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Balancing Exploration and Exploitation in Small World Clean-Tech Cluster

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ABSTRACT

Clean technology clusters of firms around the world are strategically learning how to scale up to meet institutional investor objectives. Building out value chains through partnering so as to create value in small world clusters is posited as key to achieving stable long-term returns and reduced risk. Alliances in the small world cluster build cluster stability if there is a balance of exploration and exploitation in: 1) tacit knowledge sharing, 2) ambidextrous multi-function partnerships, and 3) internationalization. Theoretical development is illustrated by a small world cluster of smart grid energy firms. Thus, this paper develops a novel portfolio theory approach to directly value a small world cluster by presenting a framework for incorporation of small world cluster structural factors into a robust valuation model.

BACKGROUND

Global economic stimulus programs aimed at green growth have impacted job and GDP growth, resulting in emergent industries, comprised of clean-tech companies (product and service firms that serve to decrease carbon emissions and water use) that are increasingly organized into proximal (building to sub-national regional scales) economic development clusters. These clusters, which aim to attract investors and corporate partnerships, have taken on many forms, but no dominant structure or entity has emerged yet. The composition of the clusters ranges from R&D firms to repositioned legacy industries. The represented clean-tech sub-domains within the clusters can be either thematic (e.g., smart grid, energy efficiency) or broadly defined (e.g., energy, water, LED lights). Increasingly, the clean-tech cluster firms are interconnecting to create small world networks, inclusive of local and international partners.

These emerging alliances are increasingly driven by technology and development partnerships between clean-tech startups and mature firms, as well as among small firms, within and across regional boundaries (Parker and Youngman, 2010). These trends are similar to what has been observed in other industry lifecycles such as that of bio-tech, information and communications technology (ICT), and social networks, when industry standards or dominant designs have not yet been established. What is unique about clean-tech as an investment domain, relative to ICT or bio-tech, is the heterogeneity of products, services, and markets, and its dependence on new business models and policy-driven price signals for companies to be able to extract value (Adriaens, 2010). These uncertainties drive the need for alliances on a global scale.

This research combines networks with learning and portfolio theories to build a valuation model for a small world cluster in clean technology. A small world is a network structure having local clusters and a short path length (Uzzi and Spiro, 2005; Watts, 1999; Kogut and Walker, 2001). Small world networks are a form of social organization that is made up of many clusters of tightly interconnected actors having sparse connections between the clusters (Uzzi and Spiro, 2005). Within the clusters, the same information is shared and circulated through strong ties, whereas new information is obtained through weaker bridging ties to other clusters (Burt, 2004; Granovetter, 1973; Moody and White, 2003). Strong ties may arise because of past collaborations (Uzzi and Spiro, 2005; Gulati, 1995a, 1995b; Gulati, 1998) and, as this paper will posit, the balancing of exploration and exploitation across several possible dimensions of alliances also strengthens ties. The small world clusters facilitate an interdependent group dynamic (Uzzi and Spiro, 2005), creating social capital (Coleman, 1988), that may build a stronger and more stable entity than a firm on its own could represent to investors.

As clean technology firms grow and build a small world through new partnerships, they depend on a mix of grants, debt and equity financing. However, the industry is still evolving in response to macroeconomic and policy drivers (Adriaens, 2010). For instance, Kauffman (2012) suggests that new investment strategies and management structures across geographies and technologies are required to develop a separate asset class in clean-tech. The financial model approach developed in this paper, which incorporates alliance structures that improve stability of the small world through a balance of exploration and exploitation, has the potential to be responsive to investment criteria by addressing stability and size requirements. Modern portfolio theory has not been applied to new investment domains such as clean-tech, which are characterized by complex value systems, highly variable investment horizons and sales cycles, and slow market penetration.

A small world network is built from value chains of inter-firm alliances that are, "…voluntary arrangements among independent firms that exchange or share resources and engage in the co-development or provision of products, services, or technologies (Gulati, 1998). Alliances serve various purposes and take on different forms, such as joint ventures, affiliation in research consortia, collaborative R&D, and joint marketing efforts." (Lavie and Miller, 2008: 623). In addition, they exhibit substantial uncertainty in their stability and their success has been difficult to determine (Hamel, 1991; Amaldoss and Staelin, 2010). Our research stipulates that balancing exploration and exploitation in alliances, across a number of factors, strengthens the integrative ties in a small world cluster (Tiwana, 2008). Factors relevant to clean-tech include the exchange of tacit knowledge, ambidexterity in multi-scope alliances, and internationalization. Theoretical development supports the factors' incorporation into a valuation model.

We propose that investment in a small world cluster, as a portfolio of allied firms, is more attractive than in a firm on its own. Through its multiple relationships, a small world cluster offers stable long-term returns and improved risk diversification as compared to an individual firm. Hence, the small world portfolio, offers an investment scale similar to other asset classes (e.g., mutual funds, private equity, and venture funds), that can potentially be defined by a separate set of fee structures, margins and holding times (Kauffmann, 2012). The stability of a cluster is determined through the small world structure and its interrelationships (Kogut and Walker, 2001; Rivkin and Siggelkow, 2007; Fleming, King, and Juda, 2007). A balance between exploration and exploitation in the inter-organizational relationships (IORs) maintains this stability, lowering risk, while maximizing long term value (March, 1991; Im and Rai, 2008; Uotila et al., 2009; Lavie, Kang, and Rosenkopf, 2011).

Therefore, in this research we ask, "What is the valuation change of a small world cluster portfolio when a new member links into the cluster as an alliance partner?" We contribute to theory by developing the area of small worlds in network theory and propose a novel approach to valuation that incorporates portfolio and learning theories. Also, we extend alliance theory by interweaving into it learning theory so as to propose how important inter-relational factors can strengthen alliances and, ultimately, the small world cluster. The idea that cluster stability can be valued and is valuable to investors is a new approach to thinking about small world clusters based on value chain relationships that build social capital (Coleman, 1988; Walker, Kogut, and Shan, 1997). Moreover, we extend portfolio theory by developing a valuation model for a set of highly interdependent firms.

Previous research on small worlds has not been aimed at financial valuation that incorporates an interorganizational learning perspective (March, 1991; Koza and Lewin, 1998;

Im and Rai, 2008). The value of cohesion in networks has been considered more often in terms of learning, information dissemination, innovativeness, and stability (Fleming et al., 2007; Kogut and Walker, 2001; Lazer and Friedman, 2007; Rivkin and Siggelkow, 2007; Burt, 2007, 2009). Thinking concretely about the value of network structures could offer stronger justification for theories about the value of social capital (Coleman, 1988; Burt, 2007, 2009). Network and alliance theories are informed in multiple ways through this investigation. Alliances are viewed as dyads in networks and are often unstable, but this instability is difficult to predict (Li and Guisinger, 1991; Gulati, 1995a, 1995b; Khanna, Gulati, and Nohria, 1998; Larsson et al., 1998). A cluster of strong alliances offers reassurance that if one alliance breaks down, the entire cluster system remains in good operation and it can repair itself, either by installing a familiar cluster firm or another that may be reached by brokerage, and thus retain its value (Burt, 2007, 2009; Tiwana, 2008).

Measuring the value of a small world cluster is challenging since it rarely has binding hierarchy and common reporting (Markowitz, 1952; McEntire, 1984; Perold, 1984). This type of portfolio has value in the assets, the connections between them, and the overall structure of the network. As alliances turn over, the portfolio value changes positively or negatively, thus impacting alliance strategies. Moreover, if cluster firms can predict their collective value in response to development or dissolution of partnerships, that knowledge could foster more stability when positive portfolio value is at stake. Also, valuation can identify which partnerships should be dissolved, when partners have a negative impact on portfolio value.

This research focuses on two network levels of analysis: the interorganizational and structural levels, since the inter-firm connections build the small world clusters in the small world network. First, the theoretical development at both levels explicates the logic behind the financial model that values a small world cluster and the propositions that justify the factors in the model. Second, this paper develops a first version of a small world cluster valuation model in the context of a subset of the Global Clean-tech Cluster Association's (GCCA) 46 clean-tech clusters, comprising over 5,000 firms across the Asia-Pacific, Europe and North America (Adriaens, Taube, and Lesser, 2012). Third, we illustrate theory with an example of a developing small world clean-tech cluster comprised of smart grid firms. The last section of the paper concludes and outlines limitations and future research.

BALANCING EXPLORATION AND EXPLOITATION IN SMALL WORLD CLUSTER ALLIANCES

The literature relating to small worlds examines how networks evolve and which structures are effective for collaboration, including alliances. Small world network configurations are highly clustered but have low overall density and short characteristic path lengths where a characteristic path length is the mean geodesic length (average shortest distance) in the network (Watts, 1999; Robins, Pattison, and Woolcock, 2005). Given a random network having n actors and k relationships, with limiting values for the average path length, ln(n)/ln(k), and clustering coefficients much greater than k/n, the network is considered a small world (Watts and Strogatz, 1998). Robins et al. (2005) use network simulations to discover how local patterns generate a global structure. A global network structure can be understood only by examining large parts of or the entire network. Similar to other simulation work (Rivkin and Siggelkow, 2007), it is assumed that network actors know their local surroundings, but are not cognizant of the entire network or the consequences to it when they make local changes (Pattison and Robins, 2002; Johanson and Vahlne, 2003). This is a realistic assumption for firms in globally distributed clean-tech clusters that exist in a diffuse network. Coviello (2006) examines the dynamics of international new ventures (INV) networks to show that networks do not increase or maintain their closure as density decreases. Hence, coordination may be required for local clean-tech innovations to achieve scale through small world networks. A financial valuation model based on the small world portfolio may provide some impetus to coordinate, because as networks widen, access to financing, markets, referrals and contacts, and distribution channels increases.

Hence, if more firms are tightly knit in a cluster, the value systems are well integrated and coordinated for increased productivity (Fleming et al., 2007). The more holes that are bridged, the more cohesive the network becomes (Burt, 2007, 2009). Rigid specialization occurring in cohesive clusters can make change difficult and lead to decay (Grabher, 1993; Burt, 2009). Does a well-integrated value system, consisting of supply chains, robust information flow and financing relationships, translate into higher value? Lazer and Friedman's (2007) research suggests that that value systems, configured as small world networks, may not find long term solutions, but they will be efficient at information sharing.

By using a portfolio theory approach to the valuation of small world clusters, we will address the previous question directly. Since most of the inter-firm collaborations are alliances, we will approach the assessment of cluster stability and value initially from a dyadic perspective. Alliance dynamics can lead to success or failure from cooperative and competitive points of view (Gulati, 1995; Khanna et al., 1998; Larsson et al., 1998). The concept of co-opetition is becoming prevalent in the clean-tech domain, as firms cooperating in value chains are competitors coordinating with each other for the purpose of scalability, product diversification, and market access. Firms in horizontal or scale alliances pool resources for the same stage(s) of the value chain, whereas, in up and downstream (link alliances) relationships, firms compete for margins (Kalaignanam, Shankar,and Varadarajan, 2007; Cheung, Myers, and Mentzer, 2011).

Some literature points to the underlying trust that enables the cooperation and coordination required for learning complex and tacit knowledge leading to horizontal alliance stability and success (Hamel, 1991; Gulati 1995; Hyder and Eriksson, 2005). However, competitive aspects can lead to very unstable situations of learning races (Khanna et al., 1998; Aggarwal, Siggelkow, and Singh, 2011). Recent work indicates that cross-function alliance partners tend to invest more than partners in same-function alliances (Amaldoss and Staelin, 2010). Kalaignanam et al. (2007) further showed that, in asymmetric alliances, there is an absence of an endorsement effect related to working with a larger well-known firm, on the financial gains of smaller firms (Rao, 1994). Also, the literature on international alliances tends to view national culture as a stress on IORs, as it is viewed as “cultural distance” (Jain, 1989; Kogut and Singh, 1998; Lavie and Miller, 2008).

We find it useful to consider Kalaignanam et al.’s (2007) net present value (NPV) approach to measuring alliance success. Clean-tech firms vary in size, ranging from pre-revenue R&D firms to small and medium enterprises, and occasionally as listed companies. Hence, the revenue and cost model as well as investor return expectations vary greatly, thus necessitating a normalization approach such as is afforded by valuing alliance success. A problem with short-term abnormal stock returns is that the measure varies with firm size such that larger firms tend to report lower returns than do smaller ones (Anand and Khanna, 2000). Internal Rates of Return (IRRs) are another option, but they require the assumption that the discount rate will be the same for all the firms in the portfolio and over time. Since NPV can be calculated using firm cash flows, preferable for the equity-invested clean-tech context, we will use NPV for this valuation design.

In thinking about how alliances add value, research has furthered work on learning alliances through the lens of exploration versus exploitation (Lavie and Rosenkopf, 2006). Seminal research has taken a view that exploration is associated with experimentation and more transformative changes whereas exploitation is concerned with incremental improvement, learning by doing, and specialization (Levinthal and March, 1993; Levinthal, 1997; Benner and Tushman, 2002). The two concepts, exploration and exploitation, could therefore be part of the same continuum or separate constructs, and are thus mutually exclusive or complementary (Gupta, Smith, and Shalley, 2006; Baum, Li, and Usher, 2000; Beckman, Haunschild, and Phillips, 2004; Koza and Lewin, 1998). For example, Uotila et al. (2009) assumed that exploration and exploitation are on a continuum such that there is a trade-off due to limited resources. They found an inverted U-shaped relationship between the relative share of explorative orientation and firm financial performance. The relationship is pronounced in R&D-intensive industries. In this research, we examine how a small world cluster's financial value changes as its member firms exploit and explore through new interorganizational relationships.

Although firms have been the focus in the learning literature (Rothaermel and Deeds, 2004; Lavie and Rosenkopf, 2006; Wadhwa and Kotha, 2006; Im and Rai, 2008; Yang, Lin, and Peng, 2011), it has been adapted for IORs. Firms balance the costs and possible future benefits of exploration with the shorter term gains of exploitation (March, 1991). Koza and Lewin (1998) extended firm level work by categorizing alliances depending on whether they are for exploration or exploitation. Some recent work continues this dichotomous view (Rothaermel and Deeds, 2004; Yang et al., 2011), whereas other research adopts the more nuanced view that an alliance is not necessarily one or the other. Lavie and Rosenkopf (2006) posit that alliances are comprised of three domains: function, structure, and attribute domains. Each domain could involve exploration or exploitation such that, overall, an alliance could be a mix of the two. For example, in the function domain, upstream activities are considered of an explorative nature, and downstream activities as exploitation. In actuality, based on the definitions of exploration and exploitation, any value chain function can exploit or explore. Our research revises the view of functions, proposing ambidexterity and, thus, stable alliances. Also, when firms share knowledge in supply chain relationships, more risky exploration supports the long-run survival of the larger system whereas, the same firms may seek short-term rewards for survival of system components through less risky exploitation (Im and Rai, 2008). An ambidextrous approach offers performance improvements, avoiding the consequences of overembeddedness (Im and Rai, 2008).

When considering the value of a firm in a small world cluster, all of its direct tie alliances matter, but whether indirect ties should be included is less clear. Ahuja (2000) considered the value of direct and indirect ties. The logic of that research was that indirect ties could be valuable because they can supply diverse information through direct ties without requiring the costly maintenance that direct ties require. Thus, having a few direct ties connected to many indirect ties is potentially a valuable structure. Indirect ties were shown empirically to have a small effect, and thus little value. Further, tacit information, important to the development of value chains, is not exchanged via indirect ties (Uzzi, 1996; Ahuja, 2000). These arguments suggest that indirect ties do not need to be considered in the valuation of small world cluster firms.

The impact of tacit knowledge introduced by a new partner on alliance stability and value

When tacit knowledge is introduced by a new partner into a cluster, it represents an interorganizational effort to learn. Tacitness is an attribute of knowledge such that the knowledge has implicit rules, difficult to convey explicitly (Polanyi, 1958; Nelson and Winter, 1982; Martin and Solomon, 2003; Nonaka and von Krogh, 2009). This type of knowledge is abstract and consequently, it requires active interaction between individuals for its transfer (Polanyi, 1966; Teece, 1977; Wadhwa and Kotha, 2006). This is a key point that underlies why tacit knowledge, rather than explicit or codifiable knowledge is considered here as underlying cluster stability. Tacit knowledge is also a source of competitive advantage because whatever is tacitly understood is more difficult to copy than codified information (Wernerfelt, 1984; Winter, 1987; Barney, 1991; Amit and Schoemaker, 1993; Gerwin and Ferris, 2004; McEvily and Marcus, 2005; Coff, Coff, Eastvold, 2006; Nonaka and von Krogh, 2009). For example, in the context of new product development alliances, Gerwin and Ferris (2004) suggest that when there is more tacit learning obtainable from a partner, then there is greater potential competitive advantage.

Strong underlying trust in the relationship is often credited for enabling the cooperation and coordination required for learning complex and tacit knowledge (Hamel, 1991; Gulati, 1995; Uzzi, 1996; Adler, 2001; Hyder and Eriksson, 2005; Li, Poppo, and Zhou, 2010). These highly embedded relationships support deeper communications, effective feedback mechanisms, and the transfer of tacit knowledge (Dhanaraj et al., 2004; Wadhwa and Kotha, 2006). However, the relational mechanism must also be combined with the cognitive mechanism of absorptive capacity (Cohen and Levinthal, 1990; Li et al., 2010). A firm's absorptive capacity is its ability to acquire, assimilate, and absorb knowledge from its external environment (Cohen and Levinthal, 1990; Li et al., 2010). Absorptive capacity is considered crucial for innovation so that the firm may recognize the value of new, external information, assimilate it, and apply it for commercial ends (Cohen and Levinthal, 1990). In the context of a foreign subsidiary attempting to work with local subsidiaries, trust is associated more with the acquisition of tacit rather than explicit knowledge (Li et al., 2010). In the context of international cooperative ventures (ICVs), firms also find it challenging to absorb tacit knowledge (Shenkar and Li, 1999). Firm motivations are aligned by shared equity so as to avoid specifying activities (Hennart, 1988; Osborn and Baughn, 1990). Thus, although Gerwin and Ferris (2004) argue for the competitive advantage in tacit knowledge sharing, other literature has hinted that it may not always result in net positive outcomes.

When taking together the previous understandings and our own views, in the clean-tech context, a possible implication is that the level of tacit knowledge, transferred by a new partner, may reflect both exploitation and exploration. The rationale for the clean-tech alliance context is that deployment (exploitation) of solutions for sustainability is driven by innovations (exploration) from smaller firms that seek to leverage established platforms and channels. The diversity of product and services across wide areas of application lends itself to a wide range of exploratory-exploitative alliances. This counters Yang et al. (2011) who associate tacit knowledge with exploration alliances, and not with exploitation alliances. In light of the earlier literature, our work takes a nuanced view that alliances are not necessarily purely for exploration or exploitation (Lavie and Rosenkopf, 2006; Im and Rai, 2008), as has been argued before (Koza and Lewin 1998, Dussauge, Garrette, and Mitchell 2000). As explicated earlier, exploitation occurs when an organization builds on its existing technological trajectory, whereas exploration represents a shift to a different trajectory (Benner and Tushman, 2002). Thus, we propose that a partner that offers a low amount of new tacit knowledge (relative to what the focal firm can absorb) cannot dramatically change a focal firm's trajectory because insufficient information is available for significant innovation in any part of the value chain. The new knowledge may help the focal firm to learn better how to do what it is doing already, such as improving existing manufacturing processes to reduce waste, reduce costs, and increase product quality.

In the clean-tech industry, the variation of the types of firms and functions in the value chain offers the possibility for different levels of tacit knowledge transfer. In the case of very low tacit knowledge transfer, the alliance is a weak tie (Granovetter, 1973). Controlling for other influences that could affect the strength of the alliance, it could be very short lived after the knowledge transfer (Hamel, 1991). Thus, the low level of tacit knowledge transfer does not build alliance stability and neither does trust or absorptive capacity (McEvily and Marcus, 2005). This end of the tacit knowledge sharing spectrum is much more exploitative than explorative. At the other end of the spectrum, when a new partner attempts to transfer a significant amount of tacit knowledge, exceeding the focal firm's absorptive capacity, alliance instability results. A highly explorative approach can be too costly; hence, many explorative relationships in clean-tech build in an element of technology integration (exploitation). When the right balance of exploitation and exploration is found, it is reflected in a range of tacit knowledge transfer that is absorbable by the focal firm and sufficient such that it successfully alters its trajectory through its exploration. Also, the firm manages to exploit outputs from that trajectory such that its NPV increases above its initial level, prior to the knowledge transfer.

At some optimum level of tacit knowledge transfer, NPV is maximized. Hence, tacit knowledge influences the development of a stable alliance through positive partnership-specific experiences (Gulati et al., 2009). Often in these cases, the alliance partners have made specific investments in each other that create unique value (Williamson, 1983). In fact, transfer costs are higher with tacit knowledge compared to explicit knowledge (Martin and Solomon, 2003). The intense and/or long term use of tacit knowledge between the partners builds strong ties

(Granovetter, 1973; Uzzi, 1996, 1997; Tiwana, 2008), but we suggest that because of the high costs and difficulties associated with tacit knowledge, there is a limit to the benefits of intensity or high levels of tacit knowledge transfer. Ties may be weakened when knowledge transfer is too high, too much for the partners to absorb and make use of, even causing organizational strife, resulting in negative performance. Ultimately, we suggest that there is an inverted U-shaped relationship between the amount of tacit knowledge transfer and NPV. Thus, we posit a novel view such that strong performance, as a result of balancing exploration and exploitation in tacit knowledge usage, is expected to lead to valuable and stable cluster alliances, as is seen in many clean-tech firm technology and development partnerships.

PROPOSITION 1: As the level of tacit knowledge that a new partner brings increasingly represents greater balance between exploitation and exploration on the part of the original clean-tech cluster firm, the greater the NPV of the cluster.

The impact of multi-scope alliances on portfolio valuation

Ambidexterity, punctuated equilibrium (or organizational vacillation), and a combination of the two have been applied in intra-organizational research, more so than in alliances (Boumgarden, Nickerson, and Zenger, 2012; Gulati et al., 2006). Ambidexterity refers to simultaneous exploration and exploitation, whereas punctuated equilibrium describes a temporal alternation (March, 1991; Gibson and Birkinshaw, 2004; Gupta et al., 2006). Recent research considered ambidexterity in long term interorganizational relationships (IORs), indicating that the two types of learning are synergistic and self-reinforcing (Im and Rai, 2008). This balance enhances problem solving because the amount of knowledge increases while, at the same time, problems become more apparent for proactive improvement and innovation (Im and Rai, 2008). Lavie et al. (2011) suggest that firms can better manage a balance of exploration and exploitation across many alliances by exploiting in one alliance while exploring in another. Their work was in software whereas ours is in a more heavily capitalized clean-tech context having more complicated and varied value chains. So instead, we suggest that between the same two partners, their alliance can be of a multi-function nature that balances exploration and exploitation ambidextrously. This may naturally occur or it could be recognized and planned.

Alliances between medium-sized clean-tech cluster firms have the potential to entail multiple value chain functions (e.g., manufacturing, technology development, software service) if one or the other partner has the required capabilities or can effectively develop them. A multi-function alliance incorporates multiple ties between the same firms that may act like repeated ties since functional engagements will not likely all be initiated at exactly the same time. A characteristic of repeated ties is that they generate and reinforce clusters in a network, even making them more concentrated (Davis, 1967; Sorenson and Stuart, 2008). Thus, we suggest that multi-function alliances could impact the entire small world cluster. Evidence is emerging that clean-tech firms are engaging in technology integration (exploitation) and technology development (exploration) partnerships, while at the same time developing a buyer-supplier relationship (exploitation), as well as engaging in project-specific joint ventures (exploration) for clients. This is particularly relevant for clean-tech industries, because dominant business models have not yet been developed in many clean-tech sub-domains, and will continue to drive multi-function alliances between firms across the entire value chain. The solar value chain used to be dominated by value extraction from the supply chain, until new business models shifted value towards installation and, more recently, towards data mining and aggregation, resulting in value from energy price arbitration.

Simultaneous exploration and exploitation improves learning and maintains the vibrancy of long term IORs (Im and Rai, 2008). Firms engaging with each other across a broader scope of activities enhance future learning through absorptive capacity building. Resultant diverse technological knowledge bases improve innovation investment performance (Wadhwa and Kotha, 2006). Gulati and Singh (1998) consider activities such as the sharing of complementary technologies and production facilities, and joint product development that build interdependence in an alliance. Interdependence builds a stronger partnership with a lower risk of breaking down than when partners are not tightly allied (Walker et al., 1997). The stronger relationship is built through the sharing and integration of knowledge across functions, in efforts to both explore and exploit simultaneously. The shared knowledge is technologically complex and partner-specific.

An evaluation of how balanced, in terms of exploration and exploitation, the partnership is, based on functional scope, becomes necessary so as to judge its likely stability and value. Given an example where firms are engaged in an R&D and manufacturing partnership, R&D is considered exploration because, per the definition used in this research, the function is often intended to take the firms onto new technological trajectories (Lavie and Rosenkopf, 2006; Benner and Tushman, 2002). However, R&D could result in the improvement of existing processes or initiate incremental changes to products and therefore, could be exploitative (Tushman and Anderson, 1990). Manufacturing is generally exploitative unless innovation occurs in the manufacturing processes (Lavie and Rosenkopf, 2006; Teece, 2007; Hatch and Mowery, 1998). For example, consider the redesign of a metalworking process to become compatible with biodegradable chemicals, resulting in reduced environmental emissions. Safer chemicals could alter the outputs, but they could also change the entire image of the firm and reduce its risk for fines and law suits. This is exploration that takes the firm onto a new trajectory. Manufacturing tends to be categorized as exploitation (Lavie and Rosenkopf, 2006), but given the potential for transformational innovation in processes, this categorization should be reconsidered (Teece, 2007; Hatch and Mowery, 1998). Therefore, we suggest that each function be evaluated on the basis of definitions of exploration and exploitation rather than automatically categorized, possibly incorrectly based on preconceptions. The latter illustration points to the great potential for and variety of ways of balancing exploration and exploitation in multi-scope alliances. The following proposition summarizes the ideas expressed here such that an ambidextrous balance, through a multi-functional alliance, can create higher cluster value.

PROPOSITION 2: As the combination of functions a new partner plays in the alliance increasingly represent a greater balance of exploitation and exploration on the part of the original clean-tech cluster firm, the greater the NPV of the cluster.

The impact of internationalization and cultural distance on portfolio valuation

Firms in the clean-tech context (such as GCCA cluster firms) choose partners for a variety of reasons, especially for building out their value chains because they cannot manage or afford to perform all functions in-house, or they need to integrate new technologies in existing platforms to serve customers (Amaldoss and Staelin, 2010; Adriaens and Faley, 2012). For example, most product developers require cash to infuse into development and cannot afford diversion into many other activities on their own, such as manufacturing. As a category, clean-tech firms perform a wide array of different functions in value chains and these differences determine many reasons for choices of international partners. Often, firms seek to internationalize because they want to expand into other markets, integrate new products and services, or reduce labour costs. The international business literature has explicated on these typical reasons for internationalization at length (Dunning, 1988).

Firms enter into internationalization with caution since it also adds complications that a firm may prefer to avoid (Lavie and Miller, 2008). Cultural distance arises when managers, having different cultural backgrounds, perceive costs and uncertainty differently such that there are country patterns in choice of entry mode (Hofstede, 1983, 2003; Kogut and Singh, 1988). Also, different types of trust-building processes are used in different cultures and interorganizational trust affects inter-firm exchange and competitive advantage (Doney, Cannon, and Mullen, 1998; Zaheer, McEvily, and Perrone, 1998). National culture has been an enduring factor affecting management practices (Hofstede, 2001) due to stable differences between cultures in their value systems and defined cultural dimensions that underpin a measure of cultural distance (Kogut and Singh, 1998). Lavie and Miller's (2008) measure of alliance portfolio internationalization (API) identifies aspects of foreignness in a firm's alliance portfolio, but some measures within it are problematic such as geographic and economic distance. Research has highlighted that the main issue in internationalization is national culture (Jain, 1989; Subramaniam and Venkatraman, 2001). Thus, this research considers cultural distance on its own.

We propose that clean-tech firms may choose international partners for three main reasons: 1) for continuing or expanding on current activities (e.g. achieving scale or cost-effectiveness), 2) when there are some distinctive value chain partnering advantages (e.g. access to resources or additional alliance functions), or, 3) when the international context offers advantages for innovation (e.g. technology partnerships to shift lines of business) because of its uniqueness (Subramaniam and Venkatraman, 2001). The latter reason views the foreign context as an opportunity and clean-tech can particularly take advantage of foreign differences due to the idiosyncratic and varied nature of the related technologies and business models that allow the firms to extract value. For example, culture and policy differences affect a sales model of solar panels in one country to become a lease-and-service model in another, affecting pricing strategies and market adoption. By taking advantage of these unique opportunities, a firm shifts to a different or additional technological trajectory as a result of its internationalization. Evidence is seen, for example, when telecommunications and renewable energy firms in the Finnish Cleantech Cluster partner with communication network and energy management firms in the San Diego CleanTech cluster to shift towards services in the smart grid.

Internationalization often occurs for the purpose of repeating familiar routines in other locations (Dunning, 1988, 2000; Anand and Delios, 2002; Meyer and Sinani, 2009). Firms find lower cost labor, exploit resources, or expand their markets. Learning is still required in order to make incremental adjustments so that the focal firm may deal with its local international partners and context. Based on the definitions of exploitation and exploration, this kind of learning, to get over the cultural obstacle, is exploitative. Further, the clean-tech firm may seek capabilities from international partners that it cannot find at home (Dunning, 2000). The firm requires the unique expertise, but if it existed in its home environment then the focal firm would choose to acquire the expertise at home, avoiding the cultural differences and context that add complexity to inter-firm relationships. Even though the new capabilities sought from the international partner may take the focal firm onto a new trajectory, the learning required for dealing with the cultural distance is a separate issue. Since cultural distance is a barrier to other benefits obtainable from the IOR, cultural learning is exploitative. However, internationalization could be useful for a partner firm's intrinsic diversity. The partnership spurs creative ideas and innovations that are culturally and/or locally related, to match or satisfy local environmental and social conditions (Subramaniam and Venkatraman, 2001). Because the focal firm finds itself on a new trajectory, this effect of internationalization qualifies as exploratory learning.

We propose a novel view on internationalization, such that a balance in exploration and exploitation in international alliances is suggested for strengthening those ties and ultimately increasing cluster NPV. However, the benefits of this balance are moderated by cultural distance. If national cultures of the home and host firms are similar then there is not much richness to be found in the minimal diversity for generating exploratory opportunities. However, exploitation is easy because there are not the communication difficulties and resultant mistrust. As cultural distance increases, greater richness in the diversity offers more unique opportunities for exploration; the opportunities are waiting for discovery in the unfamiliar culture and related context. However, when national cultures are too distant, the firms may have difficulties coordinating due to overriding misunderstandings and communication problems such that trust cannot be built to support strong ties (Doney et al., 1998; Granovetter, 1973; Gulati, 1998). No matter how rich the context, the firms cannot explore or exploit since relationships break down. Thus, IOR performance, as related to cultural distance, is an increasing function that begins positively, hits an optimal threshold and turns negative to an extent that negative firm performance occurs at very high levels of cultural distance. Consequently, a medium level of cultural distance, as measured by Kogut and Singh's (1988) composite measure of Hofstede's (2001) dimensions, is expected to be most productive. This increases the success of the balance in exploration and exploitation of the internationalization activities because the cultural context has richness to offer for exploratory activities, but at a level that does not stunt trust building and strong tie building. This explains how cultural distance moderates the balance in the internationalization activities, as proposed below.

PROPOSITION 3: The greater the balance between exploitation and exploration in internationalization on the part of the original clean-tech cluster firm moderated by a medium level of cultural distance, the greater the NPV of the cluster.

A SMALL WORLD CLUSTER VALUATION MODEL FOR CLEAN-TECH

The previous sections developed theoretical propositions to support factors that are part of the financial model described here. The factors are: 1) the level of tacit knowledge, 2) ambidexterity across alliance functions, and 3) a balance in internationalization activities interacted with cultural distance. To value small world clusters of firms, portfolio theory is applied. The relevance of portfolio investing to clean-tech is emergent and particularly relevant due to the complexity of revenue generation in the clean-tech domain value chains. Consider recent investments in various forms of energy generation companies, where dependence on commodity prices (natural gas) is offset by a fixed return on variable generation (wind). Or investments in joint ventures between value-add wood product startups and international partners with processing capability, where scalability- and long-term revenue growth risk is mitigated. Early portfolio theory is often credited to Markowitz (1952) since this work defined the set of efficient portfolios and thus, the efficient frontier. The efficient frontier is defined by a set of portfolios that offer either the highest expected return given an upper bound on the variance or a lowest expected return given a lower bound on the variance (Markowitz, 1952; Perold, 1984), and subsequent work built on this approach (McEntire, 1984; Rubenstein, 2002; Bilbao et al., 2006).

Portfolio theory often assumes that the assets are not independent, such that n assets in the portfolio x are jointly distributed with mean vector u and covariance matrix C. An assumption of interdependent assets mirrors the firm relationships in small world clusters since they are affected by each other through various types of alliances. Perold (1984) builds on Markowitz's (1959) work by adjusting expected returns through the incorporation of transaction costs which could be applicable when a firm joins a small world cluster since it may pay a fee to join. Also, Perold (1984) discusses portfolio turnover and minimum trading size. Portfolio turnover is calculated as the sum of sales or purchases, divided by net asset value and is often a constrained factor. High turnover in a cluster reflects the instability of alliance relationships. Minimum trading size can be a concern because many small holdings are not efficient to monitor, but this has not been implementable in models. In a small world cluster, firms must have a minimum size that enables them to manage alliances, serving and utilizing other cluster members. Perold (1984) also states that mean-variance optimization has been infrequently applied to portfolios of bonds and other types of fixed income securities. Since firms in cluster portfolios may receive different types of financing including debt, equity, and venture, mean-variance optimization may prove opportune for dealing with these varying circumstances.

Bilbao et al. (2006) opts for Sharpe's (1963) single-index model to determine the covariance between pairs of asset returns when there are large numbers of assets. Markowitz's mean-variance model has been useful but, it requires forecasts for the expected return, the variance of return, and the covariance (Markowitz, 1952; Perold, 1984; Bilbao et al., 2006). The forecast of the joint movements of the securities, the covariance, is a major difficulty (Bilbao et al., 2006). It is relevant for modeling the tightness of the relationships between firms in alliances in a small world cluster. Sharpe's approach still requires the estimation of beta for each asset in the portfolio (Bilbao et al., 2006). In usual practice, the estimation is first based on historical betas and other past data. Analysts then adjust the baseline betas using their expectations of future events that may affect asset volatility relative to the market, or beta.

Another consideration is the n of a portfolio, the number of assets to be included. Bilbao et al. (2006) mention that diversifiable risk tends to zero as the number of assets in a portfolio increases. Some literature explicates that the general recommendation of ten to fifteen stocks to eliminate diversifiable risk is incorrect and instead, the numbers should be thirty stocks for a borrowing investor and forty stocks for a lending investor (Statman, 1987). However, if firms are added to a small world cluster the effect on diversifiable risk is unpredictable. Like stocks and/or bonds in a portfolio, the firms could diversify each others' risk, but since their businesses are very interdependent, the risk may increase or simply not change.

The goal of the following set of calculations is to map the risk, σ_p, and return, E_p, values of a small world cluster, before and after a new firm partner is introduced into the cluster, onto the efficient frontier (Markowitz, 1952). All of the efficient pairs, (E_p, σ_p), make up the efficient frontier (Markowitz, 1952; Bilbao et al., 2006). Therefore, both the portfolio risk σ_p and expected return E_p of a small world cluster are required. The framework for calculating the value of a small world cluster is based on a sum over all of the net present values of each firm in the cluster where there are n firms, $NPV_p = \Sigma^n_{i=1} NPV_i$. Therefore, $E_p = NPV_p$ and this value is required for calculating portfolio risk, σ_p.

Since a firm, in a small world cluster, will have many factors affecting its value, the following regression equation is helpful for estimating coefficients using estimated cross sectional firm data. The exact mathematical relationships between the m factors, F_m, that affect the value of the firm and NPV_i is unknown so using constructed data in a regression is the best first approximation so that the γs can be estimated. Having the estimates, γs, completes the equation so that, after plugging in the estimated factors, F_m, for a particular cluster firm, its NPV_i can be estimated.

$$NPV_i = \alpha_i + \gamma_{i1}F_1 + \gamma_{i2}F_2 \ldots + \gamma_{im}F_m + \varepsilon_i$$

Next, $$E_p = NPV_p = \Sigma^n_{i=1} NPV_i$$

Case A: Firms with Similar Capital Structures

Sharpe's single index model is used to estimate the standard deviation or risk of the portfolio, σ_p (Sharpe, 1963; Bilbao et al., 2006). β_p is estimated first and $\beta_p = \Sigma^n_{i=1} \beta_i$. If the firms in the portfolio have similar capital structures (e.g., venture capital, private equity or debt), then one regression can be used to estimate β_p of the portfolio given that the E_p has been estimated. β_p is the coefficient on an index variable, I_m. The market index, I_m, although often a stock index, could be one of many indices that includes debt (bonds) and equity so as to approximate the risk in a portfolio of firms supplied initially with capital from the government for economic development and that later obtains debt financing or a mix of debt and equity. For example, a bond index made up of US investment grade bonds is Barclays Capital Aggregate Bond Index. If the firms are in emerging markets and are primarily debt financed, then an example bond index is the JPMorgan Government Bond Index-Emerging Markets index.

$$E_p = NPV_p = \alpha_p + \beta_p I_m + e_p$$

Having estimated $\beta_{p,}$ then σ_p can be deduced from the following equation, as a square root.

$$\sigma^2_p = \beta^2_p\, \sigma^2_m + \Sigma^n_{i=1} x^2_i\, \sigma^2_{ei}$$

A complication is expected to be encountered in calculating the σ^2_p because the small world cluster will have diversifiable risk, as expressed by the latter term in the equation above, $\Sigma^n_{i=1} x^2_i\, \sigma^2_{ei}$. Although the member clusters of the Global CleanTech Cluster Association have 10-1000 member companies (Adriaens et al., 2012), the small world clusters do not necessarily have at least ten firms, thus the latter term does not necessarily conveniently tend to zero. Also, since a small world cluster is made up of connected firms, through alliances, it is expected that their returns are highly correlated with each other and therefore, risk is not diversified. However, the residual for each firm, σ_{ei}, may be estimated when using Sharpe's model and the proportion of each firm in the portfolio, x_i, is known. If the portfolio of firms were considered well diversified then $\sigma^2_p = \beta^2_p\, \sigma^2_m$ and $\sigma_p \rightarrow \beta_p \sigma_m$. Thus, $\sigma_p\ \alpha\ \beta_p$.

Case B: Firms with Dissimilar Capital Structures

The subset of the firms, considered in this paper, is in economic development clusters so a simplifying assumption of similar capital structures is possible, as in Case A, above. However, over time, some firms may attract significant amounts of external funding, whether debt or equity from other sources beyond government, thus the firms may begin to diverge in terms of differing capital structures. Thus, a second approach to the estimations could consider these differences. If the firms in the small world cluster do not have similar capital structures then the E_p is calculated as above, but the β_p and/or σ_p must be calculated differently. It is necessary to estimate the β_i for each firm, using different market indices, I_{mi}, that reflect the differing capital structures of the firms and using the NPV_i for each firm.

$$E_i = NPV_i = \alpha_i + \beta_i\, I_{mi} + e_i$$

Solving for all of the firm βetas, β_is, then β_p can be found, $\beta_p = \Sigma^n_i x_i\beta_i$, where x_i is a proportion of the total portfolio for each firm such that $\Sigma^n_i x_i = 1$. However, due to the diversifiable risk, as mentioned above, when there are not enough firms and/or they are highly correlated, it cannot be assumed that σ_p is directly proportional to β_p. The standard deviation of the portfolio, σ_p, can be found from a calculation of the variance, σ^2_p.

$$\sigma^2_p = \Sigma_i x^2_i \sigma^2_i + \Sigma_i\Sigma_{j\neq i} x_i x_j \sigma_i \sigma_j \rho_{ij}$$

The Pearson correlation coefficient, ρ_{ij}, is calculated as:

$\rho_{ij} = \mathrm{cov}(E_i, E_j)/ \sigma_i \sigma_j$ where $\mathrm{cov}(E_i, E_j)$ is the covariance between the returns or NPVs of firms i and j.

$\sigma^2_i = \beta_i^2 \sigma^2_{mi} + \sigma^2_{ei}$ where σ^2_{mi} is the variance of the market index and is a known quantity; the variance of the residual is known from the Sharpe estimation.

If σ_p and β_p are separately calculated, then they can be compared to consider the extent of diversifiable risk in the cluster portfolio. If σ_p is much greater than β_p, then there is significant diversifiable risk since $\sigma^2_p = \beta^2_p \sigma^2_m + \Sigma^n_{i=1} x^2_i \sigma^2_{ei}$. This comparative calculation is informative because it indicates that adding more firms to the small world cluster could provide diversification that may reduce risk.

After the calculation approach is chosen, depending on whether the capital structures of the cluster firms differ significantly or not, (E_p, σ_p) pairs are calculated and are mapped onto the estimated efficient frontier to see where each portfolio is positioned with respect to risk and returns. A pair closer to the efficient frontier is expected to be preferred by most investors. The earlier propositions further specify the valuation model so that it includes the factors that bind alliances and thus, stabilize the small world cluster.

Incorporation of Alliance Factors into the Valuation Model

The propositions suggested factors that potentially affect a firm's NPV, and thus the valuation of the portfolio of small world cluster firms, as exemplified by companies currently organized in emerging clean-tech clusters. Derived from the earlier propositions, the following are the corresponding independent variables: 1) the level of tacit knowledge, 2) ambidexterity across alliance functions, and 3) a balance in internationalization activities interacted with cultural distance. Kalaignanam et al. (2007) identify additional independent variables useful in determining an NPV of a focal firm such as: *alliance experience*, expressed as the number of alliances entered into over a period of time; *alliance scope*, which considers the number of functional areas that partners are involved in together; *alliance type*, meaning scale or link alliances; *partner reputation*; *partner innovativeness*, measured based on patents a partner has acquired over the past five years; *firm size*, measured by a logarithm of assets; *firm age*; and, *macroeconomic conditions*, measured by the 30-day US treasury bill return to control for the fact that more alliances are entered into when there are favorable economic conditions. In valuing firms, it may be useful to consider that in better times, some firms in particular industries could be overvalued and vice versa under difficult economic conditions so controlling for macroeconomic conditions is prudent. Next, is an illustration of how the factors are working in an existing clean-tech cluster.

CLEAN-TECH SMALL WORLD CLUSTER ILLUSTRATION

The CleanTech San Diego cluster is a private, non-profit collaboratory connecting 851 firms to catalyze emergent industry value chains in clean-tech sub-domains such as smart grids, energy efficiency, and renewable energy generation. We are providing an example for the companies in the emerging smart grid business ecosystem. A smart grid is a transmission and distribution system that ties energy sources (generation) to end users in a "smart way" meaning that the grid incorporates sophisticated control and information systems to manage power stability and financial decision-making, while maintaining flexibility in its network topology. The network consists of highly variable power generation and storage systems, and makes use of technologies that improve fault detection and allow self-healing of the network without the intervention of technicians. For example, energy flows from wind turbines and solar panels, discharge/recharge of fuel cells, and bidirectional energy flows to/from batteries of electric cars need to be managed so as not to disturb the stable flow of energy to users. Additionally, the energy flows need to be optimized both from an economic and a system constraint perspective. The clusters of firms (Figure 1) are part of a smart grid value chain system, which is connected internally (i.e., within the smart grid San Diego cluster), domestically, and internationally. Although, at this time, a small world cluster or wider small world network design has not yet emerged, the structural evidence in the figures suggests that interconnected clusters are building as this industry is maturing. Hence, as will be discussed further, the emergent cluster structures imply that value is created and extracted at multiple levels. For illustrative purposes and brevity, we will emphasize the main theoretical tenets of this paper using a subset of seven of the firms, that are predominant in communication and control systems (See the circled firms in Figure 1.).

{Place Figure 1 about here}

Following brief descriptions of the seven firms, the IORs are discussed in terms of how they may: 1) exchange tacit knowledge so as to balance exploration and exploitation, 2) achieve ambidexterity through multi-scope alliances and, 3) balance exploration and exploitation through internationalization. Three firms in the network subset of Figure 1 (bold outlined) that are part of CleanTech San Diego are: OSIsoft (San Leandro, CA), Power Analytics (San Diego, CA), and Viridity Energy (Philadelphia, PA). Other, smaller, connected firms not in the cluster are Space-Time Insight (Fremont, CA) and Greenlet Technologies (Israel). SAP, a business software provider, and Cisco, a network solutions provider, are well-established generalist firms; they did not originate in the smart grid business, but have leveraged their assets into this area. The other five firms are specialists that focus on providing smart grid solutions. The firms are color-coded depending on where they are positioned in the smart grid value system: data-management of generative capacity (Power Analytics), geospatial and information visualization software for transmission and distribution (Space-Time Insight), communications and controls (OSIsoft and SAP), energy management and market analytics (Viridity Energy and Cisco), and consumer services and end products (Greenlet Technologies). The order of these system classifications roughly traces the power flow from generation through to the end user.

OSIsoft is a 30-year old growth capital and equity-funded company that offers data infrastructure solutions for the management of resource consumption. Its enterprise software system receives data from the energy systems and aids in business decisions for grid management. It is highly connected with the other firms in the diagram through technology development and integration partnerships, as well as multi-tiered customer relationships through its Virtual Campus (V-campus) partner development program. Viridity Energy is a later stage (‘series C’) private startup company founded in 2008 that develops and deploys market-informed software to turn temporally-variable energy consuming and producing assets into virtual power plants. The financial inputs result from price arbitrage of grid and distributed energy generation, and feed into OSIsoft’s communication platform. Both firms are connected to Power Analytics, a 30-year old firm in the cluster that is private and customer-funded. It provides solutions for the design, testing, and management of complex power systems. Space-Time Insight is a 20-year old private early stage ('A-round') startup that is a leading provider of situational intelligence solutions, geospatial and visual analytics solutions that transform large amounts of real-time data into visual displays. Lastly, Greenlet Technologies (founded in 2008) is an early stage ('A round') startup that collaborates as a technology development partner with Viridity on WiFi-based load management systems for residential and commercial buildings. [Debbie – do we need to add On Ramp Wireless ?]

The opportunity for tacit knowledge exchange in these high-tech firm relationships is evident because of the complexity of integrating various software components, and interfacing these master controller and financial systems with smart meter, sensor, and phaser (ultra-fast sensor) hardware. For example, STI and OSIsoft must closely interact to develop and integrate their technologies, which involves collaborative R&D. Similarly, STI delivery of geospatial visual analytics to the OSIsoft enterprise software system requires both technology and development partnering. Another example of a considerable transfer of tacit knowledge occurs in the OSIsoft - Cisco partnership to improve real-time gathering and monitoring of process data; the control and communication integration is highly dependent and adaptive to the smart grid architecture across all system components. In the OSIsoft - Viridity Energy and Power Analytics - Viridity Energy partnership, employees are embedded with each other for the R&D, thus a high level of tacit knowledge transfer has occurred. In these partnerships, while they have explored to develop new solutions and/or integrate them, they have jointly exploited them successfully to derive value. It appears that they are engaging in the right level of tacit knowledge transfer to enable a balance of exploration and exploitation.

At the same time, these connected firms are involved in ambidextrous multi-scope alliances. For example, Viridity Energy and Greenlet Technologies are technology partners who have developed a wifi-based load management system. Thus, they have explored together to develop a new product, but they also are exploiting together through a joint venture for technology deployment. Power Analytics and OSIsoft are technology partners (exploration) by integrating their solutions to improve reliability and energy efficiency. However, they also have buyer-supplier relationships and thus, are engaged in exploitation. Viridity Energy and Power Analytics are both development and integration partners, having created the world's first use of real-time software systems serving as a master controller in a live customer installation. Thus, they have exploited their existing knowledge through integration, but they have also needed to explore for development. In general, most alliances are multi-scope and arguments can be made that they balance exploration and exploitation across at least a couple of functions.

Finally, in this cluster, most firms are US-based. However, Greenlet Technologies is based in Israel. In addition, outside of the circle of firms discussed earlier, is Concentrix Solar, a German firm founded in 2005. Recently acquired by Soitec (a 20-year old French company), Concentrix Solar is working with Power Analytics in a more hands-off technical collaboration to integrate solar microgrids. Because the German technology is a dynamic (rotating) solar system, additional controllers and communications need to be integrated with Power Analytics' Paladin® Smart Grid tool, it is thus likely that some degree of development needed to occur. In the US-Israeli case, the cultural distance is medium whereas in the US-German case, the cultural distance is low to medium, based on Hofstede's (2001) dimensions that underpin cultural distance. In terms of our theory, the inter-firm international activities would qualify as second case scenarios where the US firms are engaged with international partners for their special expertise, not for an extension of familiar activities or for benefits from cultural insights. Thus, internationalization is more for exploitation than exploration. Since the cultural distance is not extreme, not very low or high, then the relationships are not rendered unstable.

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This research has made several theoretical contributions through the development of a financial valuation approach for a small world cluster of firms, in the clean-technology value system context. First, we add to portfolio and social capital theories through the development of our financial model. We show that a small world cluster of firms can offer value and lower risk, associated with IOR stability, likely preferred by institutional investors. Although, a small world cluster's asset interdependence seems to reduce opportunities for diversification, in fact, the structure offers more stable returns and value through mechanisms that a firm or a standard portfolio of firms cannot replicate. In a small world cluster, clean-tech firms are densely connected by upstream, downstream, and cross-level alliances that are strengthened when exploration and exploitation are balanced through: 1) tacit knowledge transfer, 2) ambidextrous multi-scope partnerships, and 3) internationalization. Thus, the small world cluster can build cohesion and redundancy that offers stability and resilience to perturbations. Our model incorporates the resilient alliance attributes as factors and the accumulation of many strong ties is reflected in the NPV summation.

Another theoretical contribution is made to alliance theory, given the clean-tech context. Previous research has argued that stability is not an indicator of alliance success. However, by incorporating a specific area of learning theory into alliances, we show that stability and value are complementary. In the value chain context, most types of IORs are more effective if they are long term. Whether in supply, research, design, manufacturing, or distribution, learning curves and large investments such as those in capital equipment, make short term relationships unviable. Long term stability is preferable and situations such as learning races in alliances are not effective. A balance of exploration and exploitation is posited to foster the long term alliance stability and value. In the case of clean-tech cluster firms that span a wide range of corporate entities (startups, SMEs, and public firms), firms can combine both exploration and exploitation over multiple dimensions of the IOR. Thus, unless an alliance is consistently explorative or exploitative in all aspects, it cannot be solely one or the other. This is an additional argument, also a contribution to learning theory and alliance literatures.

Other contributions of this paper to strategy and organizations theory are related to the factors in the model. We explained how the amount of tacit knowledge, ambidexterity across multi-scope alliances, and internationalization are impactful on alliance stability and ultimately cluster value when a balance between exploration and exploitation is found. For the most part, this suggested inverted U-shaped relationships such that neither pure exploitation nor exploration tends to build strong ties. Also, internationalization activities may be exploitative or explorative and moderated by cultural distance which can create and enhance opportunities. This view of cultural distance as a potential positive factor is relatively novel in the literature on national culture.

In many cases, limitations, as outlined here, lead to future research. First, the factors considered in the financial model are limited to the interorganizational level. For example, Uzzi and Spiro (2005) developed structural network theory showing that extra value is found in a cluster's cohesive structure. A future financial model could consider this in the NPV equation. Also, network positions of actors could be factored into the NPV calculation. Governance of the small world clusters may incorporate hierarchy (Baum et al., 2003; Eguíluz et al., 2005). For example, management of a clean-tech cluster may add value to a cluster. New insights may be discovered by considering previous networks research in the context of clean-tech.

Further, time is not reflected in the value of the cluster, but is critical in the development of an investment asset. As mentioned earlier, there is a learning curve and investment required to absorb tacit knowledge. The transfer of knowledge in an alliance could cause an initial setback in one or both firms. The time delay could be highly consequential to realizing benefits because the firm's context changes over time. For example, unexpected competitors could preempt the development of new firm alliances. Consequently, the calculation of the (E_p, σ_p) pairs should be made over time intervals to generate improved, realistic valuation strategies.

Other future research could examine the entire clean-tech small world network and consider its oversight. If the GCCA were to adopt an advisory or supervisory role over its network, then it could direct construction of the small world network. This notion is supported by work of Gibbons (2004), who simulated innovation to guide network building and found that proximity encourages the development of the network, but that industrial associations can assist in partnering. This suggests a potential coordinating role for the GCCA as an international industrial association for clean-tech. The model developed in this paper, and organizational direction may be the right combination of ingredients to support the development of a clean-tech cooperative small world network, and the positioning of new investment asset class with characteristic holding times and risk-reward structures.

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