

# Broker-oriented Networks: Facilitating Commercialization for Technology Ventures

## **Abstract**

This research aims to investigate the role of broker-oriented networks in successful commercialization of new products in technology ventures. Innovation brokers such as private consultancy firms, government agencies, research institutions, and incubators primarily focus on enabling technology ventures to innovate and market their innovations. This study focuses on broker-oriented networks of six UK-based nanotechnology ventures. Semi-structured interviews were conducted with senior managers to examine their collaborative network formation, types of brokers used, and their impact on commercialization process. Analysing these networks' value-creation logics revealed that broker-oriented networks are advantageous to commercialization and are particularly useful when technology ventures decide to enter a new market or start a new field of activity. Our findings indicate that private broker companies and governmental agencies can contribute considerably to the international expansion of technology ventures. Research centres and universities also play an important brokerage role between ventures and large incumbents by supporting them in testing, validation, prototyping as well as providing pilot facilities.

## **Keywords**

Collaborative Commercialization Networks; Technology Ventures; Broker oriented networks; Nanotechnology

## **1. Introduction**

The ever-increasing costs and challenges of commercialization of a new product or service has made it progressively difficult for any individual technology venture to rely solely on their own limited resources in successfully launching the new offering to the global market. As such collaborative commercialization networks are increasingly formed to facilitate this process and to ensure the success of the new product/service launch (Aarikka-Stenroos & Sandberg, 2012). Collaboration with different external actors such as customers, partners, suppliers and knowledge institutions (e.g. universities or government laboratories) are considered as vital commercialization sources for technology ventures in order to gain access to and integrate various resources reside within the embedded collaborative commercialization networks to generate commercially viable offerings (Hemert et al., 2013). Among these diverse external actors, innovation brokers or intermediaries are organizations with great potential to contribute to the commercialization process for technology ventures (Batterink et al., 2010; Lee et al., 2010).

Previous research on innovation brokers illustrate different ways through which these actors can have positive influence on innovation success, e.g. by acting as a catalysts and closing gaps between supply and demand sides (Howells, 2006; Klerkx & Leeuwis, 2009), enhancing the scope of external innovation search and reducing search costs given the increased knowledge intensity (Lin et al., 2016), and facilitating new product development (Colombo et al., 2015). The increasing positive impacts of brokers on innovation success implies that technology ventures inevitably need insight into what makes brokers more valuable and thus enabling these technology ventures to make informed decisions as to what kind of innovation brokers should these collaborate with (Kirkels & Duysters, 2010).

Despite the significant role that innovation brokers play in successful commercialization of a new offering, there is a lack of systematic research on the role of broker organizations in the commercialization networks of small technology ventures. Few attempts have been made to unveil approaches of technology ventures toward brokerage, type of broker organizations they choose to collaborate with, and the broker-oriented networks they form to facilitate commercialization (e.g. Tran et al., 2011, Lichtenthaler, 2013; Boari & Riboldazzi, 2014). This research aims to address this gap by providing a contextualized understanding of the formation of broker-oriented networks by technology ventures and their impact on the commercialization process and success.

This research follows a qualitative approach and uses a multiple case study method to examine the complexity of the collaborative broker-oriented networks that are being investigated. Six cases of UK nanotechnology ventures and their embedded networks are studied in this research. The field of nanotechnology provides a suitable context to study commercialization of a novel technology. R&D activities relating to nanotechnology were initiated in the 1980s, but the large-scale investment in this domain began in the early 2000s and has resulted in many discoveries (Shapira and Youtie, 2011). New ventures are an important vehicle for commercializing this radical technology and play a critical role in bridging the gap between scientific knowledge and wide-spread market acceptance (Maine et al., 2012).

The unit of analysis in this research, is the business network surrounding technology ventures, that is, the set of actors with whom the technology venture collaborates and the set of linkages between actors. The actor may be any type of organization such as a firm, university, research centre, government agency, etc. The linkage embraces a diversity of collaborative forms including strategic partnerships, joint development or production activities, marketing alliances, distribution coalitions, etc. In particular, this research is interested in the immediate network that a technology venture intentionally forms or joins for commercialization purposes. What is shared among all cases investigated in this research is that all technology ventures have established linkages with broker organizations with the aim of facilitating commercialization. This enables us to compare and contrast various broker-oriented networks and examine how they could be conducive to commercialization.

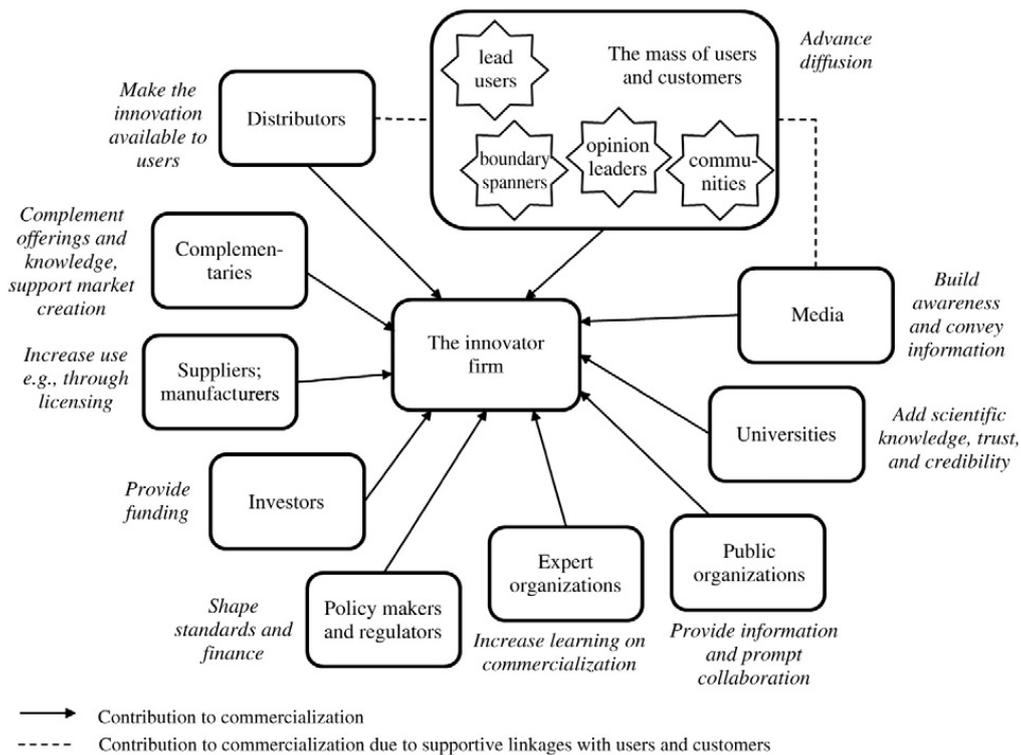
## **2. Collaborative Commercialization Networks**

The concept of *commercialization* is directly connected with the concept of *network*. Dorf and Worthington (1987) explain that commercialization of a new technology can be seen as a process. Such a process includes taking research outcome as they emerge in research institutes and laboratories and transform them into a new product that is received positively in the market. In technology ventures context, the concept of commercialization is often concerns how a promising technology can result in prolific economic returns for different stakeholders such as venture founders, investors and employees (Gans and Stern, 2003; Lockett and Wright, 2005). Such a trajectory involves interactive process of value creation and realization for technology ventures. The critical aspect of this concept is the creation of value for the end user. The value adding process requires involvement of several different

actors with a wide range of complementary competencies to purposefully interact with each other to develop tactical as well as strategic planning (e.g. product planning and marketing strategies), to discuss product/concept, launch (Hemert et al., 2013) or to negotiate with potential buyers, intermediaries, or any other relevant players in the network that the business venture is embedded in (Aarikka-Stenroos et al. (2014).

To facilitate the commercialization process, technology ventures need to build and maintain relationship with a diverse set of actors such as profit and not for profit organisations, research institutes, communities, and even key individuals. Such relations help the technology venture to form and orchestrate a unique business network that can help them in commercialization of their new technology. Aarikka-Stenroos et al. (2014) developed a framework that illustrates the diverse set of actors and their unique contributions in helping the innovator firms i.e. the technology ventures in commercializing their new product (see Figure 1). These actors include universities and expert organizations, investors, suppliers, distributors, and media among others.

This framework is very useful and practical in developing an understanding of any roles that different actors may have in the commercialization process. It can also be used by the technology venture to better orchestrate these different actors that are embedded in its network. The management of such commercialization network is a key success factor. Network links or network ties i.e. the connection between two actors within the commercialization network can be created either directly between the technology venture and any given actor in the network; or can be facilitated and arranged by a broker organization. Thus, in this research we define a broker-oriented network as a commercialization network in which a broker is a key player in facilitating the formation of a business relationship between the technology venture and other organizations in the network. The focus of our research is therefore on broker-oriented networks used by technology ventures; we aim to study the formation of such networks, different types of these brokers, and their potential impact on successful commercialization of new products by those technology ventures.



**Figure 1. An integrative framework of actors within a commercialization network of a technology venture (Aarikka-Stenroos et al., 2014).**

## 2.1. Broker-Oriented Networks

Innovation brokers also called innovation intermediaries are one of the most important actors in commercialization networks. Winch and Courtney (2007) define innovation broker as “*an organization acting as a member of a network of actors in an industrial sector that is focused neither on the organization nor the implementation of innovations, but on enabling other organizations to innovate*” (p.751). Although innovation brokers have shown positive influence on successful commercialization process of a new technology, these brokers have even more added value when they are part of a bigger commercialization network with diverse set of actors, particularly when they are in charge and take the lead for innovation initiation, network formation, and innovation process management (Batterink et al. (2010). Howells (2006) discussed the growing role of innovation brokers in facilitating the creation and protection of an intellectual property as well as distribution of any outcome of any collaborative innovation activities.

Kirkels and Duysters (2010) refer to these brokers as ‘bridging organizations’ since their role is mostly development and transfer of knowledge. Studying networks of small high-tech firms in Southeast Netherlands, they found that most of these brokers are more present and

active in the non-profit and science sectors. Similarly, Tran et al. (2011) confirmed the critical value-adding role of these innovation brokers in development of fashion product in fashion industry. They further discussed the unique capability of these brokers in reducing overall costs and enhancing the new product development process.

Innovation brokers can be in the form of a private consultancy company or they can be virtual. Examples of virtual brokers include InnoCentive.com, NineSigma.com, and Yet2.com. These brokers use web-based technologies to connect those with a specific problem with potential firms that can offer a solution to those problems. Conversely, they can showcase solutions to potential buyers. Alternatively, they can even arrange for strategic alliances and facilitate joint venturing between multiple parties (Hacievliyagil et al., 2007). Existing research on the role of virtual brokers with large firms indicates that these brokers can significantly contribute to the research and development function of large organizations (Hacievliyagil et al., 2007) as well as helping firms in the science-based sectors for reaching to a potential partner (Billington and Davidson (2013). It is also shown that the use of an innovation broker in the context of multinational firms is significantly cheaper than the conventional mechanisms for developing innovative solutions (Billington and Davidson (2013).

Government agencies are yet another type of firms that provide brokerage services for technology ventures (Caloffi et al. (2014)). These agencies provide direct support in terms of network database, network construction, and network management as well as indirect supports in terms of facilitating collaboration and addressing cultural differences (see Figure 2) (Lee et al., 2010). Cunningham and Ramlogan (2012) provide a general view of how a government can intervene to support innovation in a network. They distinguish between three levels of supports a government agency may offer including network formation and development, addressing network barriers, and formation of supportive activities.

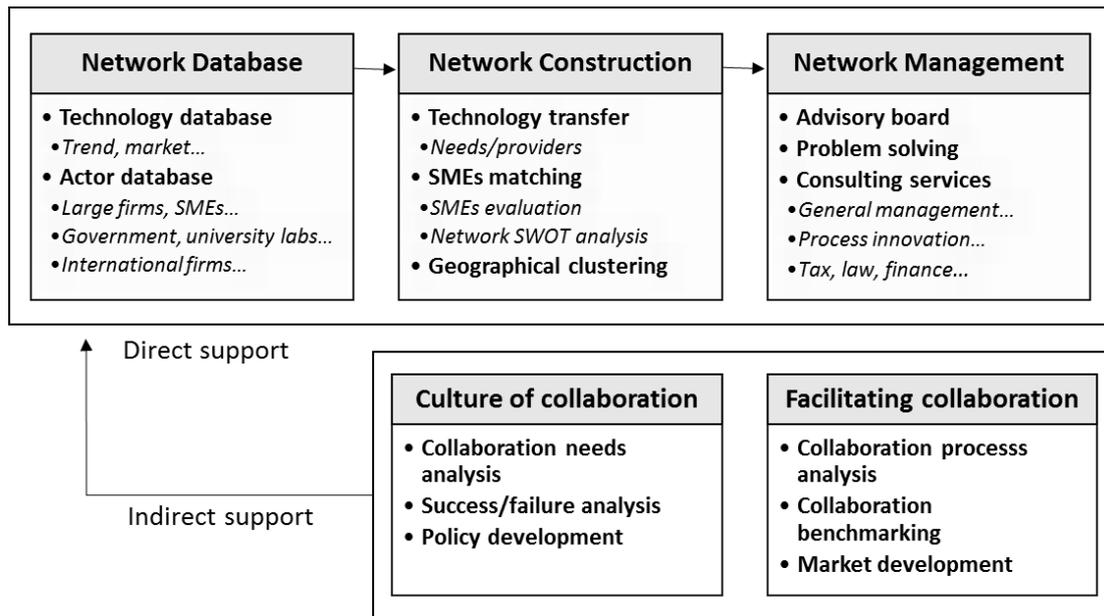


Figure 2. Direct and indirect supports of a government agency as an intermediary to facilitate formation and management of networks for innovative small firms (Lee et al., 2010); p.293

### 3. Methodology

This research pursues a qualitative exploratory approach and uses multiple case study method to address the research questions. Case study research is concerned with the complexity and particular nature of the case in question (Stake (1995) and focus on a bounded situation or system, an entity with a purpose and functioning parts (Bryman and Bell, 2011). In this study, six cases of Nanotech ventures and their surrounding networks are investigated (Table 1). The cases are selected from the UK Nanotechnology directory based on the need to satisfy theoretical replications (Eisenhardt, 1991). In all cases, at least one broker organization is present in the network and collaborates with the technology venture with the purpose of commercialization. In addition, cases are selected according to their value chain position to make sure they represent Nanotech ventures in all parts of the value chain including upstream (nano-materials), mid-stream (nano-intermediates), and down-stream (nano-enabled final products).

Table 1. Basic Company Information

Company Name	Year Established	No. of Employees	Total Assets (GBP)	Product
NV1	2011	30	<1m	Graphene
NV2	2007	30	1-3m	Copper nanoparticle based ink
NV3	2003	11	1-3m	Graphene
NV4	2008	5	<1m	Electrospun scaffolds for regenerative medicine and drug discovery
NV5	2008	35	>3m	Nano-enabled Medical devices

Company Name	Year Established	No. of Employees	Total Assets (GBP)	Product
NV6	2010	16	<1m	Printed Logic Circuits

To collect primary data, 12 semi-structured interviews were conducted with senior managers of Nanotech ventures and key informants in the field of Nanotechnology in the UK. Also, we used company websites, FAME (2014) database of companies in the UK and Ireland, companies' annual reports, press releases and other types of reports as sources of secondary data.

According to Miles and Huberman (1994), qualitative data analysis usually requires several levels of analysis to extract both explicit and implicit meaning from the data. We divided the analysis into two parts. In the first part, a detailed description of the cases and their surrounding network were developed, based on the interviews and other sources of data. In the second part, a more analytical investigation of the cases was conducted using 'thematic analysis' for analysing each case and cross-case investigation. We pursued the 'systematic combining' approach grounded in 'abductive' logic which calls for a continuous movement between the empirical observations and theory (Dubois and Gadde, 2002). This process enables researchers to expand their understanding of both theory and empirical phenomena. We used Nvivo 10 to organize and systematize the data coding and analysis.

## 4. Findings

### 4.1. Case Study Evidence

This section presents detailed descriptions of cases of Nanotech ventures and their networks for commercialization. Network pictures are used to demonstrate the diverse actors in the network and the type of relationships they have with the focal firm.

#### 4.1.1. NV1

NV1 is a graphene producer company, established in 2011, with operations in the UK, US and Taiwan. NV1's products include graphene ink, a graphene-silicon mixture for battery anodes, and arrays of graphene transistors. Their leading product is Grat-Film<sup>TM</sup>, a large area variety of single layer graphene that can be grown to a size as large as 24 inches in diameter, and is currently sold on PET, SiO<sub>2</sub>, and quartz. A novelty introduced by NV1 is a certificate of quality included with every sample, together with Raman maps and optical images. NV1 has focused on applications of graphene for batteries, lighting/LEDs, and screen displays.

NV1 started its operations in the UK through a strategic partnership with the University of Manchester and the National Graphene Institute. The company has set up one branch in Manchester by registering a company with five employees, three of them are post-doc researchers at the university funded by NV1. The company had a similar strategy in establishing its Taiwan branch, i.e. entering the country through collaboration with a well-known research institute in the graphene field. NV1 aims at establishing close collaborations with large incumbent firms for further development and commercialization of its products. In the US market, using the CEO's personal network, they have directly approached large firms and have been successful in initiating joint development partnerships. To enter the UK and Taiwan markets, the company is looking for such partnerships to be realized through a relationship with a broker organization that has the required scientific capability as well. NV1 has formed broker-oriented networks for commercialization of its products in the UK and Taiwan.

The change NV1 has experienced since its establishment is the shift in the focus from radical applications of graphene to more incremental applications where there is lower technical risk and higher quantity of mediocre quality material is required. NV1 also has retail (online and offline) selling of material to universities and research centres and small firms.

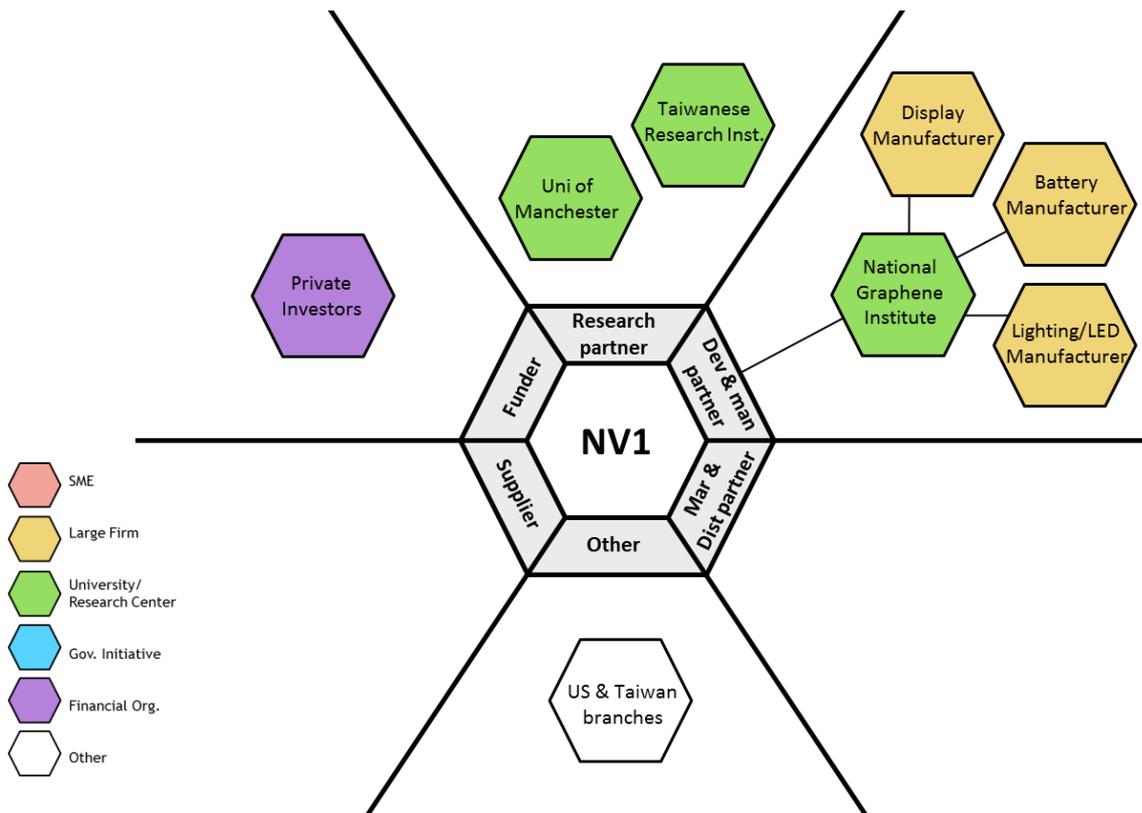


Figure 3. NV1 Network

#### 4.1.2. NV2

NV2 was founded as a QinetiQ corporate investment in 2001 and became a standalone company in 2007. NV2 was successful in raising VC money in the US and moved its headquarters to Rochester, US with R&D and production in the UK. The companies' main focus is on production of stable nano-metal powders and inks formulations, e.g. copper-nanoparticle based ink. NV2 also offers laser sintering systems for the printed electronics industry.

NV2's main route for commercialization of their product has been initiating "funded development" projects through government and EU programs. NV2's managers believe that these programs bring several advantages for the company including access to financial resources, collaboration partners with complementary technological capabilities as well as potential customers. NV2 has been involved with five FP7 projects, four InnovateUK projects and another development project with the SunShot Initiative of the US Department of Energy to develop different applications of their nano-metal powders and inks. NV2 uses these collaborative projects as a way to find SMEs or large firms as potential development partners

or customers. They have also been approached by some large firms directly and have joint development agreements in place with them. Currently, NV2 has a mix of large firms and SMEs as customers of their inks and materials, and devices.

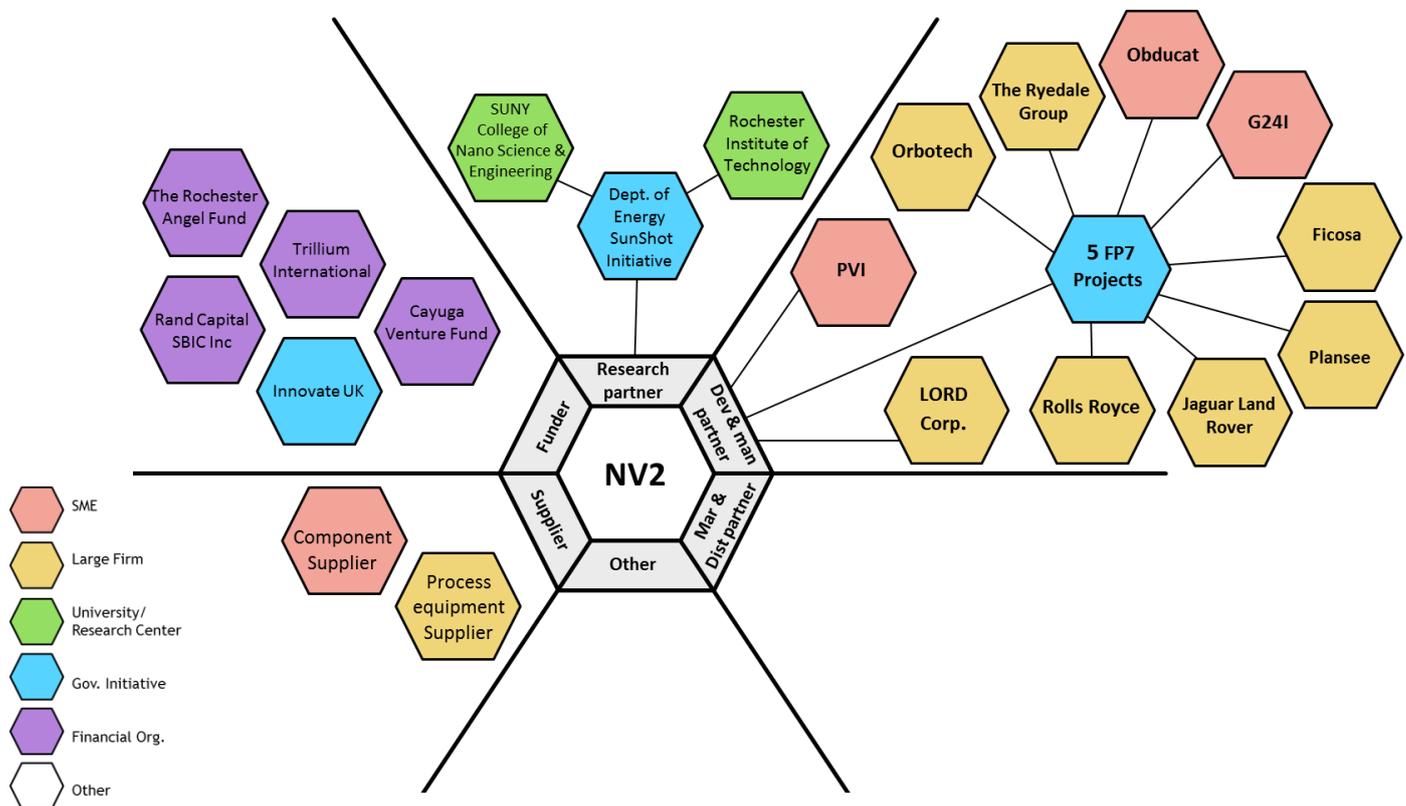


Figure 4. NV2 Network

### 4.1.3. NV3

NV3 was established in 2003 as a spin out from Swansea University and initially focused on purifying and liberating carbon nanotubes (CNTs), allowing them to be surface engineered for integration into host membranes or matrices. NV3 holds a patent portfolio in the production, processing and application of carbon nanomaterials. NV3's expertise in carbon nanomaterials was subsequently applied to converting mined graphite ore into graphene nanoplatelets. NV3 has developed a patent-pending proprietary scalable plasma process to functionalise graphene and other nanomaterials. NV3 claims that this enabling technology can provide a rapid and highly cost-efficient method of supplying tailored solutions to enhance applications for both raw material suppliers and product manufacturers. NV3 tries to differentiate itself from other companies active in the graphene area by emphasizing their

material functionalization capability. This change of focus from producing nanomaterials to functionalization of existing materials could be considered as a shift in the value chain position of the company from upstream to midstream. NV3 aims at facilitating the application of graphene and other nanomaterials in fields such as inks, sensors, energy storage, photovoltaics, composites, paints and coatings. The company started trading on the AIM stock exchange in 2014.

NV3 pursues a collaborative approach for commercialization and has been actively seeking collaboration opportunities with leading incumbent firms in each application area and has joint development agreements in place with a few large established firms. In addition, NV3 actively approaches companies that can play a brokerage role and link NV3 with potential development partners or customers. NV3 tries to strengthen its international presence by having marketing and distribution agreements with well-known international distributors in the graphene field.

In all their announced distribution partnerships, NV3 also considers a brokerage role for their partner to be important, which means that distributors and consulting firms are expected to help NV3 find potential R&D collaborators or business clients. They also consider the INSCX<sup>1</sup> online platform as a good route to the market. NV3 also has online selling of its products as another route to market.

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<sup>1</sup> Integrated Nano-Science and Commodity Exchange

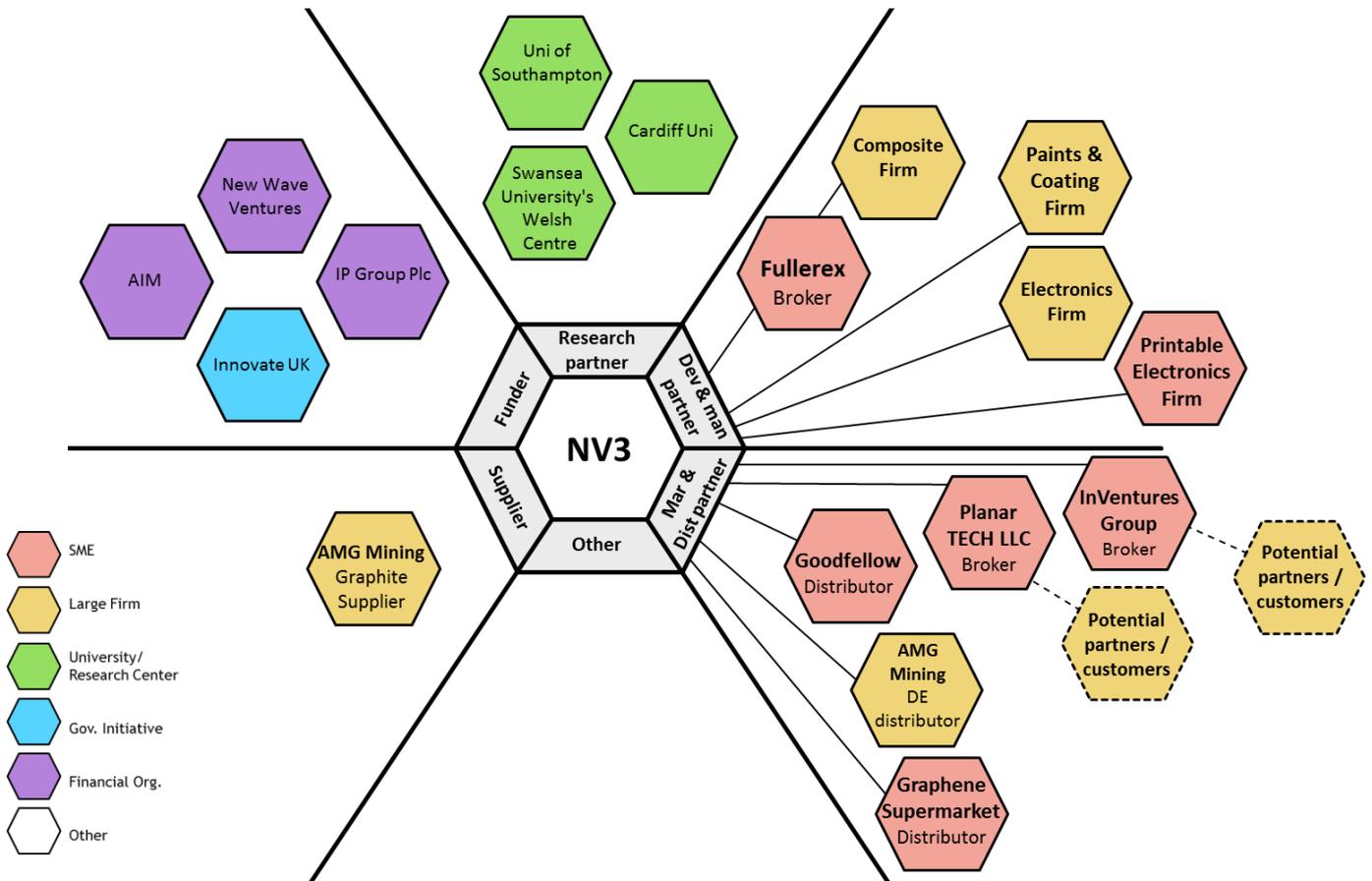


Figure 5. NV3 Network

#### 4.1.4. NV4

NV4 started its operations in 2010 to develop products utilising the electrospinning platform at the Rutherford Appleton Laboratory in Oxfordshire in the UK. NV4 develops and manufactures electrospun polymer scaffolds, which provide an environment for supporting the growth of cells in 3D. NV4 sells a range of ready-to-use, sterile tissue culture plates containing the Mimetix® scaffold for tissue engineering, regenerative medicine and drug discovery research. In 2013, NV4 launched a 96-well plate containing the Mimetix scaffold, laser-welded by a proprietary process into the base for use in drug discovery, where more predictive in vitro 3D cell-based assays could reduce the rate of expensive clinical failures and replace certain animal studies. NV4 also provides scaffold development services where they can tailor the biomaterial or architecture to suit the application.

NV4's network orientation is toward collaborations with European SMEs and high-profile universities in the UK. Through two FP7 funded consortia they are developing products along

with more than eight other SMEs, where each partner provides complementary technological capability. NV4 has been primarily offering products to researchers, including universities, in the area of regenerative medicine. The main channel for selling the product so far has been the company's website. Recently, they have added application of their product for drug discovery to their activities and expect to have more industrial customers in this new area. Their latest product which is a 96-well scaffold is mainly targeted for industry use. NV4 also has collaboration with broker governmental organizations. Examples are NanoKTN, Growth Accelerator and the European Space Agency Business Incubation Centre (ESABIC) through them NV4 has reached potential customers and technology development partners.

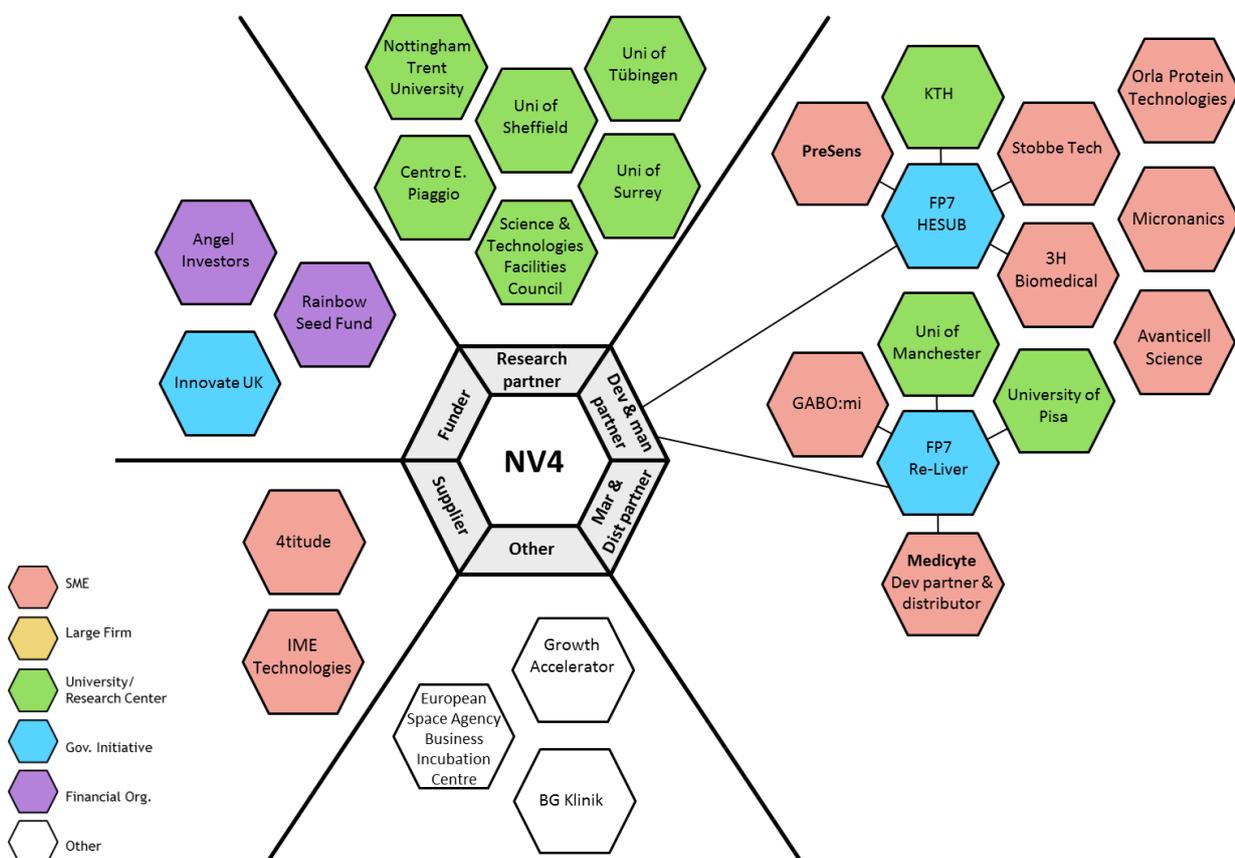


Figure 6. NV4 Network

#### 4.1.5. NV5

NV5 develops life sciences tools and diagnostics with operations in the UK, US and Singapore. Their activities focus on DNA testing process, from extraction to amplification to detection. NV5 started its operations in Sussex, but moved out to South Africa soon after establishment to get a real feel to the ultimate market they aimed to serve. Through a joint

venture with the government of South Africa, they had access to various hospitals and were able to develop the sample preparation side of their activities. After two years, they moved to Newcastle and signed licence agreement with Harvard and Yale University for a family of patents related to nanowire sensors. This enabled the company to take the technologies that were developing in South Africa from a sample preparation point of view and integrate them into a nanowire sensor that had huge array capabilities. Since then the company has been successful with raising private investment and public grants and expanding its activities internationally.

NV5 has long-term joint development and manufacturing agreements with research and engineering institutes in Singapore. They collaborate with three NGOs, where in addition to funding, they play a brokerage role for NV5 to access new markets and distribution channels. NV5 also works with private broker companies to get connected to regulatory and standard bodies in the US. Recently, NV5 started collaboration with a UK SME for design and large scale production of their device.

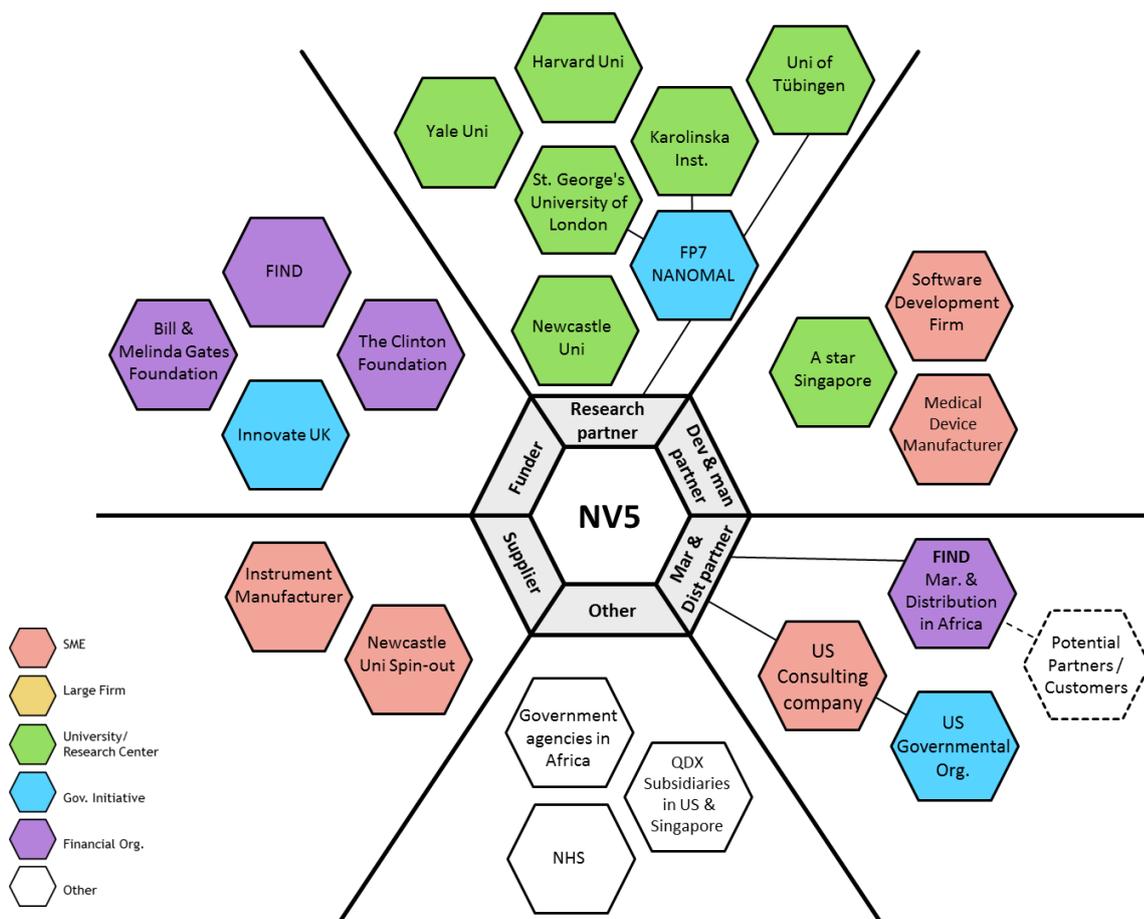


Figure 7. NV5 Network

#### 4.1.6. NV6

NV6 started its operations in Manchester and acquired the printed electronics business of a University of Manchester spinout company and extended their patented imprinting process to conventional thin film transistor designs and a variety of self-aligned structures. This approach allows a full range of device and circuit architectures to be printed in transparent, flexible semiconductors at micron and sub-micron scale. Two years later, NV6 moved to Cambridge “*because of the larger pool of expertise in the area of printed electronics, on the development side*” (NV6 COO Interview). NV6 targeted three application areas of their technology including anti-counterfeit security products, animated packaging, and electronic features in toys and greeting cards.

NV6 describes their network as being in two categories: technology development and product development. For the technology development, they have partnerships with the Holst Centre, Centre for Process Innovation (CPI), the University of Cambridge as well as an informal network of SMEs in the printed electronics field that closely collaborate together to supply complementary technological capabilities or components to each other. In addition to joint technology development, the Holst Centre and the University of Cambridge play a brokerage role for NV6 to get connected to incumbent firms as product development partners and potential customers.

For the purpose of product development, NV6 has initiated joint development agreements with large established firms in security printing, greeting cards, consumer goods, and the toys and games areas. NV6 is concurrently involved in three network types (i.e. incumbent-oriented with proactive SME, broker-oriented, and SME-oriented networks) to commercialize its technology.

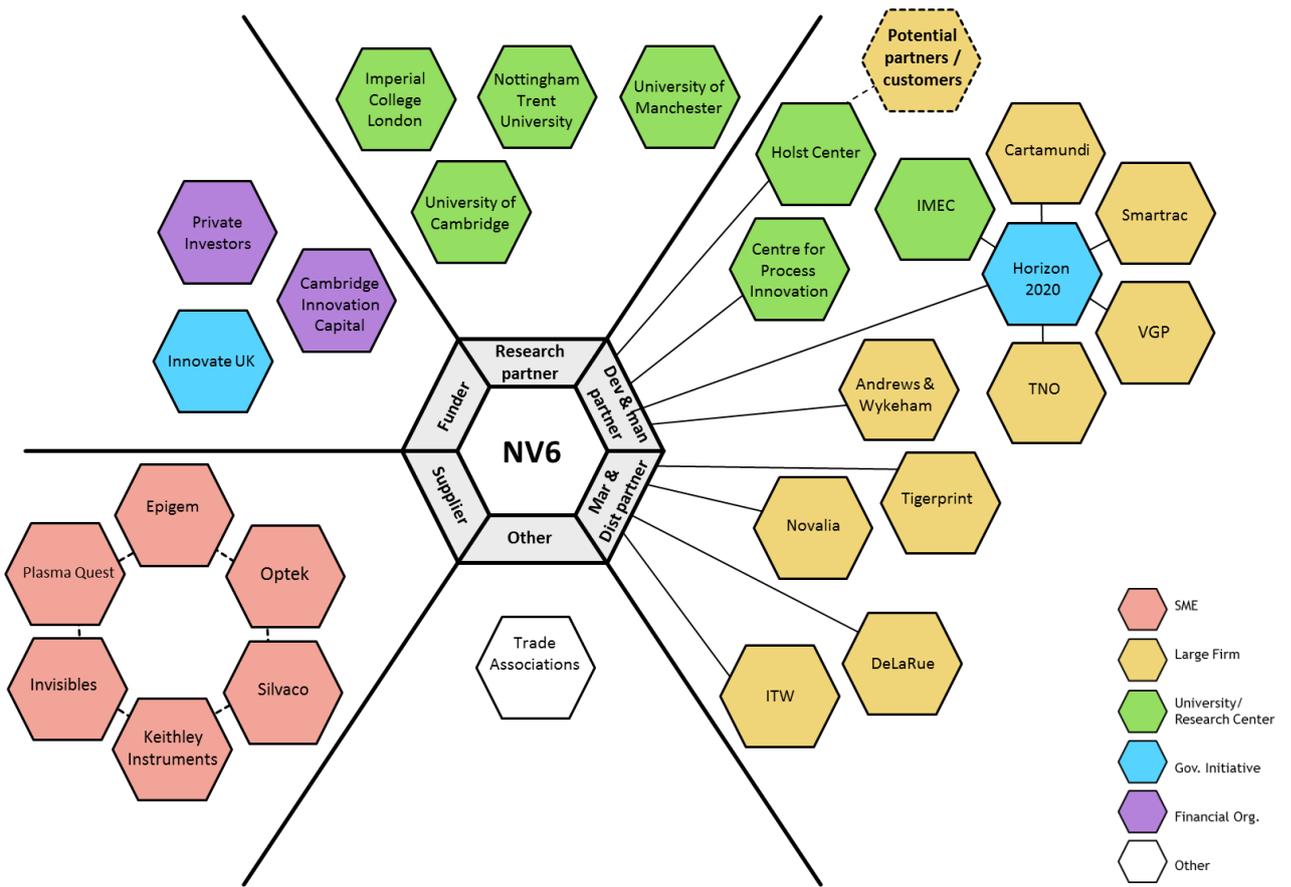


Figure 8. NV6 Network

## 4.2. Cross-Case Comparison

Table 2 shows Nanotech ventures with broker-oriented networks and the type of organization that played the brokerage role for these companies.

**Table 2. Nanotech ventures with broker-oriented networks**

Co.	Value Chain Position	Actor that played brokerage role			
		Private Company	University or research centre	Funding Agency	Gov. Initiative
NV1	Upstream		✓		
NV2	Upstream			✓	✓
NV3	Upstream & Midstream	✓			
NV4	Downstream			✓	✓
NV5	Downstream	✓		✓	✓
NV6	Midstream		✓		

### 4.2.1. Approach of Nanotech Ventures towards Brokerage

In all broker-oriented networks in the study, the Nanotech venture has been the prime mover in approaching the broker, except for one case in the network surrounding NV3, where a broker organization approached the venture. Nanotech ventures have been prime movers in initiating relationships with broker organizations that can connect them to potential partners or customers and provide them with additional resources required for the partnership formation and the ultimate goal of commercialization.

There is only one venture, namely NV1, that their main strategy for commercialization has been solely using brokers. The other five ventures make relationships with brokers as one route to the market in addition to the other types of partnership. In the cases of NV3 and NV5, private companies are used as brokers. Other ventures in this study do not have tendency to use private companies as brokers, e.g. consulting companies that can link them to potential customers or development partners for a brokerage fee. However, the role of brokerage is appreciated by these ventures and they try to use other organizations such as universities, research centres, funding agencies and governmental initiatives as brokers that can link them to potential customer or partners.

#### 4.2.1.1. Private Companies as Brokers

##### *Advantages*

There are two cases (NV3 and NV5) in which private companies are used as brokers. NV3 uses INSCX<sup>2</sup> to introduce their nanomaterial and functionalization capabilities to other companies, especially large polymer producers.

*“They (INSCX) have a number of partners in their organization, industrial firms looking for types of nano-materials as a means of enhancing their own applications ... So, it’s another route to market for us which is a quite important one ... We are beginning to see quite a lot of enquiries from the polymer nano world.”* NV3 interview CEO

Another reason that NV3 values this partnership is that they pay the broker only if sales agreements are in place:

*“They are opening up a new market for us. Add a new sales force. We don’t have to pay until the sales are made. It’s another way of increasing our visibility to the market.”* NV3 interview CEO

To find more international partners, NV3 has another similar agreement with a company that is active in the US and Asia markets and provides process and analytical equipment for 2D materials synthesis such as graphene as well as process equipment for other nanomaterials. According to this agreement, the partner company plays a brokerage role for NV3 because they have the necessary knowledge and know-how in the area of 2D materials. They also have links with leading research institutions and some large industrial players in Asia:

*“Their industry knowledge and connections are substantial with a track record of success in the region. This agreement will enable NV3 to significantly increase its presence in a major, rapidly growing market. We expect this agreement to allow a greater number of potential R&D customers to test and analyse our plasma functionalised materials for integration into their specific products and applications.”* NV3 Press release, CEO's comment

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<sup>2</sup> Integrated Nano-Science and Commodity Exchange

Another private company that NV3 has similar collaboration with is a US consulting firm that aims to accelerate the process of identifying the most promising commercial applications of NV3's technology and materials throughout North America. NV3 considers this collaboration as another important route to the market regarding the substantial experience and network of the consulting company.

*"Their reputation, relationships, and network of partners and customers combined with their experience in overcoming the hurdles that face companies introducing new materials into established markets will serve NV3 well as we look to expand the impact of our technology and our presence in North America."* Press release, NV3 CEO Comment

Similar to NV3, NV5 uses partnership with a private consulting firm to assist them in expanding their activities internationally, i.e. in the US and Brazil. They use brokers to facilitate making and maintaining relationships with government organizations in the US as potential customers.

*"I suppose our best example of this [brokerage role] is a company that we work with in the States that introduces us to the government; so they hand-hold us through the process of engaging with government... So they handle a lot of that conversation for us. And essentially they're consultants that help us understand the mechanism that is hugely complex."* NV5 interview COO

NV5 follows a similar strategy to enter new markets in other countries:

*"Brazil – again, very different [mechanism]. You have to work through an intermediary in order for your product to be taken up."* NV5 interview COO

Both NV3 and NV5 use brokers when they want to access international markets. BST has also a similar strategy, but the difference is the type of organization they consider as broker.

### ***Disadvantages***

Beside advantages, Nanotech ventures specified two disadvantages of working with private brokers including expensive services and lack of necessary technological expertise. Five Nanotech ventures agree that brokers do not often have the required technological knowledge

and know-how to be able to find and link them to potential partners and customers. For instance, the COO of PRP explains why their previous relationships with private brokers have not been very fruitful:

*“We’ve done a little bit of that without a huge amount of success and we find often that type of broker doesn’t really understand enough to do that job well enough. Now not to say that’s always the case, and it may vary by industry, but it’s clearly better if we can have that direct relationship, not just from a financial perspective, but also we can usually get to an understanding of what they want much quicker than working through a third party.”* PRP interview COO

These disadvantages cause Nanotech ventures to either make direct relationships with their potential clients or make indirect relationships through other organizations that have the necessary technological expertise and do not charge them for brokerage services. Therefore, universities and research centres that are prominent in the same technological areas as Nanotech ventures and have close collaborations with industrial partners are good targets to play the brokerage role.

#### **4.2.1.2. University as Broker**

NV1 used a partnership with the National Graphene Institute at the University of Manchester as its entry point to the UK market. Being located at the university which is known as the ‘home of graphene’, significantly increased NV1’s exposure to potential industrial partners. This also provided access to the large pool of scientists as well as facilities and equipment.

*“Manchester [University] provides this huge pool of scientists and so it’s a very strong source of knowledge for companies here ... we actually can use a lot of their equipment, which would – if we were to try and buy all the equipment which we use at the moment—We would have spent millions and millions.”* NV1 interview R&D Manager

Another advantage of collaborating with the university for NV1 is the opportunity of getting involved in the development process of other 2D materials and the standardization efforts that university spin-out companies and NGI are undertaking in the area of graphene:

*“There are other things which the University are doing which are of interest to us. Something CompanyX [a University of Manchester spin-out graphene firm] are trying*

*to do about standardising various characterisational and production procedures ... So that's another useful thing which is useful for us to be involved with. It adds some credibility to us in the long run.” NV1 interview R&D Manager*

Similarly, for NV6, collaboration with the University of Cambridge provided access to technological expertise, facilities, and network of companies that work in partnership with the university. Moreover, NV6 was successful in securing major investment from the venture capital arm of the University of Cambridge to scale-up its operations.

#### **4.2.1.3. Research Centre as Broker**

Research centres that closely collaborate with large industrial firms are also considered as valuable brokers by Nanotech ventures. NV6 describes their relationship with Holst Centre to as a strategic relationship for the purpose of further technology development and for their brokerage role to link them to large firms. Holst Centre is a leading technology centre in printed electronics and has numerous collaborations with SMEs and large industrial companies.

*“Holst Centre provided us with a body of knowledge and support that we were able to draw on and to use in our process development. They were the sort of initial key pins in terms of our technology development and finding potential partners.” NV6 interview COO*

Another important actor in NV6's network is the Centre for Process Innovation. Through this partnership NV6 was enabled to run their pilot-scale production process. They also played a broker role and introduced NV6 to new potential partners for large-scale production and commercialization. The role of research centres as brokers goes beyond mere introduction of potential partners and involves helping ventures to enhance their technologies to the extent that could be offered in an industrial quality and scale and persuade industrial players to get involved in the integration and implementation process.

#### **4.2.1.4. Funding Agency as Broker**

Both NV4 and NV2 have used their network of partners in FP7 projects to develop and commercialize their technologies and products. Besides access to funding, these projects have provided a platform for these ventures to find development partners or potential customers:

*“Working with the EU brings a network of people to interact with, and funding, because we have a lot of relationships with universities but there’s always a lack of funding to actually do the feasibility experiments. So this actually allows you to develop, to work together.” NV4 interview CEO*

Another outcome of these collaborations has been access to complementary technological capabilities of European SMEs (for NV4) and large firms (for NV2).

#### **4.2.1.5. Government Initiatives as Broker**

Nanotech ventures used several governmental initiatives as brokers in their networks. Brokerage services of these organizations have been mainly provided through events such as workshops, exhibitions and in some cases through specific support programmes. For example, NV2 has developed one of its novel materials through collaboration with a research centre and a large incumbent firm with the financial and brokerage support of InnovateUK. Such a broker-oriented network has been evaluated as conducive to commercialization by NV2, as it enabled close collaboration with a large incumbent firm initially as their development partner and later as their customer. Another example of a governmental organization having a brokerage role is seen in the collaboration between NV5 and the government of South Africa that has helped them to gain a first-hand experience and knowledge about African market they targeted.

*“That partnership was actually a joint venture, so that was an interesting one. That allowed us a lot of access into various hospitals in South Africa, and merely being situated there, you’re getting a lot of experience. And certainly, you get to understand and get a real feel for the market, the ultimate market that we would like to help.” NV5 interview COO*

#### **4.2.2. Outcome of Broker-oriented Networks**

Studying activity links and resource ties that Nanotech ventures have formed within their broker-oriented networks demonstrate how such networks can facilitate commercialization. First of all, broker oriented networks have been particularly helpful when Nanotech ventures wanted to enter a new market or a new country. Access to new markets, faster market penetration, presence in targeted geographical regions, and forming new international

partnerships have been the outcome of collaboration with brokers for NV1, NV3, NV4 and NV5.

Secondly, broker-oriented networks have been useful when Nanotech ventures decided to enter a new field of activity (e.g. in the case of NV2). NV2, NV6 and NV3 have emphasized the role of broker organizations in accelerating the commercialization process by supporting ventures from one side and the incumbent firms on the other side in incorporating and integrating ventures' novel product or technology.

## **5. Discussion and Conclusion**

The findings of this study reveal that broker-oriented networks can facilitate the commercialization process for Nanotech ventures by reducing both technology and market uncertainties (Maine et al., 2012), enhancing their transformative capacities (Garud and Nayyar, 1994) and enabling faster integration of products into end user applications. Firstly, broker-oriented networks eased the international expansion of Nanotech ventures' activities. Consequently, they can provide opportunities that increase ventures' survival (Lee et al., 2012). This finding is similar to the functional role of innovation brokers in commercialization found by Howells (2006) and Lee et al. (2010) which includes identifying market opportunities and helping establish and run sales channels.

Secondly, broker-oriented networks have been influential when a Nanotech venture decided to enter a new field of activity by providing testing and validation services, prototyping and pilot facilities, and support in scale-up (Salehi, 2016). This role is in line with the 'Testing, validation and training' function of innovation brokers identified by Howells (2006). Furthermore, broker-oriented networks can provide the opportunity for Nanotech ventures to break into the supply chains of large established companies, especially by using virtual brokers that showcase technological solutions of Nanotech ventures to large industrial firms. This is congruent to the findings of Hacievliyagil et al. (2007) and Billington and Davidson (2013) regarding the opportunities virtual brokers provide for multinational companies, i.e. extend the boundaries of partner search for multinationals and allow their procurement departments to source innovation from small firms or individuals outside their traditional supplier networks.

In this research only few Nanotech ventures used private companies as brokers. However, the importance of the brokerage role was acknowledged and valued by all Nanotech ventures and

they tried to find broker organizations that have the necessary technological expertise and their brokerage service is free of charge. The findings showed that universities, research centres, funding agencies, and government initiatives are among organizations that can play a significant brokerage role for Nanotech ventures and facilitate and accelerate the commercialization process. For some of these organizations the brokerage role is defined as one of their primary missions. Others are public or semi-public organizations and funding agencies that act as brokers as a by-product of their major activities (Winch and Courtney, 2007). The brokerage role of these actors in the network is analogous to the intermediary role of organizations that act as agents that transfer technology between hosts and users in the UK biotechnology sector (Shohet and Prevezer, 1996). These agents (public or private organizations) mediated contractual and financial relations, provided a liaison and bridging function, particularly for younger and smaller firms and were able in some cases to provide complementary assets for technology development or to signpost nascent spin-off firms to sources of finance (Shohet and Prevezer, 1996). Moreover, in cases where famous universities or research centres act as brokers, the good reputation of these organizations was advantageous for the Nanotech ventures to get linked to large established firms.

Our findings also show that EU and UK government initiatives and funding organizations play influential brokerage roles for Nanotech ventures. The European Union Framework Programs as an institutional arrangement not only set norms, rules and values for creating internationally and institutionally diverse research networks (Pandza et al., 2011) but also act as brokers that can facilitate commercialization for Nanotech ventures (Salehi, 2016). In line with the finding of Lee et al. (2010), government initiatives can help ventures in commercialization by providing various direct and indirect supports for network construction and network management. Our empirical study shows that government-backed brokers, such as NanoKTN and GrapheneSIG, support commercialization by facilitating initiation of collaboration networks for ventures and providing financial support. This confirms the importance of involvement of ventures in policy-supported networks which change a firm's relational patterns and leads them to collaborate with a wider variety of actors (Caloffi et al., 2014).

Considering the value chain position of ventures in this study, the findings show that particularly Nanotech ventures in the upstream part of the value chain have used broker-oriented networks as their main strategy for commercialization. This might be related to the

higher levels of technology uncertainty for firms producing nano-materials, the generic nature of their technology, potential applications in multiple markets and the need for further process innovations by customers (Maine et al., 2013). Broker-oriented networks can play a significant role in facilitating commercialization of nano-materials by reducing these uncertainties for ventures, assisting them to try different application areas, finding suitable industrial partners and helping them enhance their transformative capacities (Garud and Nayyar, 1994; Salehi, 2016). The rise of specialist virtual brokers in the area of nanomaterials may also indicate the higher degree of difficulties and challenges associated with commercialization of nanomaterials and the greater need for involvement of brokers. In other words, although broker-oriented networks can facilitate commercialization of nano-intermediate and nano-enabled products, their role is highly influential in commercialization of technologies or products developed in the upstream part of nanotechnology value chain (Salehi, 2016).

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