of Manufacturing project (WEF, 2012), addresses key competitive factors in three critical areas: strategic use of public policy, innovation and technology advancement, and human capital and talent development. In the Manufacturing for Growth report (WEF, 2013) recommendations to drive economic growth and high value job creation through manufacturing industry sectors were put forward, and a Public Policy for Science, Technology and Innovation which promotes advanced manufacturing is identified as essential. According to the report, this involves policies which support the development of powerful “manufacturing-innovation ecosystems”.

Although this is an important step forward and one where STPs can play a leading role, some of the models proposed in the report for the development of these ecosystems seem to be outdated. A well-known model, for example, still recommended in the case of India, is that of industrial clusters with state-of the art infrastructure, creating integrated industrial townships. While this model may be suitable for attracting investment, it makes little progress in developing a manufacturing ecosystem. Another model, widely used in STPs and proposed for the USA in the WEF report, involves developing areas to co-locate research institutions, companies, and the best talent, all focused on advancing research to full commercialization. This model has the drawback that normally it does not include co-locating actual manufacturing production and, as a result, it does not incorporate mechanisms to understand and integrate knowledge developed in the production process.

This paper argues that STPs should follow more recent proposals, such as that of the UK government, promoting the co-location of R&D with production, to maintain and build an “industrial commons” (Foresight, 2013). By adopting this approach to the future of manufacturing in the UK, products dependent on process-driven innovation benefit from the co-location of different parts of their production systems. The Government has a major role to play, nationally and locally, in encouraging greater agglomeration and clustering of particular activities, including encouraging the co-location of production alongside research and development[7]. China also seems to endorse this approach, with one of the policy directions in the 12th Five-Year Plan being the promotion of the strategic union of production and R&D and promoting coordinated development of industrial areas in High-End manufacturing.

STPs have an opportunity to take an active role in fostering the systematic development of these “manufacturing-innovation ecosystems”. STPs contribute to the socio-economic development of their areas of influence by creating high technology economic development. They are well (and sometimes uniquely) placed to put these initiatives into operation, given their knowledge of the regional environment and their relations with the government, the industrial and business companies, and the teaching and research institutions.

[7] This model is also coherent with Lundvall´s approach to National Innovation Systems (Lundvall, 2005). Lundvall developed a distinction between two modes of innovation, which he called STI and DUI modes of innovation. The first one, STI mode, is based on science, R&D and access to explicit codified knowledge, whereas the DUI mode is based on learning by doing and using implicit or tacit knowledge developed in the production process. Lundvall´s approach is that an innovation system needs to encompass elements that refer to the two modes of innovation.

Traditionally, manufacturing activities were excluded from STPs; manufacturing understood as large scale production of goods. It is only in more recent years and in STPs of recent creation, that manufacturing is permitted (see IASP, 2012). The views on the future of manufacturing described in this paper show that perhaps, it is time for STPs to reconsider this position and lead the systematic development of manufacturing-innovation ecosystems by promoting the co-location of R&D with production to generate potential models for scalable, public-private partnerships following the "industrial commons" approach.

This new approximation to manufacturing encompasses the needs arising from the implementation of programs supporting the provision of what is known as Technology Extension Services (TES) and those generated by policies for the factory of the future.

As it has been shown in this paper, governments from both the developed and emerging economies are recognizing the need to increase the productivity and innovation level of established SME manufacturers. Although in programs such as MEP (in the U.S.) and MAS (in the U.K.) the support services are provided by the program staff or independent consultants, initial findings from a study, commissioned by the Inter-American Development Bank (IDB) and produced by IDOM, on analysing relevant TES programs in five Latin American countries (IDB, 2013), show that applied research institutions are actually the main providers of these services. In many cases this is due to the availability of laboratory instrumentation and certified equipment (basic industrial commons) that these institutions make available to companies. Applied research institutions have traditionally been tenants of STPs, thus making it easier for STPs to articulate the public-private partnerships required for the set up and operation of these programs.

STPs can also place themselves at the core of the new Industry 4.0 initiatives, providing and operating specialist physical infrastructure (industrial commons) that might be required in the initial stages of new manufacturing start-ups. With this in mind, it is important to work both at the national and regional levels. In addition to the previously discussed country policies supporting advanced manufacturing, in Europe some of the Regional Innovation Strategies for Smart Specialisation being developed for the 2014-2020 period (RIS3, 2014)[8], have advanced manufacturing as a main priority. This is the case in the Basque Country, where the Smart Specialisation Strategy includes Advanced Manufacturing as one of three priorities for the 2014-2020 period. It is foreseen that a Centre for Advanced Manufacturing will be created in the Bizkaia Science and Technology Park, with the involvement of stakeholders of the aeronautical sector in the region (Spri, 2014).

STPs could promote and articulate community initiatives such as the U.S. new Federal partnership, the "Investing in Manufacturing Communities Partnership" (IMCP). The IMCP seeks to enhance the way the U.S. government leverages federal economic development funds to encourage American communities to focus not only on attracting individual investments one at a time, but transforming themselves into globally-competitive manufacturing hubs (EDA, 2014). The first step in building a community partnership involves building an organizational backbone with the insight needed to strengthen manufacturing and fully support the work that follows. STPs are well placed to carry out bottom-up community building, for example, by organizing seminars, cross-business meetings and get-to-know events. These activities should complement a proactive approach towards developing the community hub, bringing new manufacturing companies to the region, as well as creating and hosting new Industry 4.0 manufacturing start-ups.

6. Conclusions

According to the IASP 2012 survey, most STPs can be characterized by a model focused on innovation and technology related activities, where manufacturing, to a great extent, is not

[8] Following the European lead, Regional Smart Specialisation Strategies (RIS3) are also being developed in other countries such as Chile (proyecto RED, 2014) and Mexico where IDOM is developing Strategies for ten states (Conacyt, 2014). Of the ten states, two (Guanajuato and Veracruz) have manufacturing related to the automotive sector in the first case and metal-mechanical in the second, while in the other eight states new manufacturing capacities would need to be developed to boost the agroindustrial sector.

permitted, except for prototyping purposes. This STP model usually involves developing (high-standard) areas to co-locate research institutions, companies, and the best talent, all focused on advancing research-based knowledge to commercialization. This paper argues that not co-locating actual manufacturing production in an STP has an important drawback, i.e., it does not incorporate mechanisms to understand and integrate knowledge developed in the production process. This knowledge, called tacit or implicit knowledge, also gives rise to innovation and technology development, the type of innovation that Lundvall calls "learning by doing" (Lundvall, 2005).

Based on a review of policies to support manufacturing, this paper further argues that perhaps it is time for STPs to reconsider the currently accepted models and lead the systematic development of manufacturing-innovation ecosystems, by promoting the co-location of R&D with production to generate potential models for scalable, public-private partnerships following the "industrial commons" approach. In this approach, technological innovation would cater for the needs of current SME manufacturers as well as for those of the factory of the future.

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