The Influence of Network Characteristics on Standard Dominance
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The Influence of Network Characteristics on Standard Dominance

By

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Abstract

Electronic products that can connect and interact with each other offer consumers a superior value. These interactions however require specifications of how components of these products should interact with each other which is achieved by setting a standard. This study has researched standards in the electronics arena. Most of these standards are promoted by standards organizations which have the goal of making their standard dominant. Companies can become members of these organizations. The strategy of the standards organization is determined by the firms in the board. These board memberships can be used to construct a network of firms and standards organizations. Similar to the benefits for firms of being in a network, this study proposes that the network benefits the standards organizations. This research project aims to provide a better understanding of the effects of these network characteristics on the success of the standard. To reach this goal literature on standards battles and related subjects has been consulted to derive hypotheses.

Standards organizations in an influential position possess more and shorter ties and can thus receive and send information faster and with more integrity. Organizations bridging structural holes provide information benefits and can gather information from different markets. These concepts are measured by calculating eigenvector respectively betweenness centrality from the two-mode networks of firms and standards organizations. Aside from these structure-related hypotheses other hypotheses have been tested as well. A board with a diverse composition provides different types of information benefiting the standards organization. Because of proposed reinforcing effects the flexibility of the standard development has also been taken into account. Flexibility has been proposed to directly affect the success of the standard as well. All of these concepts affect the dominance of the standard. Standard dominance has been operationalized by counting the total amount of members of the standards organization.

These hypotheses have been tested using multiple statistical methods. A model without reinforcing effects has been tested using generalized estimating equations. Diversity and flexibility are significant unless the influential position of a standards organization is added. Multicollinearity could be a possible explanation for this. No evidence has been found for positive effects on bridging of structural holes. The reinforcing effects between flexibility and diversity have been tested using partial correlations and structural equation modeling. Neither of these methods provided evidence for reinforcing effects.

As the influential position of the standards organization, measured using eigenvector centrality, is significant it can be inferred that network characteristics are important for standards organizations. An influential position can be acquired by having board members that are board members in many other organizations. Hence standards organizations should try to persuade these influential board members to join their standards organizations as to launch a successful standard. Moreover these result show that network characteristics affect the success of standards organizations.

Keywords: Standard dominance, network characteristics, social network analysis, centrality, standard flexibility, reinforcing effects, structural equation modeling, generalized estimating equations.
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Chapter 1: Introduction

Problem Setting

Computers, mobile phones, televisions and other electronic appliances are common in almost every household nowadays. Communication and interaction between these devices enhances the user possibilities of these devices and thus increases the value to the customers. Examples of interaction between devices include transferring data or sharing common devices, such as network printers or home theater systems.

To facilitate communication and interaction between these digital devices connections between these devices need to be established. These devices can be connected directly or indirectly through a local network using wired or wireless transfer methods. Wired networks can use a myriad of different cables such as power lines, coaxial cables, telephone lines, twisted-pair cables or optical fibers. Wireless connections can be facilitated using different frequency bandwidths. Using the same transfer method however is not sufficient to ensure interoperability as the interface needs to be compatible as well. Interface protocols called standards are often established to specify how the components of a system should interact with each other (Gallagher, 2007).

Multiple transfer methods exist and for some of these connection methods multiple standards exist as well. The standards compete with each other for market share in a standards battle. Instead of determining the outcome of a standards battle through competition, these battles may well be determined by intervention of a regulating authority which may steer the development of standards. Alternatively several stakeholders in a standards battle may cooperate to reach agreement on a single standard. Cooperation also plays an important role in competition between standards, as firms can form standards organizations to promote their respective standards. These technological partnerships have the goal to maintain, develop and promote their standard (van de Kaa, 2009). Firms can become members of a standards organization which provides them with certain benefits such as voting right and technical information.

Aside from connecting with each other through a network these products also use similar methods of data storage or direct connectivity. SD-cards and USB cables for example are used in computers and mobile phones as well as in cameras, car GPS systems and televisions. DVDs and Blu-Ray discs can be used to watch movies, but are also used in gaming consoles and computers. Similar situations arise for the software of these devices. To assure compatibility on these aspects standards need to be set resulting in similar standards battles.

Companies can therefore participate in several battles simultaneously. Many of these firms produce multiple types of products hence they have stakes in several standards battles. Computer manufacturers for example have been observed to produce televisions, mobile phones and other electronic products as well. These products utilize different types of standards and hence these firms participate in multiple standards battles. As many of these products can be used to perform similar tasks, competition is not only with direct competitors, but also with substitute products. Smart TVs for example can be used to browse the internet and mobile phones can be used to send e-mails, therefore these products can become substitutes for computers. This phenomenon removes boundaries between markets and increases the importance of interaction with organizations and firms outside of the main market.
These standards battles therefore take place across industries, which include industries such as consumer electronics, telecommunications, home networking and information technology. As most of the markets in these industries are characterized by network effects it is beneficial to select a standard.

Establishing a dominant standard enables focusing of resources in research, manufacturing and marketing, which facilitates exploiting economies of scale and learning (David & Greenstein, 1990; Rosen, Schnaars, & Shani, 1988). Moreover a single standard increases the availability of complementary products, as the risk for manufacturers of complementary products is reduced by the selection of the dominant standard (David & Greenstein, 1990; Schilling, 2010).

Failing to set a dominant standard can result in large uncertainty for customers and firms. This in turn could result in stalling of purchasing or slowing down of product development. Should a standards organization fail to promote, develop or maintain their standard, the firms that have invested in this standard will lose their sunk costs and could incur reputation damage (Shapiro & Varian, 1999). Customers that have bought products advocating to this failed standard are left with few complementary products and a much less valuable product (David & Greenstein, 1990). Therefore the uncertainty of standard battles and the resulting negative effects are a problem to both consumers and firms (Rosen et al., 1988).

In the electronics markets that have been studied for this project many standards have been created and several of these standards have been dissolved. No standard has become the dominant standard for all appliances and roughly similar standards continue to coexist. The coexistence of standards may result in compatibility problems, as customers are not able to connect all of their devices to each other since different connectivity standards have been implemented. This incompatibility reduces the value of the products as customers are limited in their use of the products.

From a scientific point of view the coexistence of multiple standards makes these markets an interesting subject for research. Researching the standards battles in these markets increases the understanding of the standards battles hence reducing the uncertainty associated with standards battles. The findings from this research project could be used by managers to steer the development of their standard or standards organization to increase the odds of success for the standard.

Many studies have researched the influence of factors on standard dominance (Schilling, 1998; Shapiro & Varian, 1999; Suarez, 2004; van de Kaa, van den Ende, de Vries, & van Heck, 2011). Empirical evidence has shown that the standards organizations and the composition of their network of board members influence the chances of standard dominance, but the role of the industry-wide network of standards organizations has not been researched thoroughly (van de Kaa, 2009; van den Ende, van de Kaa, den Uijl, & de Vries, 2012). By researching this gap in the literature this study contributes to the literature on standard dominance.
Research Objective

The purpose of this research project is to understand the influence of network characteristics on standard dominance. This has been researched in the electronics arena using longitudinal data from the Actor Network Standard (ANS) database (van de Kaa, 2009, 2012). This electronics arena includes markets in industries such as consumer electronics, telecommunications, home networking and information technology. These standards battles have aspects of both competitive standard setting and cooperative standard setting.

The longitudinal data used in this study spans the period from 2000 to 2010. The technology changed rapidly during this period and many of these industries experienced technological convergence. The phenomenon of technological convergence entails the process by which products that used to perform distinct functions are unified into new platforms (Yoffie, 1996). Examples of this include smart phones that can be used to browse the internet, as task that used to be performed by computers. Technological convergence causes the borders between industries to fade and thereby compelling firms from previously distinct industries to interact with each other in order to achieve success. This dynamic environment and presence of many standards and standards organizations makes this electronics arena a very interesting research domain.

From the literature on standards battles multiple factors with respect to standards battles have already been identified (van de Kaa et al., 2011). As many factors have been shown to affect standard dominance the scope of this study cannot contain all of these factors. Incorporating all of these factors would require tremendous amounts of information on every standards organization. Testing of these factors would require a large sample size. Therefore this project has focused on the network characteristics of the standard supporters. The supporters of the standards are an important factor in standards battles (van de Kaa et al., 2011). Literature on the effects of networks on participants is abundant, but the role of the industry wide network characteristics on standards organizations has not been researched thoroughly. Researching the role of the industry wide network addresses a literature gap and provides a better understanding of the phenomenon of standards battles in general. The findings of this study could contribute to the list of factors that have been shown to affect the standards battle.
Research Questions

The research objective resulted in the main research question: "How do network characteristics influence standard dominance?" This research is data driven and has been performed using the Actor Network Standard (ANS) database consisting of longitudinal data on standards organizations (van de Kaa, 2009). This database contains information on many factors and additional variables can be calculated from this data. This makes focusing of the research efforts on a smaller amount of factors necessary. This focusing has been driven by the literature leading to the first research question.

Sub-question 1: What are important network characteristics and how do they relate to standard dominance?

The literature on standards battles has provided evidence for the importance of various factors in standards battles (van de Kaa et al., 2011). This project has focused on the network characteristics of the supporting standards organizations. Therefore literature from standards battles, as well as literature from different related subject has been used to determine a focus on certain network factors. Using the literature important variables have been selected and relations between these variables have been proposed. The resulting factors had to be tested resulting in the second research question.

Sub-question 2: What is the effect of network characteristics on standard dominance?

The factors from the literature on standard dominance and related subjects have been proposed to affect standard dominance in several standards battles. The studied standards battle in the electronics industry is likely affected by these factors as well.

Sub-question 3: What is the effect of reinforcing effects between variables affecting standard dominance?

The factors influencing standard dominance as researched in the second sub-question have been proposed to affect the network characteristics themselves through reinforcing effects. Research has already shown that these reinforcing effects can be quite substantial (van den Ende et al., 2012). These reinforcing effects can make the dependencies between the different factors and standard dominance much more complicated.
Chapter 2: Theory

Theory Overview

Standards often compete with each other to become the dominant standard in processes called standards battles. Most famous are the cases of AC versus DC current, VHS versus Betamax and the more recent Blu-ray versus HD-DVD case (Cusumano, Mylonadis, & Rosenbloom, 1992; Shapiro & Varian, 1999; van den Ende et al., 2012).

The concept of standards battles is closely related to the concept of emergence of dominant designs as developed by Utterback and Abernathy (Utterback & Abernathy, 1975). Many authors use these terms interchangeably although other authors clearly distinguish between these concepts. Standards and dominant designs have two main distinctions. Firstly, standards are part of a much narrower class than dominant designs. Whereas dominant designs refer to the architecture of a broad class of products, standards refer to specific elements of the design (Gallagher, 2007). Therefore standards can be owned by a single firm whereas this is generally impossible for dominant designs. Secondly standards can be defined *ex ante* before the product is launched whereas dominant designs can only be defined *ex post* after products have been launched (Gallagher, 2007). It has been argued that both standards battles and battles for dominant designs are different aspects of the emergence of a dominant technological trajectory that has to compete with other trajectories (Suarez, 2004). Due to these similarities some of the literature on dominant designs can be applied to standards battles as well.

Multiple types of standards exists, such as safety standards, compatibility standards and measurements standards (Blind, 2004). Compatibility standards have been research for the purpose of this research project. These standards are codified specifications that specify how components should interact with each other to ensure compatibility and interoperability and as such compatibility standards are closely related to the architecture of the design (van den Ende et al., 2012).

Most of the literature on standards battles treats standards battles that have been set in a competitive setting. Dominant standards can however also be the result of cooperative standard setting. As Leiponen showed standards are often set in cooperative organizations of firms where the firms negotiate with each other to reach agreement over the standard specifications (Leiponen, 2008). Competition often occurs between these standards organizations or alliances, although some firms have been supporting multiple competing standards (Rosenkopf & Tushman, 1998; Vanhaverbeke & Noorderhaven, 2001). In the markets of this research project both competition between standards organizations and cooperation between firms in standards organizations takes place.

In standards battles multiple scenarios are possible and the importance of factors can vary depending on the phase of the development (Suarez, 2004). In many cases one standard eventually emerges as the dominant standard adhered to by most of the customers and firms (Utterback & Abernathy, 1975). Network externalities are often responsible for the emergence of a dominant design and selection of a standard as some goods become more valuable if more people consume or use it (Schilling, 1998). Due to network externalities standards battles are often path dependent. Therefore it is necessary to build a large installed base to reap the benefits of network effects (Schilling, 1998, 1999). A large installed base also increases the availability of complimentary goods (Katz & Shapiro, 1985). Aside from this economies of scale and learning effects can also play a role (Schilling, 2010).
The literature on standards battles has provided evidence for the effects of numerous factors on standard development and on the outcome of the standards battle. A comprehensive literature review has been conducted by van de Kaa et al. categorizing these factors into five categories: characteristics of the standard supporter, characteristics of the standard, standard support strategy, market characteristics and other stakeholders (van de Kaa et al., 2011). The characteristics of the supporters of the standard are therefore important factors in the standards battle according to the literature (Foray, 1994; Willard & Cooper, 1985). The supporters of the standard in the case studied for this project are the standards organizations with their members. The characteristics of these standards organizations therefore could influence the outcome of the standards battle.

Standards organizations have the goal to promote, develop and maintain their standards. To achieve this a strategy is determined by the board of directors. The board can approve revisions to the standards and determines the market strategy (van de Kaa, 2009, 2012). Board members are people representing the interests of their firm in the standards organization. Instead of focusing on the individual board members, this study focuses on the firms represented by these individuals, as the board members are expected to serve the interests of the firm instead of their individual interests. Firms can be board members of multiple standards organizations. In most cases it is allowed to participate in competing standards organizations as well.

Through these interlocking board memberships a network emerges, with standards organizations as the central nodes. Networks can be analyzed using social network analysis. Originally social network analysis was used by anthropologists in their research on the relations between people, one of the first people to systematically research these relations was Barnes in 1954 (Wolfe, 1979). In the seventies social network analysis was applied to research on interlocking board memberships (Faust, 1997). In the following decades authors have shown that social network analysis can also be applied to the networks of firms created through interlocking board memberships (Mariolis & Jones, 1982; Mintz & Schwartz, 1981a, 1981b).

Many authors have researched the benefits of networks. One of the main benefits of networks is the acquisition of information through ties in the network. Weak ties have been argued to provide more diverse information, whereas strong ties provide more specific information (Suarez, 2005). Utilizing information from partners in a network may require some stretching of the existing knowledge, which provides learning benefits (Nooteboom, Van Haverbeke, Duysters, Gilsing, & van den Oord, 2007; Powell, Koput, & Smith-Doerr, 1996). Networks and alliances also enable firms to access each other’s complimentary assets such as distribution and manufacturing capacity, reputation and marketing (Teece, 1986). Research has indicated that firms participating in consortia more frequently use each other’s patents (Delcamp & Leiponen, 2013). Moreover, networks provide opportunities for joint development (Powell et al., 1996). The costs and the risks of joint development can be shared (Eisenhardt & Schoonhoven, 1996). Through partners in a network, firms can also get information about other potential partners, which aids in the formation of new alliances and facilitates creation of trust (Coleman, 1988; Gulati, 1995, 1999). Utilizing the network has been shown to greatly affect firms in their performance. Studies have shown that firms that are embedded in the network and maintain close relationships have higher chances of survival (Uzzi, 1996).
In interorganizational networks however the literature more commonly focuses on the benefits for collective actions and coordination of tasks (Provan, Fish, & Sydow, 2007; van den Ende et al., 2012). Interdependent firms are better able to coordinate their action. Sharing of knowledge can increase interdependence (Soh, 2010). As launching a successful standard requires coordination between the firms using this standard it is important for them to coordinate their strategies. Collective action is necessary for successful marketing of the standard as different options for entering the market exists (Ehrhardt, 2004; Katz & Shapiro, 1994). Standards for example can be made open access of proprietary which requires collective action of the supporters of the standards. Aside from this the financing of the marketing strategy and the research and development costs also require collective action (Schilling, 1999).

Standards organizations are not independent actors as their course is determined by their board members. A standards organization can be considered a collection of actors. A standards organization supported by firms that have a successful reputation with previous-standards battles will benefit from that reputation (Axelrod, Mitchell, Thomas, Bennett, & Bruderer, 1995; Foray, 1994; van den Ende et al., 2012). Some large companies can be very influential and their membership might persuade others in joining the standards organization (Foray, 1994; Rosen et al., 1988; Suarez & Utterback, 1995). Moreover a standards organization with members with resources and knowledge can benefit from these resources (Teece, 1986). As the network benefits firms, these benefits also aid the standards organizations where these firms are member.

Two types of networks can be distinguished from the membership data. One type of network is the internal network of the board members of a standards organization. This part of the network is analyzed at the organizational level (Provan et al., 2007). The second type is an interorganizational industry-wide network resulting from the connections of these board members to other standards organizations. This industry-wide network is a whole network and is analyzed at the interorganizational level (Provan et al., 2007). It has been argued that the characteristics of the standard itself influence the membership of the standards organizations, therefore variables at the standard level have been taken into account as well (van den Ende et al., 2012).

**Characteristics at Industry Level**

Studies have shown that the network of interlocking directorates affects the organizations (Mariolis & Jones, 1982; Mintz & Schwartz, 1981a, 1981b). Similarly the network of the board members of the standards organization can affect the standards organization. The board members of standards organizations are firms. These firms can be board members of multiple standards organizations. Firms with more board memberships have access to more information and resources. The information and resources can be used in the standards organization or the firm (Suarez, 2005; Teece, 1986). As these members interact with more firms and participate in more organizations they can exploit more learning opportunities as well (Powell et al., 1996). Increased participation in standards organizations also means that these firms are more active and hence more influential on development of standards in general. The extent of the connections from these firms to standards organizations can be used as a measure of their influence in the industry-wide network (Borgatti, 2005; Borgatti, Jones, & Everett, 1998).

Standards organizations gain access to multiple short paths to other firms and standards organizations within the industry network through the connections of the board members. As information diffuses through the network from actor to actor it is important to keep the paths to other firms and organizations short to acquire information early (Powell et al., 1996; Soh, 2003). Information is transmitted faster and with more integrity through a network with shorter paths (Schilling & Phelps, 2007; Watts, 1999).
The electronics market at study is characterized by rapid technological change and fast changing consumer preferences and hence it is important for standards organizations and firms to adapt their standards and products at a fast rate to satisfy needs and to keep up with the pace of technological progress (Tripsas, 2008; van de Kaa, 2012). Therefore acquiring information before the competition does can create a competitive advantage (Deeds & Hill, 1996). By implementing this information to the standard, the standard can be better adapted to the customer needs and hence it will be more successful (Shapiro & Varian, 1999).

Having multiple short paths to other actors is also beneficial for spreading information (Provan et al., 2007). It is impossible for every actor to have complete information about every other actor in the network; hence it is necessary to actively find potential partners by transmitting information on your available knowledge, assets and resources. Potential partners in the network can become interested if they receive information about the standard and the organization behind it through their network (Gulati, 1999). As more actors are able to observe the actions of a central organization being more central facilitates finding partners as the reach from a central organization is larger. Aside from this being central in a network aids in building a reputation and gaining trust (Powell et al., 1996). The actions of a standards organization in a central position in the network will be more visible. This increased exposure of the standards organizations can be used to promote the supported standard. The promotion of the standard might persuade firms to join the standards organization and to use the standard in their own products.

Additionally firms in a central position in the network are able to gain better access to the network and to exert more influence on other actors in the network (Soh, 2010). The board members of the standards organization can use their influence in the network to persuade other firms to choose that standard. Influential firms in the board can use their influence to try setting the standard in a standards battle single-handedly if they are industry leaders (Rosen et al., 1988; Suarez & Utterback, 1995). Their presence in a standards organization can hence persuade others to join the standards organization (Foray, 1994). These members increase the strength of the organization both by increasing the reputation as well as by increasing the available resources and knowledge (Axelrod et al., 1995; Teece, 1986). Research has shown that firms may switch standards if their current situation in the standards battle becomes unfavorable (Vanhaverbeke & Noorderhaven, 2001). Hence influential board members can convince others firms directly or indirectly to join the standards organization.

A standards organization with influential board members will be located more centrally in the network as the organization and hence will possess more and shorter paths to firms outside of the standards organization through the connections of the board members. This increased exposure can be used to promote the standard. Moreover the influential board members can use their influence to convince other firms to join the standards organizations and to use the standard. These additional member firms can implement the standard in their products increasing the amount of complementary products which positively affects the chances of standard dominance and the installed base (Shapiro & Varian, 1999). Hence the influential position of the members can put the standards organization into a more influential position increasing the chances of success of the standard.

**Hypothesis 1:** A standard supported by a standards organization in a more influential position in the industry wide network will have a higher chance of becoming dominant
All ties can provide information, but if the same information comes from different ties these ties are redundant. It is important to possess non-redundant ties, as these ties can provide different information more efficiently (Burt, 1992, 2004). Non-redundant ties exist when few connections between groups of actors exist. Due to the limited connections between the groups the actors in the different groups possess different information. The separations between these groups are called structural holes (Burt, 1992).

Structural holes can be bridged by actors that have ties with both groups. As the different sides of the structural hole hold different information, a bridging actor can create value by combining information (Burt, 2004; Hargadon & Sutton, 1997). Organizations bridging structural holes can serve as an obligatory passage point for information across the structural hole (Owen-Smith & Powell, 2004; Rosenkopf & Tushman, 1998).

Firms active in different markets or niches will interact less often than firms active in the same market. Structural holes will therefore likely exist between different markets or niches. Firms and standards organizations separated by a structural hole possess different information (Burt, 1992). This information includes technical information but also information about consumer preferences and the market environment. Many products and standards can be used for different applications due to technological convergence; the process of unifying the functions of previously distinct products into new platforms. Consequently standards organizations are often active in a combination of smaller markets or industries. Standards that can be used for distinct applications require more technological know-how to ensure compatibility.

Aside from technological knowledge, information about the consumer preferences and the market environment is needed to launch a standard successfully in a new market or niche. This information can be used to determine the required strategy and the required properties of the standard (Schilling, 2010). Organizations bridging structural holes can receive this information for different markets and niches. This consumer information can be used to adapt the strategy of the standards organization, which enables launching products adhering to the standard in multiple markets. The information about consumer preferences can also be used to adapt the properties of the standard to the demands of customers in multiple markets. This would enable successful launching of the standards in multiple different industries, which would increases the potential market size of the standard. Launching products with the standard in different markets increases the installed base and the amount of complementary products which increases the chances of standard dominance (Shapiro & Varian, 1999).

The existence of structural holes also means that only a few connections between the groups on different sides of the holes exist. Therefore the valuable consumer information is not available to other standards organizations, only to the organizations that bridge the structural holes. Hence this information can result in a competitive advantage for the standards organization (Schilling, 2010).

Hence standards organizations bridging structural holes have access to valuable information for different markets, which aids these organizations in launching the standard for different applications and markets. This information is only available to standards organizations bridging the structural hole. As the standard can be launched in different markets the installed base and the amount of complementary goods increases, which increases the chance of the standard becoming dominant (Shapiro & Varian, 1999).

Hypothesis 2: A standard supported by a standards organization bridging structural holes in the industry wide network will have a higher chance of becoming dominant
Characteristics at Board Level

Aside from the position in the industry network the composition of the board members has also been argued to affect the outcome of the standards battle. The board members constitute a smaller sub-network of the industry network. This network at the organizational level consists of the board members of the standards organization.

As argued in the previous section, acquiring diverse information is important for the success of the standards organization. One way of acquiring this information is bridging structural holes at the interorganizational industry wide network. A diverse network of heterogeneous board members from different markets and industries will provide diverse information as well (van de Kaa, 2009). As firms operating in different contexts experience different events they will acquire different information. A diverse network will therefore provide more diverse information (Gilsing, Nootboom, Vanhaverbeke, Duysters, & van den Oord, 2008). Furthermore, acquiring information from multiple sources provides information on the generalizability of the knowledge and facilitates drawing causal inferences (Beckman & Haunschild, 2002). Firms from different industries have a higher cognitive distance and have different knowledge. By sharing this knowledge and interacting they are required to stretch their knowledge which can help them achieve better learning (Nootboom et al., 2007). Additionally the interaction also provides benefits for knowledge spillovers (Sakakibara, 2001).

As networks can be used to share resources and capabilities, it is important to have different capabilities and resources available in the network (Vanhaverbeke & Noorderhaven, 2001). A diverse network enables matching of capabilities with firms possessing complementary knowledge or capabilities (Chung, Singh, & Lee, 2000; Hagedoorn, 1993). All kinds of digital devices need to be able to interact with each other as it is beneficial for the consumer to have compatible products. A standard tailored to one specific appliance would hence be unlikely to be successful in a broad market. A standards organization supported by members from multiple industries can better adapt their standard to the wishes of consumers from these industries. Therefore this standard can be applied to more types of products, hence increasing the installed base and the amount of complementary goods. As complementary goods and installed base are important for standard dominance a standards organization with more diverse members is more likely to produce the dominant standard (Shapiro & Varian, 1999).

Hypothesis 3: A standard supported by a standards organization with a diverse network of members will have a higher chance of becoming dominant

Characteristics of the Standard

Although characteristics of the standard are not network characteristics and as such not in the direct scope of this project, research has shown that characteristics of the standard affect the composition of the network and hence it will be included in this model (van den Ende et al., 2012). Aside from this, characteristics of a standard have been shown to affect the outcome of standards battles. A technologically superior standard offering a superior performance and more complementary goods has an increased chance of becoming dominant (David, 1985; Schilling, 2010). The ability to innovate and adapt the standard to the wishes of the consumers is also important (Shapiro & Varian, 1999). A standard can be adapted to increase the match with user requirements through revisions of the standard. Through these revisions the standard can be tailored to offer a superior performance to the customer.
A standard that has been adapted frequently through changes to that standard is called more flexible, this flexibility refers to the process of design and development of the standard (van den Ende et al., 2012). A standard is more flexible if it is revised more often and hence it can be better adapted to the wishes of consumers and producers. The literature suggests that to be successful in rapid changing environments, it is important to adapt flexible design procedures. Being more flexible in the design process can result in shorter development time (Brown & Eisenhardt, 1995). Moreover, flexible design processes reduce the costs associated with risks and enable implementing recent technologies to adapt the standard to consumer preferences (Thomke, 1997). By adopting flexible design procedures and revising the standard the standard can become technologically superior (Wade, 1995). Although technologically superior standards do not always win the standards battle, they are more likely to win as they offer customers a superior performance (David, 1985).

One of the main goals of establishing a standard is to assure sustained compatibility between products. Therefore it is expected that most standards are stable and rigid to assure consistency in the products and to assure compatibility. However, research has shown that successful standards have in fact had more revisions (van den Ende et al., 2012). Although a standard revision temporarily makes the standard unstable and hence less attractive, the revised version of the standard can be better adapted to the customer preferences and hence this standard will be more likely to be adopted by consumers (van den Ende et al., 2012). This will increase the installed base and can increase the amount of complementary goods increasing the chances of standard dominance (Shapiro & Varian, 1999). Therefore it is proposed that a more flexible standard will have a higher chance of becoming dominant.

*Hypothesis 4: A more flexible standard will have a higher chance of becoming dominant*

**Reinforcing Effects**

The flexibility of a standard also has implications for the composition of the network of the standard. A more flexible standard can be better adapted to the needs of consumers and hence this opens up possibilities to apply the standard in new areas and different industries. The increased consumer base can attract firms from different industries. These firms can apply the flexible standard more easily to their area of expertise. Therefore a more flexible standard can increase the diversity of the network (van de Kaa, 2012; van den Ende et al., 2012).

A more diverse network has also been argued to provide more diverse information (Gilsing et al., 2008). This information can be implemented in a standard revision. These revisions make the standard more flexible. Hence it can be argued that diversity increases the standard flexibility.

*Hypothesis 5: Network diversity and standard flexibility reinforce each other*
Research Model

Variables have been measured at different levels; the three levels that can be distinguished are industry level (interorganizational), board level (organizational) and standard level. The levels at which these variables are measured are depicted by the dashed boxes around the variables as can be seen in the research model of figure 1. Variables at industry level are influential position and structural holes, both of these variables directly affect standard dominance as proposed in hypothesis 1 and 2 respectively. These variables are both network characteristics representing the position of the standards organization in the industry-wide network of firms and standards organizations as created through the interlocking board memberships.

Board level refers to the composition of the board and one variable has been measured at this level, namely diversity. Diversity acts directly on standard dominance as proposed by hypothesis 3. Aside from this diversity also acts on flexibility, which in turn acts on diversity as well. The two-headed arrow represents the reinforcing effects as proposed by hypothesis 5.

Because of these proposed reinforcing effects from hypothesis 5 the variable flexibility has been incorporated into the model. This variable does not refer to the network characteristics of the standards organization but refers to the design of the physical standard itself; hence it is has been measured at a different level, namely at the standard level. Aside from the reinforcing effects between flexibility and diversity, flexibility has also been proposed to affect standard dominance directly according to hypothesis 4.

Figure 1: Research Model. Rectangles are concepts, arrows indicate hypotheses and dashed boxes represent the level at which the concepts are measured. The curved double-headed arrow between diversity and flexibility indicates the proposed reinforcing effects between these variables.
Chapter 3: Methodology

Unit of Analysis
Standards organizations are coalitions of firms that promote, develop and maintain a standard (van de Kaa, 2009, 2012). Literature on cooperative standard setting has indicated that coalitions play an important role in standards battles (Leiponen, 2008). Membership of standards organizations is open to firm. Companies can exert influence on the standard development through their memberships. The amount of members of standards organizations can differ vastly, the Bluetooth Special Interest Group for example has 23,913 members (Bluetooth Special Interest Group, 2014), whereas other organizations have less than ten members. For organizations with vast amounts of members it is unlikely that all these members will be equally active and influential in the standards organization.

Therefore most standards organizations provide several membership options to interested firms and individuals. These types of memberships differ in the amount of influence a firm can exert but correspondingly they also differ in the membership fee. Four different membership levels have been distinguished by Updegrove (Updegrove, 2006). Strategic members have a position on the board and can influence the strategic direction. Technical committee members have voting rights on certain decisions and can thus influence the standard directly and they can often elect several board members to represent their combined interests. Advisory members can participate in the standards organizations but do not have voting rights and can thus only indirectly influence the standard. Informational members only receive information on the standard development.

The lower levels of membership do not possess considerable power to influence the standards organizations and standard development. Therefore this study has focused on the strategic members as these members can influence the strategic direction of the organization and the standard as they decide on final approval of specifications of the standard (van de Kaa, 2009, 2012). Strategic members participate in the highest organizational unit within the standards organization, for most standards organization this is the board of directors. In other standards organizations the equivalent highest organizational level which possesses voting power has been researched. The board consists of people representing their respective firms. Although the board consists of individuals this study looks at the firms represented by these people and takes those firms to be board members. Board members are both decision makers as well as normal members. As they can influence the strategic direction of the standards organization these board members are expected to be actively involved in the standards organization.

This study has used a sample of 103 standards organizations involved in the electronics industry during the period 2000 to 2010. Membership data for 2011 has been used as well. In total this constitutes 644 complete observations. A complete list of standards organizations can be found in appendix G. Two types of statistical analyses have been used to determine the effects of the network characteristics on standard dominance. The considerations with respect to the sample size requirements of these analyses will be elaborated in the subsequent chapters of these specific research methods and in the results section.
Data Acquisition

Data from the Actor Network Standard (ANS) database has been used to carry out this project. Previously this database has been used to determine the influence of standards organization characteristics on standard dominance using event-history analysis (van de Kaa, 2009, 2012). The ANS database has since been expanded and updated for further research. This specific study required some additional data acquisition and hence additional data has been collected using procedures similar to the original procedures.

The ANS database contains data on a sample of standards organizations in the electronics arena during the period from 1990 to 2009. This arena includes markets in industries such as consumer electronics, telecommunications, home networking and information technology. Information about the standards organizations has been collected for every year resulting in one entry per year per organization. In cases where no data was available for a certain year the entry was kept blank. The list of standards organizations has been checked by an expert to determine whether the relevant standards organizations were present (van de Kaa, 2009).

The information in this database has been collected using archived websites from websites such as the Internet Archive and other sources. Information from the Internet Archive can be used at no cost for research and scholarship purposes (The Internet Archive, 1997). The Internet Archive stores archived websites online which can be visited using the search engine on their website.

The Internet Archive has been founded in 1996 and hence archived websites from before 1996 have not been stored. The archive however is not complete and contains considerably less information about websites in the nineties compared to later years. Availability of data was the first reason to use a selection of the data from 2000 up to 2009. Secondly, selection of this period provided advantages in comparing the network characteristics. Fewer standards organizations existed in the nineties compared to later years. This results in different industry network sizes, which would impede comparison of network measures. For these two reasons a selection of the data has been used. To increase the amount of available observations for the standards organizations additional data for 2010 and 2011 has been collected.

Furthermore the membership data from 2000 to 2009 has been reanalyzed to assure consistency of the old and the new data. Eligibility requirements for members differ per standards organizations and different types of memberships are available. Many standards organizations allow for individual, academic or student memberships and provide different types of corporate membership. As the focus of this project was on firms and standards organizations the individual, academic, organizational and student members have not been counted in the total membership data. This decision required reanalyzing of the data to assure consistency. During the process of reanalyzing the data additional membership information for the 2000-2009 period has been found which reduced the amount of missing data. More information on the data collection method used for this project can be found in the appendix A and in the dissertation of van de Kaa (van de Kaa, 2009).
Social Network Analysis

Networks of standards organizations and firms have been created for the years 2000 to 2010 using the available board membership data. Connections between standards organizations and firms are created through the board memberships. Consequently two groups of actors can be distinguished; standards organizations and firms. Actors from one group cannot connect directly to other actors in the same group. Firms for example cannot be board members of other firms. In social network analysis these groups are commonly called modes.

The social network analysis has been performed using the program UCInet 6 (version 6.486, 64-bits). This software converts the relational board membership data to an affiliation matrix of dimensions $M \times N$ (Borgatti, Everett, & Freeman, 2002). The resulting affiliation matrix contains $M$ firms and $N$ standards organizations. The affiliation matrix is a binary matrix summarizing the connections between standards organizations and firms. In this binary matrix a value of one indicates board membership of a firm to a specific standards organization. The resulting network can be graphically visualized using the NetDraw plugin from UCInet (Borgatti et al., 2002). Graphic visualizations of the bipartite networks of standards organizations and firms can be found in appendix B.

As the mathematics used to analyze social networks require square matrices the rectangular affiliation data matrices have been converted to square matrices. To convert this rectangular $M \times N$ to a square matrix multiple methods exist. For the purpose of this specific research project the rectangular $M \times N$ matrix has been transformed to a biadjacency matrix; a square matrix of dimensions $M + N$ (Scott, 2000). Using the biadjacency matrix preserves more of the underlying structure and has several other advantages over the method of projection which projects the $M \times N$ two-mode matrix onto two one-mode matrices of dimensions $M \times M$ and $N \times N$ (Borgatti & Everett, 1997). More information about the social network analysis can be found in appendix A.

Converting the affiliation data to a biadjacency matrix effectively treats standards organizations and firms as the same type of node. Information on the calculation of the biadjacency matrix can be found in appendix A. As this matrix is a square matrix, the routines designed for one-mode data can be used on this matrix (Borgatti & Everett, 1997). Industry wide network characteristics have been operationalized using centralities. Centralities are generally normalized to enable comparison between networks of different sizes. As connections can only be established between the two different modes, the maximum number of connections in the biadjacency matrix is lower than the theoretical maximum of an ordinary $M + N$ one-mode (Freeman, 1979). Although this does not impact the raw scores this does affect the normalized scores and hence a different normalization is necessary (Borgatti & Everett, 1997). The recent versions of UCInet are able to calculate these two-mode variables by converting the matrix and applying the correct normalization (Borgatti et al., 2002).

For some standards organizations board membership data is available whereas information on their total amount of members is lacking. As total membership is lacking, these cases cannot be used to test the hypotheses as will be explained in the subsequent paragraph. Connections from their board members however influence the structure of the industry-wide network. This network is used to determine the centralities of other standards organizations. Although the centralities of these specific standards organizations cannot used in the analysis, their presence in the network contributes to the centralities of other organizations. Therefore these organizations are included in the network analysis.
Dependent Variables

Standard Dominance. Standard dominance measures the success of the standard in the standards battle and is commonly operationalized using market share (Murmann & Frenken, 2006). As the electronics arena consists of different markets and a wide arrangement of products such as televisions, DVD players, computers, smartphones or smart meters this would result in multiple market shares for every standard. This is further complicated by the fact that many products can be used in different contexts and most firms are producing products from multiple categories, hence it is difficult to separate the sales between product categories. Products can furthermore use several standards, such as a computer with Wi-Fi, USB and Ethernet, which further complicates market share calculations for the standards.

Other research has operationalized standard dominance by determining the amount of firms developing and promoting a standard, which is called the technological community (von Burg & Kenney, 2000; Wade, 1995). Wade (1995) defines a technological community as a group of firms based on a technological paradigm or design. A standards organization with more members has more supporting firms that can use the standard in their products. As more products with this standard are produced this standard is more dominant than rival standards.

The focus in this research project is mainly on the firms in the board of the standards organization as these firms have decision power and can hence influence the development of the standard. To determine the size of the technological community data on the total amount of members has been collected. This has been termed network size and has been used to operationalize standard dominance. Individual members are ignored as the focus of this project was on firms and standards organizations; hence only corporate members were counted.

Network characteristics and standard revisions are not expected to influence the network size immediately. Therefore the influence of the network characteristics on the size in the next year has been researched. An advantage of this is that this partially corrects for standards organizations that have just been founded. New standards organizations often consist of founding members only. If this organization becomes successful membership can grow rapidly. Another advantage lies in the data collection method. Board data and membership data have both been collected from archived websites. In most cases the exact time-stamp of the website is not available; therefore membership and board data from a certain year might represent the situation in different points in the year. To assure that the network size does not predate the board membership data, which would result in causality issues, the network characteristics in the model affect size in the next year.

As standards organizations can differ vastly in their amount of members the distribution of their sizes is non-normal and positively skewed. Therefore the data has been transformed by taking the logarithm of network size to make the data approximately normal.

Members of a standards organization can differ vastly in sales volume, from large multinationals to small and medium sized enterprises. Using this operationalization all firms contribute the same to the network size making this operationalization biased towards standards with many small members. However merely being supported by large multinationals does not make the standard dominant. A standard that becomes dominant will attract small firms that want to use the standard in their own products to the standards organization thus increasing the network size. Hence a dominant standard will have a standards organization with more members, both large and small members.
Independent Variables

Influential position. Hypothesis 1 requires measuring the influential position of the standards organization in the network. To measure the value of the connections to the board members eigenvector centrality has been used which accounts for both direct and indirect ties (Bonacich, 1972a, 1987). This measure of centrality is positively related to social capital and has been used to estimate the influence of actors in previous research (Bonacich, 2007; Borgatti et al., 1998; Friedkin, 1991). Eigenvector centrality in bipartite graphs has often been used in studies of interlocking corporate boards to measure the centrality of the actors (Bonacich, 1987; Faust, 1997; Mariolis & Jones, 1982; Mintz & Schwartz, 1981a).

The eigenvector centrality of a node is proportional to the sum of the eigenvector centralities of the adjacent nodes (Faust, 1997; Scott, 2000). A node scores high on eigenvector centrality if the neighbors score high on eigenvector centrality. The calculation of eigenvector centrality is therefore an iterative process. First all nodes are assigned an arbitrary centrality value of one afterwards of which the scores of each node are recomputed as a weighted sum of the centralities of the adjacent nodes. After normalization the process of computing the eigenvector score can be repeated (Bonacich, 1972a). This process can be converted to a matrix equation which can be solved for the eigenvalues of the matrix. The largest eigenvalue provides the eigenvector centrality for all nodes. In bipartite graphs the maximum possible eigenvector centrality is lower than in one-mode networks, hence the two-mode normalization has been used (Borgatti & Everett, 1997).

Structural holes. To measure the bridging of structural holes for hypothesis 2 betweenness centrality has been used. To calculate betweenness centrality all possible shortest paths between nodes have been calculated. Betweenness centrality measures how many of these shortest paths pass through a node (Freeman, 1977, 1979). In the bipartite graph the theoretical maximum amount of shortest paths differs from the one-mode case, hence a different normalization is required (Borgatti & Everett, 1997). A node that connects groups across structural holes will lie on many of the shortest paths connecting the two sides of the hole, consequently this node will have a high betweenness centrality (Scott, 2000). Betweenness centrality is highly correlated with structural holes (Burt, 1992; Everett & Borgatti, 2005a). This concept has been used to measure access to structural holes (Gilsing et al., 2008; Provan et al., 2007; Tsai & Ghoshal, 1998). Therefore it is positively associated with social capital (Borgatti et al., 1998).

Centralities are calculated using the same affiliation data and use similar mathematics, hence centralities are often correlated. Betweenness centrality is relatively uncorrelated with other centrality measures, although it can be correlated with degree centrality (Bolland, 1988; Rothenberg et al., 1995; Valente, Coronges, Lakon, & Costenbader, 2008). The possible correlations might induce problems with multicollinearity.

Diversity. The diversity of the board has been measured by counting the amount of different industries represented in the board of the standards organization. The represented industries have been determined using the SIC codes from the Thomson One Banker database. The Standard Industry Classification (SIC) code is a four-digit number that is used to classify firms by their industry. As every industry has their own code, the amount of industries present in the board can be determined by counting the amount of unique SIC codes from the firms in the board. Some firms are present in multiple industries and thus have multiple SIC codes, in these cases their primary industry SIC code has been used. Using the board membership data the firms in every board have been determined. The counting of unique SIC codes has been executed automatically using a self-written Matlab R2014a (version 8.3, 64-bits) code, which can be found in appendix C.
Flexibility. The flexibility of a standard represents the amount of changes of a standard (van de Kaa, 2009, 2012; van den Ende et al., 2012). A standard is more flexible if it has been revised more often. This has been operationalized by counting the amount of revisions or entirely new versions for every year. Major changes to standards are often reported through press releases and hence this information can often be retrieved. In cases where no information about standard revisions was found either no revisions to the standard were made or the information on standard revisions has not been published or archived. In these cases it has been assumed that the standard did not change in that year.

Control Variables

*Year.* The goal of this study has been to determine the influence of network characteristics on standard dominance. The tested model consisting of network characteristics and flexibility is not a complete model as other factors have also been shown to affect the chances of standard dominance as well. Although these factors have not been incorporated into the model, the model has been fitted with a variable intercept for every year. These variable intercepts have been fitted using a categorical year variable. This procedure aided in accounting for exogenous effects such as market or environmental factors. As standards organizations experience similar events and a similar environment in the same year, the year could affect the network size in a certain years. This method however does not account for all exogenous effects. Hence some variance will not be explained by this model.
Generalized Estimating Equations

The model that has been tested incorporates reinforcing effects between diversity and flexibility. Because of these reinforcing effects diversity and flexibility would be both dependent as well as an independent variable. This would present difficulties in fitting the model.

To test reinforcing effects using a regression method one could test the reinforcing effects using interaction effects, which would require addition of two lagged variables; lagged flexibility and lagged diversity. Lagged variables however are heavily correlated with the non-lagged variables and addition of these variables would induce large amounts of multicollinearity. Therefore the reinforcing effects will be tested separately from the direct effects from hypothesis 1 to 4 using a different statistical method.

The data in the ANS database is sorted in long format; every standards organization has multiple entries in the database, namely one for every year for which data is available. If no information or no complete information is available for a standards organization in a certain year that entry has been excluded from the analysis. Due to these repeated measurements ordinary regression cannot be used, as ordinary regression would treat every entry as an independent measurement (Liang & Zeger, 1986). Hence a different statistical method has been used, namely generalized estimating equations, also known as GEE.

GEE is a regression method closely related to the broader class of generalized linear models. Generalized estimating equations are commonly used in biostatistics and in medicine literature to estimate the population-averaged response, but the method has been used in strategic and management literature as well (Katila & Ahuja, 2002). Generalized linear models can be used to estimate regression coefficients with data that follow other distributions than the normal distribution. These distributions can be specified by the user of the statistical program.

In GEE models the dependent variable is called the response variable and the independent variables are called predictor variables. The relationship between these variables is prescribed by the link function. This study has tested linear dependencies between the response and the predictors requiring usage of the identity link function. The response variable should approximately follow the distribution specified by the user. No distributional assumptions apply to the predictor variables.

The GEE method has been specifically developed to analyze longitudinal data with repeated measurements (Liang & Zeger, 1986). GEE accounts for repeated measurements in two ways. Firstly GEE accounts for repeated measurements by determining the average effect of the predictor variables on the response variables. In this case the effects of the network characteristics on standard dominance have been determined. Using GEE the effects averaged over all standards organizations have been determined.

Secondly, GEE allows the user to specify a correlation structure between the error terms. As the network characteristics have been measured several times for the same standards organizations these outcomes of different years are likely related. The resulting autocorrelation could cause interdependence of the error terms, violating the assumptions of regression (Hair, Black, Babin, Anderson, & Tatham, 2005). This problem could in principle be reduced by estimating the correlation structure of the errors of the response variable as is used in GEE (Liang & Zeger, 1986). This requires the user to specify a correlation structure, such as an auto-regressive, exchangeable or independent working correlation matrix. Misspecification of the working correlation matrix reduces the efficiency of the GEE method (Overall & Tonidandel, 2004).
Research however has shown that even under misspecification of the correlation matrix, the method will yield consistent estimates, albeit less efficiently (Ghisletta & Spini, 2004). The generalized estimating equations method yields consistent and unbiased estimates if the marginal expectation is equal to the partly-conditional expectation. This assumption can be mathematically expressed in the following equation but this assumption is often overlooked (Pepe & Anderson, 1994).

\[ E(Y_{it} \mid X_{it}) = E(Y_{it} \mid X_{it}, X_{jt}, j \neq t) \]

(1)

This condition means that the value of the dependent variable \(Y_{it}\) at time \(t\) depends only on the values of the predictor variables \(X_{it}\) at time \(t\). Addition of predictor variables at other times should not change the value of the dependent variable. For constant predictors this condition always holds. When the predictors are time-varying this main assumption of GEE is no longer satisfied. Therefore the estimates of the GEE procedure might be inconsistent or biased (Pepe & Anderson, 1994). Unfortunately some of the predictors in this study were time-varying and hence a solution to this problem has been devised.

A solution to this problem was the implementation of an independent working correlation matrix as suggested by Pepe and Anderson as this should provide unbiased estimates (Lai & Small, 2007; Pepe & Anderson, 1994). An independent correlation matrix does not model correlations between the errors terms and takes these errors to be independent from the errors in other years. Unfortunately this removes one of the main advantages of GEE and results in a decrease in efficiency of the GEE procedure. The resulting estimates however will be consistent. The second advantage of generalized estimating equations still applies, as the method still allows accounting for repeated measurements by estimating an average result of all the standards organizations.

In total data for 103 standards organizations are available over a period of 10 years, resulting in 644 observations. Generalized estimating equations can be used as long as there are at least 30 subjects for which repeated measurements are available hence these 103 standards organizations will suffice (Ghisletta & Spini, 2004; Norton, Bieler, Ennett, & Zarkin, 1996). As the amount of standards organizations is relatively large compared to the average amount of observations per standards organizations the results from this analysis will be efficient and consistent (Liang & Zeger, 1986; Zeger, Liang, & Albert, 1988). Therefore generalized estimating equations can be used to analyze the proposed hypotheses on this dataset.
Structural Equation Modeling

The reinforcing effects from hypothesis 5 have been tested using structural equation modeling, commonly abbreviated as SEM. Structural equation modeling is a statistical technique that can be used to estimate solutions for a system of multiple regression equations simultaneously (Hair et al., 2005).

Since SEM estimates multiple equations simultaneously the technique does not use the distinction of dependent and independent variables, but instead distinguishes between exogenous variables, which are determined outside the model and endogenous variables, which are determined inside the model. A SEM model consists of relations between the variables of interest. These relationships include paths coefficients between variables, error terms of variables and error covariance terms between variables. Together these relationships comprise a system of equations for each variable.

It is not necessary to write down this system of equations as most of the software programs can create the system of equations from path diagrams. Path diagrams visually represent the variables and the relations between these variables. The researcher can draw arrows between variables depicting the paths that need to be estimated. The most commonly used programs for structural equation modeling is LISREL, although other programs, such as AMOS and EQS are available as well (Byrne, 2001). The goal of these SEM software packages is to optimize the path coefficients, error covariance terms and error terms to create an estimated covariance matrix which resembles the observed covariance matrix as closely as possible (Hair et al., 2005). This observed covariance matrix is calculated from the raw data. Instead of the covariance matrix it is also possible to use SEM on a correlation matrix. Correlation matrices however have different distributional properties. Generally people use the covariance matrix, because this can also be used with variables that are not scale-free (Byrne, Shavelson, & Muthén, 1989).

Using maximum likelihood estimators a solution to the system of equations can be calculated. Solutions to the model can only be estimated if the amount of free parameters ($q$) is less than the pieces of information available in the covariance matrix ($p^*$). The difference between these variables is the degrees of freedom ($df$). The free parameters are the parameters that need to be estimated which includes path coefficients between variables, the error coefficients as well as the covariance between the error terms. The pieces of information available in the covariance matrix can be calculated by counting the amount of entries below the diagonal plus the amount of entries on the diagonal itself. This can be calculated using the following formulas with $p$ being the amount of observed variables.

$$ p^* = \frac{p(p+1)}{2} \quad (2) $$

$$ df = p^* - q \quad (3) $$

SEM will not identify models with negative degrees of freedom. At the bare minimum the amount of parameters to be estimated needs to be equal to the amount of information available from the covariance matrix. In practice positive nonzero degrees of freedom is required to acquire reliable estimates with standard errors. The amount of information from the covariance matrix increases quadratic with the amount of variables ($p$) as can be seen from formula 2, adding more variables rapidly increases the amount of available information. Utilizing a too small number of variables provides not enough information to acquire a model fit.
In principle LISREL can estimate as many paths as there are pieces of information in the covariance matrix. When the amount of parameters to be estimated becomes larger than the sample size however parameter estimates will become unreliable. Although LISREL can calculate models with ratios of free parameters to sample size of one, in practice more observations are required. Common rules of thumb for SEM are five or ten observations per free parameter (Hair et al., 2005). Other ratios of sample size to free parameters of 20:1 and 25:1 have also been proposed (Nachtigall, Kroehne, Funke, & Steyer, 2003; Tanaka, 1987; Westland, 2010). Although methods exist to test many relationships using a smaller sample size, this limits the research in amount of variables that can be tested (Pelham & Wilson, 1995).

Many scientific papers however do not meet these proposed sample size requirement. A study showed that 80% of the published SEM research papers used insufficient sample sizes (Westland, 2010). These papers have been published in peer-reviewed journals such as MIS Quarterly, Journal of Management Information Systems, Decision Sciences, Management Science and Information Systems Research. Smaller sample sizes are hence somewhat acceptable. For strong correlations and simple models smaller sample sizes of about 50 may suffice (Iacobucci, 2010). Moreover the amount of standards organizations is not very large which practically creates an upper limit for the sample size. Nevertheless a larger sample size is always preferred in SEM as this increases the reliability of the estimates. Because of sample size and fitting requirements balancing of the amount of parameters to be estimated is necessary. Models with too few parameters may not be identified whereas models with too many variables violate sample size assumptions and provide unreliable results. As the sample size requirements depend on the amount of free parameters assessment of sample size requirements of the used models will be implemented in the results section.

A third requirement on SEM models implies that the model should fit the data sufficiently well. Many goodness-of-fit and badness-of-fit indices have been devised to indicate the fit of the model. Researchers need not to report every single one of them as most fit indices can be calculated from other fit indices. Usually presenting the chi-square, the associated degrees of freedom, the CFI and the RMSEA is sufficient to assess model fit (Hair et al., 2005). The calculation and the meaning of these goodness-of-fit indices can be found in appendix A.

Structural equation modeling takes each row of data to be an independent measurement. Data in long format as used in GEE cannot be used because repeated measurements of the same standards organizations are not independent. Additionally this would introduce a survivor bias as standards organizations that existed for a long time have much more entries of data. To account for the repeated measurements over standards organizations the data have been formatted into wide format. Hence all data for a single standards organization have been entered in a single row, with variables per year.

A Microsoft Visual Basic program has been used to sort the data in Excel, this syntax can be found in appendix C. As aforementioned SEM has some requirements on sample size and amount of parameters to be estimated. Hypotheses 1 and 2 are merely direct effects from independent variables to the dependent variable. No reinforcing effects between these and the other variables have been proposed and hence these variables have been excluded from the SEM analysis. By excluding these variables from the SEM analysis fewer parameters need to be estimated. This has a positive effect on the required sample size and model fit. Therefore only the reinforcing effects between diversity and flexibility as hypothesized in hypothesis 5 will be estimated using SEM. Both flexibility and diversity have been argued to affect the network size directly hence these variables have been added as controls.
Practically data from a subsequent period of years such as 2006-2010 can be used to test these hypotheses. SEM however requires complete data to use the maximum likelihood (ML). Missing data requires using full information maximum likelihood (FIML) method, which cannot be used to calculate many goodness-of-fit indices (SSI Scientific Software, 2006). This method may run into issues when the percentage of missing data is high.

For many of these organizations complete data will not be available if a fixed period such as 2006-2010 is used. Standards organizations that did not exist for the full period would have to be excluded using listwise deletion. Apart from introducing a bias as only long surviving standards organizations have complete data this reduced the available sample size to levels that inhibit good model fit. Therefore the data have been sorted in wide format sequentially. In this format the first columns in the dataset contain data for the first available year of the standards organization; the subsequent columns contain data for later years. Variables are no longer determined per year (e.g. Diversity 2006) but are determined in terms of available years (e.g. Diversity year 1).

SEM models generally consists of two parts, first part is a measurement model which is used to calculate latent variables from multiple indicators. The second part is the structural model describing relationships between the variables. As this study only uses a single indicator per variable no measurement model is required and only a structural model has been tested. Structural equation modeling without a measurement model is also known as path analysis.

Structural equation modeling can be used to test hypotheses in multiple ways. SEM software such as LISREL fits a model and calculates the values of the path coefficients providing the sign of the relationships between these variables. The standard errors of these coefficients are calculated as well. Hence the significance of the individual path coefficients has been tested using a one-tailed t-test. The program LISREL provides the corresponding t-values automatically for every path coefficient and error covariance.

In this case however multiple path coefficients are estimated to determine the effect of the reinforcing effects. Although the significance of every single one of these path coefficients can be determined using the t-test, it is also necessary to test for the significance of all these paths altogether. To test the significance of all paths at once competing nested models need to be compared. A model is nested within another model if it contains the same variables but has fewer relationships (Hair et al., 2005). A competing nested model can be created by removing one or more paths from the model from the complete model.

In this case nested models can be created without reinforcing effects of diversity and flexibility by removing all direct paths between these variables. The resulting model is nested within the full model with reinforcing effects. For both of these models goodness-of-fit indices have been calculated, which can be compared to determine whether the difference between these models was significant. Several fit indicators can be used to test the significance of paths such as the CFI (Comparative Fit Index), NFI (Normed Fit Index) or the TLI (Tucker Lewis Index) or the chi-square statistic (Schumacker & Lomax, 2012).
This study compares the chi-square statistic of the competing models. This statistic can be calculated in LISREL along with corresponding degrees of freedom. The model with fewer paths will always have a larger chi-square statistic and more degrees of freedom. As the difference of two chi-square distributed variables is itself chi-square distributed the significance of the difference between the models can be tested using a chi-square test. The corresponding degrees of freedom to use in this chi-square test are equal to the difference in degrees of freedom of the competing nested models (Hair et al., 2005; Schumacker & Lomax, 2012). The following formulas are used to calculate the necessary test statistics.

\[ \Delta \chi^2 = \chi^2_{\text{reduced}} - \chi^2_{\text{full}} \]  
\[ \Delta df = df_{\text{reduced}} - df_{\text{full}} \]

If the chi-square difference is significant the removal of paths reduced the model fit substantially and hence these paths should not be removed. If the chi-square difference test is insignificant removal of the paths does not change the overall fit substantially. Therefore one might as well fix these paths to zero. As these relations do not contribute significantly to the overall model fit these relations are insignificant (Hair et al., 2005; Schumacker & Lomax, 2012).
Chapter 4: Results

Generalized Estimating Equations

Generalized Estimating Equations enable the user to specify which distribution the response variable should approximately follow. SPSS (version 20.0.0, 64-bits) has been used to test the normality of distribution of the logarithms of the network size. Two standards organizations have been excluded from the analysis as the logarithms of their network size were more than three standard deviations apart from the mean.

With 644 degrees of freedom and a W-statistic of 0.984 the Shapiro-Wilk test does not detect normality of the distribution. Although it is important to specify the correct distribution it is not necessary for the response variable to follow distribution precisely (Liang & Zeger, 1986). As can be seen in figure 2, the data does seem to follow a skewed normal distribution. It should be remarked that this graph contains multiple entries for every standards organizations. For five standards organizations with 800-900 members data is available for almost every year, which results in a peak close to 7. Although the response variable does not follow the normal distribution exactly GEE can be used provided that the residuals of the model will be tested afterwards. The residuals of the fitted model should be approximately normal and should not contain severe outliers GEE to acquire consistent results (Ballinger, 2004).

Figure 2: Histogram of Logarithm of Network Size. The resulting W-statistic is 0.984 with 644 degrees of freedom therefore the Shapiro-Wilk test does not indicate normality. The black line is the associated normal curve.
Table 1: Descriptive Statistics and Correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Log Size</td>
<td>4.51</td>
<td>1.19</td>
<td>1.61</td>
<td>7.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Flexibility</td>
<td>0.81</td>
<td>2.10</td>
<td>0.00</td>
<td>22.00</td>
<td>0.053</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Diversity</td>
<td>6.79</td>
<td>3.37</td>
<td>1.00</td>
<td>20.00</td>
<td>0.287**</td>
<td>-0.026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Structural Holes</td>
<td>0.026</td>
<td>0.021</td>
<td>0.000</td>
<td>0.117</td>
<td>0.201**</td>
<td>-0.028</td>
<td>0.686**</td>
<td></td>
</tr>
<tr>
<td>5. Influential Position</td>
<td>0.089</td>
<td>0.070</td>
<td>0.000</td>
<td>0.312</td>
<td>0.404**</td>
<td>0.047</td>
<td>0.578**</td>
<td>0.329**</td>
</tr>
</tbody>
</table>

\( n = 644. \)

\( ** p < 0.01 \) (two-tailed)

Table 1 shows correlations between the independent and dependent variables. The variable diversity significantly correlates with structural holes and influential position. Influential holes and structural holes also correlate significantly. These correlations could indicate multicollinearity. Therefore an ordinary regression in SPSS has been used to determine the degree of multicollinearity using variance inflation factors. The resulting variance inflation factors (VIF) are all well below 10 indicating no serious level of multicollinearity for ordinary regression (Hair et al., 2005). Therefore it has been assumed that the results from the generalized estimating equations are not affected substantially by multicollinearity.

Table 2: Variance Inflation Factors

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Diversity</th>
<th>Structural Holes</th>
<th>Influential Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIF</td>
<td>1.007</td>
<td>2.570</td>
<td>1.914</td>
</tr>
</tbody>
</table>

Generalized estimating equations have been performed using the GENLIN algorithm in SPSS to test hypotheses 1 to 4. For this purpose variables have been added stepwise in models 1 to 5. In total data on 103 standards organizations has been used resulting in a total of 644 valid data points. This sample size should be sufficient to use generalized estimating equations as explained in the methodology chapter.

Since the predictor variables are time-varying an independent working correlation matrix has been used as other correlation structures could result in biased estimates (Pepe & Anderson, 1994). Incidentally, this correlation structure also provided the best model fit. The variables D2000 to D2010 are time dummy variables which enable fitting an intercept varying with year. As the model has been fitted with a time dummy variable for every year a constant intercept term is redundant.

The resulting regression coefficients with the standard errors are reported in table 3. In the lower part of this table two goodness-of-fit indicators have been added. Generalized estimating equations uses the Quasi Likelihood under Independence Model Criterion (QIC) and the Corrected Quasi Likelihood under Independence Model Criterion (QICC) as goodness-of-fit indices. These fit indices are both extensions of Akaike Information Criterion. Smaller QIC and QICC indicate better model fit. Although QIC and QICC can aid with selecting the appropriate correlation structure and determining the best predictors in the model the theory should be used as well to justify the correlation structure and predictors (Ballinger, 2004).
Table 3: Generalized Estimating Equations Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2000</td>
<td>4.55*** (0.16)</td>
<td>4.50*** (0.16)</td>
<td>3.73*** (0.27)</td>
<td>3.74*** (0.27)</td>
<td>3.65*** (0.24)</td>
<td>3.66*** (0.20)</td>
</tr>
<tr>
<td>D2001</td>
<td>4.45*** (0.16)</td>
<td>4.41*** (0.27)</td>
<td>3.65*** (0.27)</td>
<td>3.66*** (0.24)</td>
<td>3.61*** (0.17)</td>
<td></td>
</tr>
<tr>
<td>D2002</td>
<td>4.40*** (0.15)</td>
<td>4.35*** (0.15)</td>
<td>3.62*** (0.24)</td>
<td>3.63*** (0.24)</td>
<td>3.65*** (0.18)</td>
<td></td>
</tr>
<tr>
<td>D2003</td>
<td>4.45*** (0.15)</td>
<td>4.41*** (0.25)</td>
<td>3.72*** (0.25)</td>
<td>3.74*** (0.23)</td>
<td>3.75*** (0.19)</td>
<td></td>
</tr>
<tr>
<td>D2004</td>
<td>4.51*** (0.16)</td>
<td>4.47*** (0.25)</td>
<td>3.78*** (0.25)</td>
<td>3.79*** (0.25)</td>
<td>3.80*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2005</td>
<td>4.51*** (0.16)</td>
<td>4.47*** (0.25)</td>
<td>3.77*** (0.25)</td>
<td>3.78*** (0.25)</td>
<td>3.80*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2006</td>
<td>4.51*** (0.15)</td>
<td>4.46*** (0.25)</td>
<td>3.75*** (0.25)</td>
<td>3.77*** (0.25)</td>
<td>3.78*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2007</td>
<td>4.63*** (0.15)</td>
<td>4.61*** (0.25)</td>
<td>3.89*** (0.25)</td>
<td>3.90*** (0.25)</td>
<td>3.90*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2008</td>
<td>4.48*** (0.16)</td>
<td>4.47*** (0.25)</td>
<td>3.81*** (0.25)</td>
<td>3.77*** (0.25)</td>
<td>3.78*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2009</td>
<td>4.52*** (0.16)</td>
<td>4.49*** (0.24)</td>
<td>3.80*** (0.24)</td>
<td>3.80*** (0.24)</td>
<td>3.81*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>D2010</td>
<td>4.57*** (0.16)</td>
<td>4.53*** (0.24)</td>
<td>3.86*** (0.24)</td>
<td>3.84*** (0.24)</td>
<td>3.85*** (0.20)</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.046* (0.019)</td>
<td>0.051* (0.019)</td>
<td>0.051* (0.019)</td>
<td>0.039 (0.021)</td>
<td>0.039 (0.021)</td>
<td></td>
</tr>
<tr>
<td>Diversity</td>
<td>0.103*** (0.027)</td>
<td>0.102* (0.041)</td>
<td>0.005 (0.046)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Holes</td>
<td>0.294 (6.8584)</td>
<td>4.290 (6.320)</td>
<td>4.731 (4.909)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influential Position</td>
<td>6.447*** (1.677)</td>
<td>6.541*** (1.442)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QIC</td>
<td>931.0</td>
<td>926.5</td>
<td>857.7</td>
<td>868.0</td>
<td>795.5</td>
<td>786.1</td>
</tr>
<tr>
<td>Difference in QIC</td>
<td>-4.5</td>
<td>-73.3</td>
<td>-63.0</td>
<td>-135.5</td>
<td>-144.9</td>
<td></td>
</tr>
<tr>
<td>QICC</td>
<td>931.1</td>
<td>927.2</td>
<td>851.9</td>
<td>853.9</td>
<td>773.1</td>
<td>771.2</td>
</tr>
<tr>
<td>Difference in QICC</td>
<td>-3.9</td>
<td>-79.2</td>
<td>-77.2</td>
<td>-158.0</td>
<td>-159.9</td>
<td></td>
</tr>
</tbody>
</table>

103 standards organizations, 644 valid observations

*p < 0.05

**p < 0.01

***p < 0.001

Two-tailed test for controls, one-tailed tests for hypothesized variables

As can be observed from table 3, addition of the structural holes variable results in worse goodness-of-fit indices compared to the model with diversity and flexibility. A possible cause for this is multicollinearity. Table 1 shows that the variables diversity, structural holes and influential position are in fact significantly correlated. A common solution for multicollinearity is the use of stepwise estimation (Hair et al., 2005). The effects of removing the correlated variables on the goodness-of-fit of the model have been inspected as to reach the best model.
Table 4: Stepwise Estimation

<table>
<thead>
<tr>
<th>Full Model</th>
<th>Removed Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>QIC</td>
<td>Diversity</td>
</tr>
<tr>
<td>795.5</td>
<td>786.1</td>
</tr>
<tr>
<td>QICC</td>
<td>773.7</td>
</tr>
</tbody>
</table>

From these results it becomes clear that influential position variable should not be removed as models without this variable have a worse fit. A better fit however can be achieved when diversity or flexibility are removed from the model. Removal of diversity results in the best fitting model, further removal of the remaining variables did not increase the overall fit of the model. Furthermore removal of the variable flexibility resulted in a worse fit as well. Model 6 therefore includes all variables except diversity.

The residuals of model 6 were tested for normality resulting in a W-statistic of 0.993 with 644 degrees of freedom with significance level of 0.003. Hence this test does not indicate normality. Plots and descriptive statistics can be found in the appendix D. Visual inspection of the histograms and Q-Q plots indicated that the residuals did not contain severe outliers and resembled a normal distribution as necessary for GEE (Ballinger, 2004).

None of the models resulted in a significance relation for structural holes hence no support for hypothesis 2 has been found. Models 2, 3 and 4 resulted in positive regression weights for flexibility and models 3 and 4 resulted in positive regression weights for diversity, supporting hypothesis 3 and 4. Addition of the influential position variable changed the regression weight of diversity substantially making it insignificant. The changes to flexibility were smaller, but addition of influential position made flexibility insignificant as well. The regression weight for influential position was positive and significant in all included models providing support for hypothesis 1.

Figure 3: Results Conceptual Model. This model corresponds to model 6. The influential position is significant at the 0.001 level. Model QIC 786.1, model QICC 771.2.
To test hypothesis 5 the correlations between diversity and lagged flexibility and between flexibility and lagged diversity have been tested. Diversity and flexibility both have been proposed to influence standard dominance. This could result in correlations between flexibility and diversity due to correlations of these variables with standard dominance, operationalized using the logarithm of network size. The partial correlations have hence been calculated while controlling for the logarithm of lagged network size. As displayed in Table 5 diversity and flexibility are significantly correlated with their counterparts in the next year. Note that the sample size is smaller because data has to be available for two subsequent years to calculate the necessary correlations.

Table 5: Correlations between network size, diversity and flexibility

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Log Size</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Flexibility</td>
<td>0.048**</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Diversity</td>
<td>0.294**</td>
<td>-0.030</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Flexibility Lagged</td>
<td>0.047</td>
<td>0.662**</td>
<td>-0.046</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>5. Diversity Lagged</td>
<td>0.286**</td>
<td>0.001</td>
<td>0.905**</td>
<td>-0.032</td>
<td>1.000</td>
</tr>
</tbody>
</table>

** p < 0.01 (two-tailed)

Sample Size = 544

Table 6: Partial Correlations Flexibility and Lagged Diversity Controlled for Size

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flexibility</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>2. Diversity Lagged</td>
<td>-0.013</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Significance Level $p_{12}$: 0.754

Table 7: Partial Correlations Diversity and Lagged Flexibility Controlled for Size

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diversity</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>2. Flexibility Lagged</td>
<td>-0.063</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Significance Level $p_{12}$: 0.144

Both correlations fail significance tests, the correlation between flexibility and diversity lagged has a two-tailed significance level of 0.754 with 541 degrees of freedom. The correlation between diversity and flexibility lagged has a two-tailed significance level of 0.144 with 541 degrees of freedom. These results therefore do not provide support for reinforcing effects of hypothesis 5.
Structural Equation Modeling

The previous analysis to test the proposed reinforcing effects did not indicate significant correlations between diversity and lagged flexibility. However, every pair of observation has been regarded as an independent observation in the correlation study. This could result in a bias, because more observations are available for long surviving standards organizations. SEM is a more sophisticated method to test these reinforcing effects and can be used to account for repeated measurements. This analysis has been performed using LISREL 9.10 (Jöreskog & Sörbom, 2012).

The focus of the SEM analysis was to research the proposed reinforcing effects. Analyzing more years would hence be preferred, as reinforcing effects take place between diversity and flexibility of subsequent years. By analyzing more years more paths between these variables can be constructed. Adding more paths however increases the amounts of variables to be estimated, which can result in convergence problems or model fit problems. Additionally analyzing more years reduces the available sample size as SEM requires complete cases. A complete case for the SEM analysis consists of flexibility and diversity in a year along with the size in the next year. The amount of complete cases can be found in table 8. As aforementioned the influential position and the structural holes variable as used in hypothesis 1 and 2 have not been tested using SEM.

Table 8: Amount of complete cases for SEM

<table>
<thead>
<tr>
<th>Amount of years</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete cases</td>
<td>103</td>
<td>93</td>
<td>82</td>
<td>65</td>
<td>55</td>
<td>48</td>
<td>41</td>
<td>36</td>
<td>32</td>
<td>26</td>
<td>25</td>
</tr>
</tbody>
</table>

Several models have been tested using different amount of years and different relationships. Models with more variables contain more error terms, error covariances and relationships between variables and hence require estimation of more parameters. Estimating models with five or more years requires estimating more parameters than the available sample size making the parameter estimates unreliable. Consequently a maximum of four years can be tested. Models with reinforcing effects require at least two years to be estimated. Therefore models with two, three or four years can be tested.

Several of these models have been tested, but this thesis includes only the results for the four year models, as these models incorporate three years of reinforcing effects. The disadvantage of this approach is that a large part of the data has not been used. Standards organizations with too few years of data were excluded from the analysis. From standards organizations with more than four years of data only the first four years have been used. The resulting 65 complete cases do not meet the 5:1 ratio of sample size to free parameters. Iacobucci however showed that a minimum of 50 cases could also be enough to use SEM especially since the total amount of standards organizations is limited (Iacobucci, 2010). Further considerations with respect to the sample size can be found in the methodology chapter.

The SEM analysis focuses on the reinforcing effects between diversity and flexibility. Both of these variables have been shown to affect the network size as well. Therefore the network size, used to operationalize standard dominance, has been incorporated into the model as a control. Diversity and flexibility affect the logarithm of the network size in the next year. Therefore one-directional paths have been specified between diversity respectively flexibility and size in the next year corresponding to hypothesis 3 and 4. Corresponding to hypothesis 5 one-directional paths between flexibility and diversity in the subsequent year have been specified.
The structural model of this study is a one-year auto-regressive model as variables in a certain year are likely influenced by the same variable in the previous year. Therefore paths were specified from variables to the same variable in the next year to account for this dependency (Biesanz, 2012; Rosel & Plewis, 2008). The first occurrences of data, namely flexibility and diversity in year 0, were taken as exogenous variables.

Size in year 1 would in principle be determined by the flexibility, diversity and size in year 0. However, as reinforcing effects do not play a role in determination of the size in year 1, these paths have been left out and size in year 1 is used as an exogenous factor. Moreover, this enabled omission of the size in year 0 from the model reducing the amount of free parameters.

As diversity, flexibility and size have been measured using the same procedure in every year, their errors are not independent. To account for this the errors of diversity, flexibility and size can covary with these variables in all other years (Schumacker & Lomax, 2012; Wheaton, Muthén, Alwin, & Summers, 1977). Error covariances cannot be specified between the diversity and flexibility in year 0 and size in year 1, as these variables are exogenous. Exogenous variables covary with the other exogenous variables as stipulated by SEM.

The resulting model could be expanded by adding additional paths if this can be theoretically justified. Adding an additional error covariance between diversity and flexibility in the same year can be justified theoretically because measurements in the same year can be correlated. Table 1 however showed that diversity and flexibility are generally uncorrelated; therefore their errors were likely uncorrelated as well. Hence the covariance between the errors has been left out. Not adding this covariance resulted in more degrees of freedom and models with better goodness-of-fit indicators. Models have been tested incorporating this covariance but these results were very similar to the results without this correlation. The resulting error covariances between diversity and flexibility were close to zero and insignificant in all cases. The results of models with this covariance can be found in the appendix F.

A drawing of the path diagram from the resulting model can be found in figure 4. This is the full model which contains reinforcing effects from flexibility and diversity and vice-versa. Testing this model requires estimation of 21 path coefficients, 12 error covariances and 12 error terms. Competing nested models can be created by removing these reinforcing paths. The SIMPLIS syntax corresponding to this path model can be found in appendix E. By removing parts of code from this syntax the nested models have been created. The path models of these competing nested models can be found in the appendix as well.

From the raw data the observed covariance matrix has been calculated as can be found in table 9. LISREL estimates the coefficients of the path model to fit the observed covariance matrix as closely as possible.
Figure 4: SEM Path Model. Drawing of the SEM path model as used to test hypotheses 3, 4 and 5. Arrows indicate the directions of the proposed paths between the variables. The variables have been measured in different years. The indicated variable size is the logarithm of size.

Table 9: Observed Covariance Matrix

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Size (t=1)</td>
<td>4.33</td>
<td>1.232</td>
<td>1.493</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Size (t=2)</td>
<td>4.45</td>
<td>1.128</td>
<td>1.275</td>
<td>1.255</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Size (t=3)</td>
<td>4.52</td>
<td>1.078</td>
<td>1.027</td>
<td>1.094</td>
<td>1.127</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Size (t=4)</td>
<td>4.60</td>
<td>1.131</td>
<td>0.962</td>
<td>1.066</td>
<td>1.140</td>
<td>1.250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Diversity (t=0)</td>
<td>6.57</td>
<td>3.527</td>
<td>0.811</td>
<td>0.638</td>
<td>0.599</td>
<td>0.638</td>
<td>12.437</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Diversity (t=1)</td>
<td>7.00</td>
<td>3.382</td>
<td>0.674</td>
<td>0.503</td>
<td>0.557</td>
<td>0.585</td>
<td>10.705</td>
<td>11.436</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Diversity (t=2)</td>
<td>6.92</td>
<td>3.174</td>
<td>0.581</td>
<td>0.437</td>
<td>0.539</td>
<td>0.564</td>
<td>9.410</td>
<td>9.786</td>
<td>10.065</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Diversity (t=3)</td>
<td>6.74</td>
<td>3.048</td>
<td>0.519</td>
<td>0.390</td>
<td>0.472</td>
<td>0.476</td>
<td>8.426</td>
<td>8.728</td>
<td>8.723</td>
<td>9.292</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Flexibility (t=0)</td>
<td>0.85</td>
<td>2.917</td>
<td>0.702</td>
<td>0.594</td>
<td>0.268</td>
<td>0.282</td>
<td>-0.302</td>
<td>-0.536</td>
<td>-0.604</td>
<td>-0.557</td>
<td>8.507</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Flexibility (t=1)</td>
<td>0.98</td>
<td>2.631</td>
<td>0.486</td>
<td>0.367</td>
<td>0.189</td>
<td>0.167</td>
<td>0.179</td>
<td>0.058</td>
<td>-0.113</td>
<td>-0.116</td>
<td>5.585</td>
<td>6.932</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Flexibility (t=2)</td>
<td>1.06</td>
<td>3.311</td>
<td>0.737</td>
<td>0.592</td>
<td>0.310</td>
<td>0.296</td>
<td>0.468</td>
<td>0.302</td>
<td>0.164</td>
<td>0.125</td>
<td>8.311</td>
<td>7.596</td>
<td>10.973</td>
<td></td>
</tr>
<tr>
<td>12. Flexibility (t=3)</td>
<td>1.00</td>
<td>2.172</td>
<td>0.363</td>
<td>0.272</td>
<td>0.169</td>
<td>0.133</td>
<td>0.804</td>
<td>0.754</td>
<td>0.679</td>
<td>0.692</td>
<td>3.639</td>
<td>4.702</td>
<td>5.827</td>
<td>4.758</td>
</tr>
</tbody>
</table>
The SEM model from figure 4 has been estimated in LISREL. The fit indices can be found in the column labeled full model in table 11. Common thresholds for the fit indices for models with these amounts of parameters are as follows: the RMSEA should be below 0.08, the CFI should be above 0.97 and the chi-square value should result in an insignificant p-value (Hair et al., 2005). These conditions were met by the full model. Table 10 shows a selection of the completely standardized estimates of the model along with the associated t-values (Diamantopoulos & Siguaw, 2000). A complete list of estimates can be found in appendix F. With 33 degrees of freedom the critical one-tailed t-value for an α-value of 0.05 is 1.692. None of the specified reinforcing paths were significant, hence these results do not support hypothesis 5.

### Table 10: Standardized Estimates of Reinforcing Effects

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variable</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility (t=1)</td>
<td>Diversity (t=0)</td>
<td>0.021</td>
<td>0.053</td>
<td>0.391</td>
</tr>
<tr>
<td>Flexibility (t=2)</td>
<td>Diversity (t=1)</td>
<td>0.033</td>
<td>0.061</td>
<td>0.546</td>
</tr>
<tr>
<td>Flexibility (t=3)</td>
<td>Diversity (t=2)</td>
<td>0.056</td>
<td>0.047</td>
<td>1.184</td>
</tr>
<tr>
<td>Diversity (t=1)</td>
<td>Flexibility (t=0)</td>
<td>-0.033</td>
<td>0.064</td>
<td>-0.512</td>
</tr>
<tr>
<td>Diversity (t=2)</td>
<td>Flexibility (t=1)</td>
<td>-0.021</td>
<td>0.062</td>
<td>-0.335</td>
</tr>
<tr>
<td>Diversity (t=3)</td>
<td>Flexibility (t=2)</td>
<td>-0.001</td>
<td>0.050</td>
<td>-0.028</td>
</tr>
</tbody>
</table>

**Critical t-value 1.692 (df =33, α=0.05)**

To test the significance of multiple paths altogether nested models were created by removing paths from the full model. Therefore three nested models have been created. The first model was created by removing paths from flexibility to diversity. Analogously a second nested model has been created by removing the paths from diversity to flexibility. Finally a nested model without any reinforcing effects has been tested. Path diagrams for these models can be found in appendix E. All of these competing models resulted in acceptable fit indices. A chi-square difference test has been used to test the significance of the reinforcing paths. These tests resulted in insignificant p-values, therefore the values of the paths between flexibility and diversity might well all be zero. Hence the results do not support hypothesis 5 as can be observed from table 11.

### Table 11: Comparison of Models without Reinforcing Effects

<table>
<thead>
<tr>
<th></th>
<th>Full Model</th>
<th>Model without Flexibility → Diversity</th>
<th>Model without Diversity → Flexibility</th>
<th>Model without reinforcing effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>χ²</td>
<td>36.404</td>
<td>36.834</td>
<td>38.921</td>
<td>39.351</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>33</td>
<td>36</td>
<td>36</td>
<td>39</td>
</tr>
<tr>
<td>p-value</td>
<td>0.3132</td>
<td>0.4301</td>
<td>0.3396</td>
<td>0.4542</td>
</tr>
<tr>
<td>CFI</td>
<td>0.996</td>
<td>0.999</td>
<td>0.996</td>
<td>1.00</td>
</tr>
<tr>
<td>RMSEA</td>
<td>0.0398</td>
<td>0.0189</td>
<td>0.0353</td>
<td>0.0118</td>
</tr>
<tr>
<td>Δχ²</td>
<td>0.430</td>
<td>2.517</td>
<td>2.947</td>
<td></td>
</tr>
<tr>
<td>Δdf</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.934</td>
<td>0.472</td>
<td>0.815</td>
<td></td>
</tr>
</tbody>
</table>

*Independence model: \( \chi^2=909.808 \) with 66 degrees of freedom*
Summary of Results

The results from the generalized estimating equations procedure provided positive and significant regression weights for diversity and flexibility in models 1 to 4. Therefore these results provide support for hypotheses 3 and 4. Addition of the influential position however made the regression weights of diversity and flexibility insignificant as can be observed in models 5 and 6 in table 3.

This change of the regression weights could be a manifestation of multicollinearity (Hair et al., 2005). From the regression weights in table 3 it can be observed that the change in regression parameter was more severe for diversity compared to flexibility. For both of these variables the standard errors remained roughly the same. Although the variance inflation factors from ordinary regression were low as can be seen in table 2, the correlation between diversity and influential position was quite high, namely 0.578. The high correlation coefficient could indicate multicollinearity between these variables and thus explain the change in regression parameters upon addition of influential position.

As the correlation between flexibility and influential position is insignificant the effects of multicollinearity would likely be smaller. The changes to the regression weight of flexibility are less severe than the changes to diversity. Before addition of the influential position the effects of flexibility are significant at the 0.05 level. The change in significance is caused by a slightly increasing error combined with a slightly decreasing regression coefficient. As the effects are not strongly significant at first, even a slight change in model may be enough to cause insignificance of flexibility. Even a low degree of multicollinearity could be enough to change the significance of flexibility.

Support has been found for hypothesis 1, namely that influential position positively affects standard dominance. In the GEE models where this variable was included the regression weights were positive and significant as can be observed from table 3. These effects were significant even at high confidence intervals of 99.9%. Not only were the regression weights significant, addition of the influential position also substantially increased the goodness-of-fit statistics as can be observed in table 3 and 4.

Generalized estimating equations have not found support for hypothesis 2 that bridging structural holes positively affects standard dominance. The standard error of the regression weight was very large compared to the regression weight itself as can be seen in table 3. Notice that the value of the regression weight changes substantially, from 0.294 to 4.920 after addition of the influential position variable. Removal of diversity from model 6 substantially reduced the standard error of the regression weight. This could indicate multicollinearity between these variables as well (Hair et al., 2005).

No support has been found for reinforcing effects of hypothesis 5 using partial correlations. The correlations between lagged versions of flexibility and diversity were not significant as can be observed from table 5. Controlling for the network size did not result in significant partial correlations either as can be observe from table 6 and 7.

Structural equation modeling has also been used to test the reinforcing effects of hypothesis 5. This method did not find support for hypothesis 5 either. None of the path coefficients between diversity and flexibility were significant and removal of these paths did not change the overall fit of the model substantially as can be seen in table 11 and 10 respectively.
Chapter 5: Discussion

Discussion of Results

Generalized estimating equations have been used to determine the influence of several network characteristics and standard flexibility on standard dominance. As addition of influential position changes the significances of the variables a summary of the results of two models can be found in the table below. These models correspond to model 4 and 6 respectively in table 3.

Table 12: Summary of Results from Generalized Estimating Equations

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Generalized Estimating Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model without influential position</td>
</tr>
<tr>
<td>1 Influenital Position</td>
<td>Standard Dominance</td>
</tr>
<tr>
<td>2 Structural Holes</td>
<td>Standard Dominance</td>
</tr>
<tr>
<td>3 Diversity</td>
<td>Standard Dominance</td>
</tr>
<tr>
<td>4 Flexibility</td>
<td>Standard Dominance</td>
</tr>
</tbody>
</table>

The proposed reinforcing effects have been tested using partial correlations as well as structural equation modeling. Neither of these methods provides support for reinforcing effects.

Table 13: Summary of Results of Reinforcing Effects

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Statistical Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Partial Correlations</td>
</tr>
<tr>
<td>5 Diversity</td>
<td>Flexibility</td>
</tr>
<tr>
<td>5 Flexibility</td>
<td>Diversity</td>
</tr>
</tbody>
</table>

This research project has used the ANS database which has been used in previous research projects. Although these previous studies analyzed the effect of flexibility and diversity on standard survival, it is interesting to compare these results with the results from this project. In previous research projects standard survival was used to operationalize standard dominance (van de Kaa, 2009). It should be noted that although the same database has been used a different time period has been used.

The results from previous studies using this database provided evidence for the positive effects of diversity and flexibility on standard survival (van de Kaa, 2009). A different model that did not include direct effects from diversity, but included direct effects from flexibility, provided evidence for the positive effects of flexibility on standard survival (van de Kaa, 2012). The results from the generalized estimating equations as can be found in table 3 are largely in agreement with these results. Model 1 included only the effects of flexibility and resulted in significant and positive regression parameter of flexibility on standard dominance. Model 2 included effects from both flexibility and diversity and provided positive and significant regression weights for both of these variables. The GEE models that did not include the influential position variable resulted in positive and significant weights for diversity and flexibility as well. The fact that studies using different operationalizations provided similar results could be seen as stronger evidence for the effects of flexibility and diversity.
Unlike the results from these studies however no significant correlations were found between flexibility and diversity and lagged versions of these variables. As such this study has not found evidence for the existence of reinforcing effects, whereas other studies have found evidence for these effects (van de Kaa, 2009, 2012). Moreover, structural equation modeling did not provide evidence for these reinforcing effects either. One of the reasons for this may lie in the fact that the studies by van de Kaa used a larger part of the database, namely from 1990 to 2009. This study however uses the data from 2000 to 2009 with addition of 2010 as a new year. Omission of the nineties may have removed valuable data whereas addition of 2010 may have introduced a researcher bias.

Flexibility has been measured by counting the amount of standard revisions in a certain year. This information was not always readily available on the archived websites and the information on the websites was not always clear, hence different people may have found different amount of revisions. Multiple people have worked on assembling different parts of this database hence this could have introduced a researcher bias, which might explain the difference between these results. To get a sense of the influence of researcher bias the data has been scanned for changes in the data with the years. The periods 2000-2006, 2007-2009 and 2010 have been researched by different people. Using independent-sample t-tests the differences between the means for these periods have been tested. These tests show that the means of most variables do not differ between these periods. Flexibility however seems to differ depending on which period has been used. Using regression analysis flexibility depends negatively and significantly on the year. This year-dependence might well be caused by researcher bias; hence the omission of years from the analysis and the inclusion of new data might have changed the significance of the relations of flexibility. It could also be possible that standards organizations made fewer revisions to their standards in the more recent years.

Diversity has been operationalized by counting the amount of primary SIC codes, similarly to the second study of van de Kaa which also controlled for network size (van de Kaa, 2012). The first study by van de Kaa however used a classification of industries to measure the diversity of the standards organization. Depending on the amount of industries present in the board this variable ranged between 1 and 4 (van de Kaa, 2009). As both operationalizations of diversity provided similar results, the operationalization of diversity from this study cannot explain the absence of correlations between diversity and flexibility.

These reinforcing effects have also been tested using structural equation modeling, but these results were insignificant as well. Although this is in agreement with the observed partial correlations, a few aspects need to be pointed out. Firstly, the used SEM model is autoregressive; hence the value of a variable in a certain year also depends on the value of that variable in the previous year. Although this is logical, it does introduce problems. As the values of diversity and flexibility in the previous year are very good predictors for their values in the next year, as can be seen in table 5, the autoregressive part of the model is already able to explain a large part of the covariances between the variables. Further aggravated by the small sample size this has left only a limited amount of covariance to explain by other variables and therefore the reinforcing effects provided limited explanatory power. In principle a non-autoregressive model could have been used. It is however hard to justify theoretically that the value of a variable in the next year does not depend on the value of the variable in the previous year. Moreover the non-autoregressive models that have been tested did not fit the data well and no conclusions can be drawn on the estimated parameters of these models with bad fit.
Aside from the variables from earlier studies two new variables have been researched as well. Using generalized estimating equations support has been found for the positive effects of the influential position in the network, operationalized using eigenvector centrality, on the standard dominance. This effect is even significant at very low \( \alpha \)-values. This implies that successful standards organizations are positioned in an influential position in the network of standards organizations. This position is likely attained through their board members who are in an influential position in this network as well. This is captured in the operationalization as the eigenvector centrality of an actor depends largely on the eigenvector centralities of the connections (Bonacich, 2007; Scott, 2000). These results are in line with earlier research, as research has shown that the supporters of a standard influence the success of that standard. The influential position variable could be seen as a case of ‘big fish’ firms. ‘Big fish’ firms are very influential industry leaders, hence their choice for a standard can influence the choice of others (Foray, 1994; Rosen et al., 1988; Suarez & Utterback, 1995). Standards organizations largely owe their influential position to the fact that their board members are in an influential position in the network. These board members might be ‘big fish’ firms, as these firms are very influential and therefore often in an influential position. Comparing the firms in this network indicated that the more renowned firms indeed scored high on eigenvector centrality, which was used to operationalize influential position. Examples of these firms include Apple, Dell, Intel, Microsoft, Philips, Samsung and Sony. Incidentally these firms were also board members of the dominant standards organizations.

The addition of the influential position changed the significance of diversity. Moreover stepwise elimination (table 4) showed that the best fit could be achieved through removal of diversity from the model. These effects showed that for this specific case influential position, an industry-network characteristic, is a better predictor for standard dominance than diversity, a board composition characteristic. From this it can be inferred that network characteristics are possibly more important than board characteristics. This implies that for the standards organization the standardization activities of the board members are more important than their industry. Possibly the significance of diversity in the other models could be because of correlations with the influential position variable.

No support has been found for the other researched industry-network variable, bridging structural holes. Two remarks about this have to be made. First, the access to structural holes has been operationalized using betweenness centrality. This is an accepted method for measuring access to structural holes but authors usually use the structural holes measures as devised by Ronald Burt (Burt, 1992). His four measures of structural holes require calculation of clustering coefficients. Clustering coefficients are calculated by counting the amount of paths of length two and cycles of length three. While these methods work correctly for one-mode networks, for two-mode networks it has been suggested to use paths of length three and cycles of length four (Opsahl, 2013). Currently UCInet does not contain options to calculate structural holes measures in two-mode networks. This is one of the reasons why betweenness centrality was used to measure access to structural holes. Betweenness measures the amount of shortest paths between all nodes that go through a certain node (Freeman, 1977). However betweenness does not distinguish between short direct paths and long indirect paths, all paths contribute the same to betweenness (Burt, Kilduff, & Tasselli, 2013).
Therefore standards organization on the edge of the network connected to more or less isolated firms possess high betweenness as all paths from these firms to other actors in the network irrespective of the length, go through that standards organization. This can be justified by arguing that these organizations are in fact the only standards organizations connected to those firms and therefore they do in fact bridge a structural hole. When looking at network graphs it became clear that many standards organizations with high betweenness centrality were indeed located at the periphery of the network. Other standards organizations with high betweenness centrality however were located in the center of the network. Although both types of these standards organizations bridge structural holes, the ones bridging the structural holes in the center of the graphs possess more valuable connections as firms and organizations in the center of the network are connected to more firms and organizations. Hence these connections provide more information than the isolated firms on the periphery of the network. The possibility remains that the effects of structural holes have been averaged out, because standards organizations in the center bridge more valuable structural holes compared to organizations in the periphery bridging invaluable structural holes.

Secondly it should be remarked that the literature on structural holes has reached no consensus on the effects of structural holes. One school of thought formed by Burt and others proposes that the presence of structural holes creates opportunities for value creation by bridging these structural holes (Burt, 1992, 2004). Another school of thought emphasizes the trust generation function of networks. A network without structural holes facilitates the generation of trust (Gulati, 1995). As all actors are connected to each other opportunistic behavior can be punished through collective action (Coleman, 1988). Following this line of thought one would assume that a network with structural holes would be less efficient in sharing of information. Hence standards organizations bridging structural holes may be faced with members that do not trust each other, which would negatively affect the cooperation in the standards organizations and the success of the standard. Evidence for the negative effects of structural holes has been found as well (Ahuja, 2000). As evidence for both schools of thought has been found it is possible that bridging structural holes might affect the standards organization both positively and negatively. Hence the average effect of bridging structural holes may indeed be zero.

Limitations
This study operationalizes standard dominance using the amount of firms adhering to the standard. Although this method has been used successfully in earlier research on standard dominance it is not the usual method to operationalize standard dominance and hence this constitutes a limitation of this project (von Burg & Kenney, 2000; Wade, 1995). Most of the research on standard dominance operationalizes standard dominance using the market share of the standard (Tegarden, Hatfield, & Echols, 1999). Operationalization using market share however was not feasible. Market shares can be calculated by dividing the amount of products with the standard by the total amount of products in the relevant product categories. Alternatively one could use the value of the sales instead of the number of products. In this specific case however both these methods were difficult to apply. Firstly many standards can be used in different applications and in different contexts. USB for example has originally been devised to connect external devices to the PC. Many smart phones nowadays use adapters to convert socket plugs to USB to charge mobile phones. This application of USB differs from the original application of connecting external devices to the computer. Similarly Bluetooth can be used to wirelessly connect devices to computers and smart phones, but can also be used to transfer data between devices. As standards can be used for different applications it is difficult to determine the relevant product category as is necessary to calculate the market share.
Secondly many products nowadays can be used to perform tasks that used to be performed by distinct devices, a phenomenon called technological or digital convergence (Yoffie, 1996). Smart TVs, smartphones and gaming consoles for example can be used to browse the internet, a task that used to be performed by computers. As different products can be used for similar tasks they become competitors in that market. This further blurs the borders of markets and product categories further complicating the calculation of market share.

Thirdly, measuring market share can be difficult as in many cases no complete list of manufacturers of the products is available. For some standards being member of the standards organization is not required to produce products using the standards. This is further aggravated by the fact that manufacturers are not required to use the standard in all products. A manufacturer might use the standard in its smartphones but not in its televisions. The manufacturer may even use the standard only in some versions of their products. To illustrate this, some of the high-end smartphones can use wireless charging whereas the low-end smartphones cannot. Similarly producers produce versions of tablets with and without 3G capabilities, the 3G versions usually being more expensive. Furthermore manufacturers can create products adhering to multiple competing standards, for example computers with both Firewire and USB ports.

Hence summing up all the sales of the manufacturers to determine the total sales is not representative for the standard sales. Therefore researchers wanting to determine the market share have to determine which versions of the products of every manufacturer adhere to the standard. The sales per product or the total amount of products sold needs to be determined to calculate market share. This information is often not publicly available and processing this amount of information may not be feasible. Due to these reasons standard dominance was operationalized using the network size as calculation of the relevant market shares was not feasible.

A second limitation lies in the network characteristics which were operationalized using centralities calculated from industry-wide networks of standards organizations and firms. To calculate these centralities bipartite networks were constructed using the information on board membership of the standards organizations. These relations are just one type of formal relations. Firms can also be a non-board member of a standards organization and participate in the standards organization. Apart from this, there may be other formal relations between firms or standards organizations that have not been used in this analysis. Relations between firms could include participation in joint ventures, strategic alliances or innovation networks. Standards organizations can also cooperate with each other, by making their standards compatible or merging their standards. Informal relations may also affect the standard setting in the network, but their informal nature makes these relations difficult to measure. Therefore some important connections might have been omitted from the created networks and the calculated centralities.

Moreover all ties of the industry-wide network have been modeled as being equally strong. Although all firms in the board can participate in the decision making of the standards organization, some firms might be more influential in this process. Large firms or firms with specific capabilities and assets would be able to exert more influence on the development of the standard. Firms may participate in the board of multiple standards organizations, but their activity in these boards could differ. For example, firms might be more actively involved a standards organization with a standard that is highly relate to the core business of the firm. This would require modeling these ties as ties of different strength. This information however is often not available. Even if this information were available it would be difficult to use, as many network measures do not exist for valued networks (Scott, 2000).
Centralities tend to be correlated resulting in multicollinearity issues with the analysis. As centralities are calculated from the same relational data using similar mathematical procedures these measures are often correlated (Borgatti et al., 1998; Valente et al., 2008). The used centralities, betweenness centrality and eigenvector centrality, are relatively uncorrelated compared to correlations of other centralities. Although using these centralities reduces the multicollinearity issues, it does not eliminate these issues. Aside from complicating the analysis, these multicollinearity issues might produce too large standard deviations increasing the odds of type II errors (Hair et al., 2005).

Non-normalized centralities can only be compared if the nodes are part of the same network. Therefore the centralities have been normalized enabling comparison between networks (Everett & Borgatti, 2005b; Scott, 2000). Normalization corrects for the effect that more ties are possible in larger networks. The centrality values were normalized using a theoretical maximum value of centrality. This theoretical maximum depends on the size of the industry-wide network, namely the amount of standards organizations and the amount of firms (Borgatti & Everett, 1997). Standards organizations however are practically also limited in their board size as the board of directors cannot be very large. Not every firm in the network can be a board member of a certain standards organization. Hence it is impossible for any standards organization or firm to attain the theoretical maximum value of centrality. This creates problems when comparing networks of different sizes. The values of the centralities are thus limited by both the network size and the maximum feasible board size. In practice the maximum centrality value will be determined by the smaller of the two, namely the maximum board size. The centrality value however is normalized using the theoretical maximum centrality value which is determined by the size of the network. For small networks the difference between these two limits is smaller and the applied normalization would be approximately correct. For larger networks the normalization is incorrect and the centrality values will generally be lower. This effect makes it difficult to compare networks of different sizes. If the networks are about equally large the normalization factors are about equal and the values can be compared. The data from the nineties therefore has not been used, as these networks were much smaller. In the period 2000 to 2010 the network contained roughly the same amount of standards organizations and firms. The networks also look roughly similar as can be observed in appendix B.

A third limitation lies in the analysis method. Generalized Estimating Equations (GEE) has been used to analyze repeated measurements. Because of the time-varying covariates an independent correlation matrix had to be specified (Pepe & Anderson, 1994). This removed one of the main advantages of GEE, namely the possibility to let residuals of different years correlate. Using the independence working correlation matrix reduced the efficiency of the GEE estimation (Pepe & Anderson, 1994). Analyses with other correlation matrices have also been performed, although these analyses yielded roughly similar results the models had much higher QIC and QICC signaling a worse fit. From this it can be inferred that using the independent correlation matrix was indeed necessary as this provided the best model fit. As the efficiency of the GEE estimation has been reduced it is possible that some relations might have not been identified. The same data could be analyzed using other regression methods suitable for longitudinal data, such as linear mixed models or SEM.
A main limitation of SEM modeling however is the fact that it is often possible to construct alternative models with different fit parameters. These models can fit the data equally well and are thus equivalent models in terms of fit. Sometimes alternative models may fit the data even better; there is no guarantee that the SEM software will provide the best model in terms of fit. Moreover it is not possible to prove using statistical analyses or any other method that a SEM model is the best fitting model (Chin, 1998; Tomarken & Waller, 2005). Although the SEM results clearly showed that no reinforcing effects take place in the researched models existence of alternative models with reinforcing effects cannot be ruled out a priori. The probability that an alternative model with reinforcing effects exists is likely small as many different models have been used with different error covariance structures, paths, different amount of years and different periods. Moreover, models have been fitted where the paths between variables were set equal to the same paths in different years. None of these models indicated the existence of reinforcing effects.

To test the reinforcing effects with SEM the data have been converted to wide format. As SEM requires complete cases of data only the first four years of every standards organization have been used to test the hypotheses. Utilizing more years reduced sample size while increasing amount of parameters to be estimated. This resulted in unacceptable fit indices and bad sample size to parameter ratios for these models. Therefore the SEM analysis has been executed on a sample of 65 standards organizations with 260 data points. Originally 644 data points were available from 103 standards organizations. 83 data points were excluded because standards organization had information on less than 4 consecutive years, 263 data points were excluded from standards organization that were included in the SEM analysis and had data for more than 4 years. Finally 38 points were excluded because intermediate data points had missing data. Obviously a large part of the data has been excluded from the SEM analysis. Exclusion of this data is not at random and thus this could have introduced biases.

Aside from this the resulting sample size was quite low. The amount of parameters to sample size did not meet the more strict sample size requirements of SEM (Westland, 2010). As the amount of standards organizations involved in this arena is limited this creates a practical upper limit to the possible sample size. Although some authors still deem lower sample sizes acceptable, these two reasons could limit the validity of the SEM analysis (Iacobucci, 2010).

It should be remarked that this study researched a ten-year period and that the industries at study are unlikely to be static. Moreover, the hypotheses that were tested are limited and the tested model is by no means expected to be a complete model. Hence many other factors might have influenced the standards battles as well. This study partially accounts for this by introducing an intercept which is variable with year. This method is unlikely to account for all exogenous effects. Important economic events, such as the dot-com bubble burst (2000) or the financial crisis (2008) might well have affected the firms and standards organizations in this study. Important technological events such as mass adoption of smart phones and more widespread use of internet will affect the industries as well. This study has not accounted for these effects.
Theoretical Contributions

Research on standards battles has found evidence for the effects of several factors on the outcome of standards battles (Schilling, 1998; Shapiro & Varian, 1999; Suarez, 2004; van de Kaa et al., 2011). Contributions to this list of factors come from different theoretical streams such as evolutionary economics, institutional economics and network economics. This research project contributes to understanding of standards battles by expanding the list of factors. The effects of network composition and the internal structure of the alliance on standard dominance have been researched before (Soh, 2010; van den Ende et al., 2012; Vanhaverbeke & Noorderhaven, 2001). The effect of the industry wide network of firms and standards organizations however has not been researched extensively. This study has found support for the positive effects of the influential position in the industry wide network on the dominance of the standard. The influential position has been operationalized using eigenvector centrality. From this it can be inferred that the position in the industry wide network is important for the success of the standards organization and the supported standard. Hence this study contributes to the existing list of factors that have been shown to affect standard dominance. Therefore the gap in the literature on standard dominance is reduced.

The effects of standard flexibility and board diversity have also been incorporated in the models tested in this study. The importance of these factors has been researched in earlier research (van de Kaa, 2009, 2012; van den Ende et al., 2012). Some of this research has been performed on parts of the same dataset. Using a different operationalization of standard dominance and a different statistical method support for the positive effects of standard flexibility and board diversity on standard dominance has been found. These findings are in agreement with previous results and thus contribute by providing further evidence for the effects of flexibility and board diversity.

Managerial Implications

The results from this study on standards organizations provide support that the influential position of the standards organization in the network affects the success of the standards organization. This would imply that to build a successful standards organization one needs support from powerful firms. Earlier research has already indicated that firms that are industry leaders, so called ‘big fishes’, affect the success of standards organizations and alliances (Rosen et al., 1988; Suarez & Utterback, 1995). This study indicates that it is important for a standards organization to have board members that are active in the industry-wide network. To a certain extent these effects will accompany each other as the industry leaders are producing many products and hence will have incentives to join the board of many standards organization to exert influence on the standardization. In the networks of this study it is observed that the firms scoring the highest on eigenvector centrality, used to measure influential position, are well-known companies who are industry leaders. Examples include Dell, Intel, Microsoft, Samsung and Sony.

Firms or organizations that develop standards should actively involve these industry leaders in the process of standard development. Involving reputable companies early in the standardization process can increase the chances of standard success as these companies can use their influence in the industry wide network. The confirmation of the effects of board diversity would suggest involving firms from different industries early in the process. Standard developers should hence aspire to involve a diverse coalition of reputable companies to increase the chances of standard dominance.
Suggestions for Further Research

One of the main limitations of this study was the operationalization of standard dominance. This operationalization was chosen because of difficulties in calculating market share and difficulties with data collection. These issues could be resolved by focusing on a couple of standards organizations in a smaller part of the market. This would enable calculation of market share which can be used to compare the dominance of the standards. Alternatively categorical variables could be implemented to distinguish between standards organizations. One could distinguish standards organizations by type of standard, involved industries or type of standards organization to enable a better comparison of standards organizations. Additionally the effect of exogenous effects such as technological or economical developments could be incorporated into the tested model. If similar results are attained with these expanded models this strengthens the generalizability of the results of this study.

Case studies could be used to research the effects of the network characteristics into more detail as the focusing on a limited amount of standards organizations enables collection of more detailed data. It might be interesting to combine network analysis on the industry wide network with network analysis on the internal structure of the standards organization. Authors have shown that the underlying structure of these alliances can be quite complicated, hence detailed analysis is necessary to research this internal network (Vanhaeverbeke & Noorderhaven, 2001). The effects of characteristics of the internal network such as betweenness centrality and the overall density have been shown to affect the success of firms in such an alliance (Gilsing et al., 2008), but might well affect the success of the standards organizations as well.

The significant effects of the influential position indicate the importance of the industry wide network on the standards organization. Future research could further explore the options of network analysis. The centralities as used in this study are node-based variables, applying to single standards organizations and firms. Other network-based measures such as structural holes measures, cliques and clans or structure of sub-networks could also be used in these analyses. Moreover one could look at the structural equivalence of standards organizations and firms to determine whether structural equivalent organizations or firms have the same amount of success (Scott, 2000). This explorative research on the network should be guided by theoretical considerations.

No support for the reinforcing effects of diversity and flexibility has been found. A major complication of testing these effects was the choice of analysis method. Studying partial correlations would yield biased results because of survivor bias, whereas testing with SEM would result in survivor bias as well, because standards organizations with few years of data had to be removed. SEM is a very flexible statistical technique and could in principle be used to test the proposed reinforcing effects. Restrictions on sample size and cases with missing data however introduced problems with fitting models. Multiple path models have therefore been tested, differing in the amount of years, variables, paths and covariances. None of these models however provided evidence for the reinforcing effects and many of these models did not provide adequate goodness-of-fit indices.

One way to solve these problems with fitting is increasing the sample size, but the amount of existing standards organizations may prove to be limiting the maximum possible sample size. Further research on the ANS database would be necessary to reduce the cases with missing data which would reduce the SEM fitting problems. It might still be the case that some of this data is simply not available anymore. By reducing the missing data to levels which can be used with the FIML procedure the SEM fitting problems could be reduced (SSI Scientific Software, 2006).
Chapter 6: Conclusion

The purpose of this research project was to understand the influence of network characteristics on standard dominance. As to reach this objective three research questions have been devised which have been answered in this thesis. Answering these research questions improves the understanding of the effects of network characteristics in standard setting.

The first research question “What are important network characteristics and how do they relate to standard dominance?” was analyzed using different literature sources. Literature on standards battles and dominant designs has been used to determine which factors were important in standards battles. Other literature such as social network analysis literature has been used as well. Most of the literature on standards battles has focused on the firms supporting the standard. In standards battles networks such as coalitions, consortia and alliances have been researched, these papers however focus mainly on the firms in these network, not so much on the network itself (Soh, 2003; Vanhaverbeke & Noorderhaven, 2001). Hence information from papers on standards battles and related subjects has been combined to derive factors for a model that could be tested.

From the literature four factors were derived that could be tested. The effects of bridging structural holes and the effects of the influential position in the industry wide network were tested. One network characteristic related to the composition of the board has been tested, namely diversity. Diversity represents the variety of firms in the board of the standards organization. A network with more diverse sources provides more diverse information (van de Kaa, 2009). Evidence in other research projects has shown that reinforcing effects between diversity and the flexibility of the standard exist (van den Ende et al., 2012). Therefore flexibility has been researched as well.

The testing of these proposed effects to answer the second research question on what the effects of network characteristics on standard dominance are has been performed using data from the ANS database. This database consists of standards organizations in the electronics market which includes consumer electronics, telecommunications, home networking and information technology (van de Kaa, 2009). Based on availability of data the period from 2000 to 2010 has been selected for hypothesis testing. This resulted in a sample of 103 standards organizations in the period from 2000 up to 2010.

As this study includes standards organizations from different markets and many standards are used in several applications multiple market shares could be calculated which impedes operationalizing standard dominance using the market share. Therefore standard dominance has been operationalized by counting the total amount of corporate members of the standards organization (von Burg & Kenney, 2000).

The industry network characteristics were operationalized using centralities, which have been calculated using the program UCInet from the biadjacency matrix. Bridging structural holes and influential position were operationalized using betweenness centrality and eigenvector centrality respectively (Borgatti & Everett, 1997; Borgatti et al., 1998). As the relations of firms and standards organizations are important for the strength of the standards organization the two-mode versions of the centralities have been used as this method preserves the underlying structure of relations between firms and standards organizations.
Diversity has been operationalized by counting the amount of industries represented in the board of the standards organization using SIC codes. Flexibility of the standard has been measured by counting the amount of revisions of the standard using information from the archived websites.

To test the direct effects of these variables Generalized Estimating Equations (GEE) has been used. This is a regression technique capable of analyzing data with repeated measurements and can be used to calculate the response averaged over the standards organizations. The first models results in positive and significant regression coefficients of diversity and flexibility. This supports hypotheses 3 and 4. These results are in agreement with earlier research on this dataset (van de Kaa, 2009, 2012). Addition of influential position however changed the significance of these relationships while resulting in a positive and significant sign for influential position providing support for hypothesis 1. The change in significance could be explained by multicollinearity. Betweenness centrality, used to measure bridging of structural holes, did not become significant in any model, hence no support for the effects of structural holes as proposed by hypothesis 2 has been found. The significant effect of the influential position might indicate that network characteristics are important for the success of standards organizations.

The third research question was: what is the effect of reinforcing effects between variables affecting standard dominance? Reinforcing effects have been proposed between diversity and flexibility as indicated in hypothesis 5. Answering this research question required usage of more complicated statistical methods. Because of the reinforcing effects diversity and flexibility become dependent variables as well as independent variables. Hence ordinary regression cannot be used to determine these effects.

A preliminary analysis has been used to determine the reinforcing effects by estimating the partial correlations between flexibility and diversity. As both of these variables have been proposed to affect the network size, the correlations have been calculated while controlling for network size. Using partial correlation between flexibility and lagged diversity did not provide any significant correlations as can be seen in table 6 and 7. Partial correlations also did not provide significant correlations between diversity and lagged flexibility. Hence this method did not provide support for reinforcing effects. The results could have been affected by survivor bias, as standards organizations surviving for a long time have more data entries and hence these organizations influence the correlations more than their short living counterparts.

Reinforcing effects have also been tested using Structural Equation Modeling (SEM). No reinforcing effects between the influential position and structural holes with other variables have been proposed hence these variables have been left out of the SEM analysis. The omission of these variables results in better and more reliable models as less parameters need to be estimated. Therefore the tested model consists only of the effects of diversity and flexibility on size as well as the reinforcing effects of these variables. Using LISREL models with acceptable model fits have been fitted. These models have been fitted for four-year periods. The resulting models did result in significant paths between flexibility and diversity as would be the case for reinforcing effects. Moreover removal of these paths did not change the overall model fit significantly. Hence the SEM analysis results correspond with the partial correlations results and no support for reinforcing effects has been found.
Concluding, this study has found support for the positive effects of the influential position in the industry wide network on the chances of standard dominance. No support has been found for the effects of bridging structural holes in the industry wide network. Diversity of the members and flexibility of the standards are positively affecting standard dominance. Addition of influential position to the model however makes these relations insignificant. Neither SEM nor partial correlations found support for the existence of reinforcing effects between diversity and flexibility.

By researching the influence of the network characteristics of standards organizations this study contributes to the literature gap as these network characteristics have not been researched thoroughly. From the positive and significant relations of the influential position it can be inferred that it is important for a standards organization to attain an influential position in the industry wide network. Influential board members that are active in standardization activities aid standards organizations in acquiring an influential position. This study has also found support for the positive effects of diversity and flexibility on standard dominance, hence confirming earlier research.
Acknowledgment

I would not have been able to write this thesis without the efforts and help of many people helped me to write this thesis. In this chapter I would like to thank all of these people for their help. Their input and advice helped me to progress in the right direction as to reach this final result.

First I would like to thank my supervisor Geerten (van de Kaa) for his support and comments during the entire process of this research project. His database has been the cornerstone of this research project and without his help and confidence this project would never have existed. Essentially his lectures on standards battles were the spark that initiated my interests for this research domain. Initially he provided me with interesting subjects that could be researched using the existing data and his knowledge of standardization literature proved to be very valuable as he provided me with a lot of good literature suggestions. He was always available for answering one of my many questions and often he would provide suggestions such that I would answer the questions myself. Furthermore I greatly appreciate his proactive attitude in arranging affairs such as workspace, meetings and software, which accelerated the pace of this project.

When I started this project I knew of the existence of SEM, but without the help of Jafar (Rezaei) I would still be stuck on reading through papers and documents regarding SEM. His literature suggestions guided me in exploring the extensive SEM literature. Furthermore his advice in preparing the data for SEM, developing a model and interpreting the SEM results have proven to be very valuable. During the process of fitting the data he was always available to help me interpret the many fit indices and other results from the LISREL output.

I would also like to thank my chairman Marijn (Janssen), although we only met a couple of times his remarks during these meetings provided valuable new insights. He correctly pointed out that things that were clear to me were not always written down clearly. Furthermore he provided some valuable suggestions of improvement of my documents.

Sorting, processing and converting the data would not have been this easy without the help of my fellow student Sujaya Shinde. Before I started working on the database she worked as a student assistant to collect and insert new data into the database. Her adapted Excel macro has been very useful to convert the data for SEM. Without her programming syntax and help with Microsoft Access sorting and converting the data would have been a painstaking endeavor.

Furthermore I would like to thank mrs. Arkesteijn in her absence, for allowing me to disturb her on a nearly daily basis by asking for access to my workspace.

Although I cannot thank them all individually I would like to thank my friends, roommates and fellow students for their input, suggestions and great tips. Their help with the absolutely necessary coffee breaks and study sessions has been greatly appreciated. Lastly I would like to thank my family for supporting and motivating me and providing the much necessary distraction when necessary. In particular I would like to thank my grandfather who passed away shortly before completion of this project, his for his interest in my study results and his willingness to listen to my stories.

Laurens Wester,
October 31, 2014
Bibliography


Appendices

Appendix A – Methodology

Internet Archive Data Collection
The data used for this project and for the Actor Network Standard database has been collected using archived webpages from the Internet Archive. The Internet Archive gathers the archived website data by scanning websites multiple times every year to look for changes using an internet bot called a web crawler. Modified versions of the website are saved along with a timestamp of the date when the web crawler visited the website. Therefore the exact date of the changes cannot be retrieved through the Internet Archive. The archived information includes data on the website, source codes, images as well as documents. Using this information websites can be reconstructed as they were at various dates in the past. This is also possible for dead links and websites that have been removed entirely. The information from the Internet Archive can be used at no-cost for research and scholarship purposes as can be found in the terms of use (The Internet Archive, 1997).

Many standards organizations own a website on which they publish news on standard development. These organizations often publish lists of membership and information about the composition of the board of directors as well. Other standards organizations publish this information in their newsletters, press releases or annual reports. This information can be retrieved from the contemporary websites of the standards organizations or the archived version of the website. Specific websites that collect press release information can also be used. Using these sources the composition of the board and the total amount of members has been determined at various dates in the past. Many standards organizations also publish information on major and minor standard revisions which has been used to determine the amount of revisions.

Not all information from the archived websites can be retrieved as access to some parts of the websites is restricted. List of members are often protected against crawler bots or are published behind a members-only part of the website which requires logging in. Some websites allow visitors to select the members from a dropdown list; these lists however cannot be archived using crawlers. Moreover the archive is by no means complete as parts of some websites have not been stored in specific years for other reasons. Owners from websites can also request for their websites or parts of them to be excluded from the archive (The Internet Archive, 1997). Because of these various reasons it has not been able to collect complete data and hence this study has incurred some missing data.

The firms in the population of this study have been categorized by industry using standard industry classification codes as can be found in the Thomson One Banker database. Financial information such as sales, R&D expenditures, assets and net income of the firms is available in the ANS database, but has not been used in this project. This information can however be used in future projects. Additional information on the collection procedure of the data and the selection of the standards organizations can be found in the thesis dissertation of van de Kaa (van de Kaa, 2009).
Social Network Analysis

As explained earlier the rectangular matrix of dimensions $M \times N$ representing the relations between firms and standards organizations cannot be used directly to calculate centralities as centralities require a square matrix. A square matrix is required because centralities are calculated using matrix algebra requiring calculations of determinants, inverse matrices and eigenvalues. Inverse matrices, determinants and eigenvalues cannot be calculated for a rectangular matrix; hence the data needs to be transformed to a square matrix.

A commonly used technique is matrix projection which uses matrix multiplication to project the $M \times N$ two-mode matrix onto two one-mode matrices of dimensions $M \times M$ and $N \times N$ (Borgatti & Everett, 1997). This results in a matrix with connections between firms and a matrix with connections between standards organizations. A one-mode connection is created if two nodes have a common connection in the bipartite graph. Therefore firms that participate in the same standards organizations and standards organizations sharing board members are connected in their respective one-mode matrices.

This method however focuses solely on either standards organizations or firms. Information about the structure of the relations between standards organizations and firms is removed. It has been argued that the method of projection cannot be used when there is not theoretical argumentation for this (Breiger, 1974; Robins & Alexander, 2004). As the strength of a standards organization is determined by the board member firms, the relations between firms and standards organizations are important. The method of projection would ignore the importance of the underlying network structure.

A further complicating factor is that whereas the two-mode matrix is binary the projected one-mode matrices will contain valued data. If two standards organizations have multiple board members in common the resulting relation between these standards organizations will have a value greater than one. Most routines have been designed for binary data and many of the concepts devised to measure network characteristics are mathematically nonexistent for valued data (Borgatti & Everett, 1997; Faust, 1997). Software often dichotomizes the valued data to enable calculations of centralities but this removes valuable information on the strength of inter-organizational relations (Borgatti et al., 2002; Faust, 1997). This dichotomization would ascribe a similar and equally strong connection between standards organizations sharing one board member and organizations sharing many members.

Aside from this the projected one-mode matrices tend to have more fully connected cliques which increase the amount of triangular paths between actors (Opsahl, 2013). This greatly affects structural holes measurements and distorts valuable information on the structure of the network (Bonacich, 1972b; Burt, 1992).

Therefore the affiliation data has been converted to the biadjacency matrix, a square matrix of dimensions $M + N$ by treating standards organizations and firms as the same type of node. This method results in binary matrices and hence no problems with valued data occur. Moreover this method does not ignore the structure of the network between standards and firms and hence the relations can be better incorporated into the network characteristics. As this method preserves the underlying network structure the amount of fully connected cliques is lower.
The biadjacency matrix \( (B) \) can be calculated using formula 6. In which \( A \) is the rectangular bipartite adjacency matrix, \( A^T \) is the transposed version of this matrix and \( 0_{(M,M)} \) and \( 0_{(N,N)} \) are zero matrices of dimensions \( M \) and \( N \) respectively (Scott, 2000).

\[
B = \begin{bmatrix}
0_{(M,M)} & A \\
A^T & 0_{(N,N)}
\end{bmatrix}
\]  

(6)

**Goodness-of-fit Indices for SEM**

The basic goodness-of-fit index is the chi-square value of the model along with the corresponding degrees of freedom. The chi-square value can be calculated by comparing the difference between the observed covariance matrix \( (S) \) and the SEM estimated covariance matrix \( (\Sigma_q) \), with \( q \) being the amount of parameters to be estimated. This is multiplied by the amount of samples \( (N) \) minus one. The degrees of freedom are calculated using formula 2 and 3 (Hair et al., 2005). A smaller chi-square value indicates a better fit; LISREL provides a p-value associated with the chi-square value and the degrees of freedom.

\[
\chi^2 = (N - 1)(S - \Sigma_q)
\]  

(7)

The chi-square value inevitably increases as the sample size increases due to the factor \( N \) in formula 7. Hence the chi-square test can result in significant p-values for large sample sizes and will reject more models when the sample size is larger. Therefore absolute fit indices are often used in SEM. One of these indices is the Comparative Fit Index (CFI). CFI is a normed index with 1 indicating a good fit and 0 indicating a very bad fit. It can be calculated by calculating the difference of the non-centrality parameters \( (\lambda) \) and dividing this by the non-centrality parameter of the null model (Bentler, 1990). The null model is usually the independence model, a model in which all measured variables are expected to be completely uncorrelated. CFI can also be used to compare two competing models with each other. In that case the null model is one of the competing models (Bentler, 1990).

\[
\lambda = \left( \chi^2 - df \right)
\]

(8)

\[
CFI = \frac{\lambda_{null} - \lambda_{proposed}}{\lambda_{null}}
\]  

(9)

A badness-of-fit index also needs to be presented. A common badness-of-fit index is the Root Mean Square Error of Approximation (RMSEA). This measure has also been devised to correct for the tendency of the chi-square statistic to reject models with large sample sizes. A smaller RMSEA indicates a better model fit. The RMSEA can be calculated using the following formula (Schumacker & Lomax, 2012).

\[
RMSEA = \sqrt{\frac{\chi^2 - df}{d(1 - 1)}}
\]  

(10)
Appendix B – Network Graphs

Using UCNet 6 (version 6.486, 64-bits) the centralities of the standards organizations have been calculated. The plugin NetDraw (version 2.139), available in UCNet 6, can be used to plot these networks. The spring-embedding algorithm has been used to sort the nodes increasing the visibility of the network. The spring-embedding algorithm is a force-directed graph drawing algorithm. These algorithms model the links between the nodes as springs. Nodes that are far apart will attract each other and nodes that are close together will repulse each other. The notions of far and close are with reference to some user-defined intermodal distance. The algorithm calculates these forces and the impact on the positions of the nodes, these changes are implemented and nodes reach a new position. This process is iterated as to reach a final layout (Freeman, 2000).

The red circles represent standards organizations and the blue squares represent firms in the board. Arrow heads and labels have been removed to increase visibility. As can be seen from these figures some standards organizations are isolated from the main network. Most standards organizations however are connected to the main network, only few standards organizations are isolated. A few standards organizations are connected to the main network through one firm. The core of the main network seems heavily intertwined. A few standards organization can be observed that have only one board member, these standards organization represent stand-alone standards.

As can be seen from these network graphs the overall structure of the network itself remains fairly constant. It can be observed that the amount of firms and standards organizations active in this industry becomes somewhat larger. Therefore the graphs from the later years seem denser. The amount of standards organizations and firms does not increase enormously.

Figure 5: Visual Representation of the Bipartite Network in 2000.
Figure 6: Visual Representation of the Bipartite Network in 2001.

Figure 7: Visual Representation of the Bipartite Network in 2002.
Figure 8: Visual Representation of the Bipartite Network in 2003.

Figure 9: Visual Representation of the Bipartite Network in 2004.
Figure 10: Visual Representation of the Bipartite Network in 2005.

Figure 11: Visual Representation of the Bipartite Network in 2006.
Figure 12: Visual Representation of the Bipartite Network in 2007.

Figure 13: Visual Representation of the Bipartite Network in 2008.
Figure 14: Visual Representation of the Bipartite Network in 2009.

Figure 15: Visual Representation of the Bipartite Network in 2010.
Appendix C – Programming Code

Matlab Syntax
After giving every firm and standards organization an identification number an Excel macro has been used to paste the SIC code next to every firm in the data. The following code has been used in the program Matlab R2014a (version 8.3, 64-bits) to count the amount of unique SIC codes as to calculate the diversity. Using an Excel macro labels corresponding to the identification number have been attached afterwards.

```matlab
A=zeros(90,1);
B=unique(SO_ID);
maxSO=length(B)
divvec=zeros(maxSO,1);
maxID=length(SO_ID);
result=zeros(maxSO,2);

for i=1:maxSO
    for n=1:maxID
        if SO_ID(n)==B(i)
            A(n)=SICCode(n);
        end
    end
divvec(i)=length(unique(A))-1;
end
A=zeros(90,1);
End

result(:,1)=B;
result(:,2)=divvec;
```

Microsoft Visual Basic Syntax
This code has been used to convert the data in long format to the wide format as required by SEM. This syntax has been adapted to sort data from 2000 to 2010 for 799 data entries of 9 variables each. Note that not all of the 799 data entries are complete data.

```vbnet
Sub SEMformat()
    Dim i As Long, j As Long, x As Long
    Dim n As Long
    Dim c As Long
    Dim yr As String

    For i = 2 To 799
        n = 0
        j = i + 1
        Do
            c = 0
            x = 0
            If n = 0 Then
                Range("B" & i & ":J" & i).Select
                Selection.Cut
                x = Range("B" & i) - 1999
            Else
                Range("B" & j & ":J" & j).Select
                Selection.Cut
                x = Range("B" & j) - 1999
            End If
```

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End If

\[ c = (9 \times x) + 2 \]

ActiveSheet.Range(Cells(i, c), Cells(i, c)).Select
ActiveSheet.Paste

If \( n > 0 \) Then
Range("A" & j & ":K" & j).Select
Selection.EntireRow.Delete
End If

\[ n = n + 1 \]

Loop While Range("A" & i) = Range("A" & j)
  If \( i = 799 \) Then
    Exit For
  End If
Next i

n = 0
For \( n = 1 \) To 11
  c = 1
  i = 0
  For \( i = 2 \) To 11
    c = \( (i + (n \times 9)) \)
    x = 0
    x = 1999 + n
    yr = x
    Cells(1, c) = yr & " - " & Cells(1, i)
    If \( i = 11 \) Then
      Exit For
    End If
  Next i
  If \( n = 11 \) Then
    Exit For
  End If
Next n

End Sub
Appendix D – GEE Residuals

After the generalized estimating procedure has been carried out the residuals of model 6 have been tested for normality. The resulting Shapiro-Wilk test was not conclusive in indicating normality, as the W-statistic of 0.993 with 644 degrees of freedom results in a significance level of 0.003. The skewness and kurtosis of the distribution are all approximately 0 as should be for a normal distribution. The mean is approximately 0 as is necessary for residuals.

When looking at the histogram of the residuals their distribution seems approximately normal. To check for outliers the Q-Q plots have been inspected. The Q-Q plot indicates that most of the data are on the straight line. For normal distributions the points in the detrended Q-Q plot should cluster randomly in a horizontal band around zero. Although the clustering does not seem entirely random no serious outliers are detected. The residuals therefore seem approximately normal as is required by GEE.

Table 14: Descriptive Statistics of Residuals

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Statistic</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.00000</td>
<td>0.042365</td>
</tr>
<tr>
<td>Median</td>
<td>-0.08319</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>1.156</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.075101</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.748</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>2.720</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>5.469</td>
<td></td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>1.398</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>0.141</td>
<td>0.096</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.320</td>
<td>0.192</td>
</tr>
</tbody>
</table>

Figure 16: Histogram of the Residuals of the GEE Analysis.
Figure 17: Q-Q Plot of the Residuals.

Figure 18: Detrended Q-Q Plot of the Residuals.
Appendix E – SEM Models

LISREL Syntax

In LISREL path diagrams can be written in either LISREL syntax or SIMPLIS syntax. The path diagrams constructed for this study have been written in the SIMPLIS syntax. This syntax has been written for LISREL 9.10 (32-bits). The following syntax represents the full model. Reduced models can be created by removing parts of the syntax. Path diagrams of these models can be found on the next page.

‘Size’ indicates size, ‘Div’ indicates diversity and ‘Flex’ indicates flexibility. Suffixes $t0$, $t1$, $t2$, $t3$ and $t4$ indicate the time at which the variable has been measured. The reinforcing effects from flexibility to diversity can be removed by removing the ‘Flex’ parts from line 6, 7 and 8. Similarly the reinforcing effects from diversity to flexibility can be removed by removing the ‘Div’ parts from line 9, 10 and 11.

Sample Size = 65
Relationships
$\text{Sizet}_2 = \text{Sizet}_1 \text{ Divt}_1 \text{ Flext}_1$
$\text{Sizet}_3 = \text{Sizet}_2 \text{ Divt}_2 \text{ Flext}_2$
$\text{Sizet}_4 = \text{Sizet}_3 \text{ Divt}_3 \text{ Flext}_3$

$\text{Divt}_1 = \text{Divt}_0 \text{ Flext}_0$
$\text{Divt}_2 = \text{Divt}_1 \text{ Flext}_1$
$\text{Divt}_3 = \text{Divt}_2 \text{ Flext}_2$

$\text{Flext}_1 = \text{Divt}_0 \text{ Flext}_0$
$\text{Flext}_2 = \text{Divt}_1 \text{ Flext}_1$
$\text{Flext}_3 = \text{Divt}_2 \text{ Flext}_2$

Set the Error Covariance of $\text{Sizet}_3$ and $\text{Sizet}_2$ Free
Set the Error Covariance of $\text{Sizet}_4$ and $\text{Sizet}_2$ Free
Set the Error Covariance of $\text{Sizet}_4$ and $\text{Sizet}_3$ Free

Set the Error Covariance of $\text{Divt}_3$ and $\text{Divt}_1$ Free
Set the Error Covariance of $\text{Divt}_3$ and $\text{Divt}_2$ Free
Set the Error Covariance of $\text{Divt}_2$ and $\text{Divt}_1$ Free

Set the Error Covariance of $\text{Flext}_2$ and $\text{Flext}_1$ Free
Set the Error Covariance of $\text{Flext}_3$ and $\text{Flext}_1$ Free
Set the Error Covariance of $\text{Flext}_3$ and $\text{Flext}_2$ Free

Path Diagram
End of Problem
SEM Path Diagrams

Figure 19: Model without Effects of Flexibility on Diversity. This model does not contain reinforcing effects from diversity to flexibility.

Figure 20: Model without Effects of Diversity on Flexibility. This model does not contain reinforcing effects from diversity to flexibility.

Figure 21: Model without Reinforcing Effects. This model does not include any reinforcing effects.
Appendix F – SEM Results

Results with Covarying Diversity and Flexibility

Although the correlation between flexibility and diversity seemed insignificant models with covarying errors of flexibility and diversity have been tested as well. In these models the errors of flexibility and diversity in the same year covary. The results of this analysis are very similar to the results without this error covariance. These models do not provide support for hypothesis 5.

Table 15: Standardized Estimates of Reinforcing Effects – Covarying Model

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variable</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility (t=1)</td>
<td>Diversity (t=0)</td>
<td>0.0303</td>
<td>0.0589</td>
<td>0.607</td>
</tr>
<tr>
<td>Flexibility (t=2)</td>
<td>Diversity (t=1)</td>
<td>0.0188</td>
<td>0.0714</td>
<td>0.792</td>
</tr>
<tr>
<td>Flexibility (t=3)</td>
<td>Diversity (t=2)</td>
<td>0.0634</td>
<td>0.0509</td>
<td>0.213</td>
</tr>
<tr>
<td>Diversity (t=1)</td>
<td>Flexibility (t=0)</td>
<td>-0.0326</td>
<td>0.0645</td>
<td>0.614</td>
</tr>
<tr>
<td>Diversity (t=2)</td>
<td>Flexibility (t=1)</td>
<td>-0.0236</td>
<td>0.0624</td>
<td>0.705</td>
</tr>
<tr>
<td>Diversity (t=3)</td>
<td>Flexibility (t=2)</td>
<td>-0.0020</td>
<td>0.0505</td>
<td>0.969</td>
</tr>
</tbody>
</table>

Table 16: Comparison of Models – Covarying Model

<table>
<thead>
<tr>
<th></th>
<th>Full Model</th>
<th>Model without Flexibility → Diversity</th>
<th>Model without Diversity → Flexibility</th>
<th>Model without reinforcing effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>χ²</td>
<td>35.692</td>
<td>36.163</td>
<td>38.304</td>
<td>38.772</td>
</tr>
<tr>
<td>Degrees of freedom (df)</td>
<td>30</td>
<td>33</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td>p-value</td>
<td>0.2183</td>
<td>0.3231</td>
<td>0.2414</td>
<td>0.3458</td>
</tr>
<tr>
<td>CFI</td>
<td>0.993</td>
<td>0.996</td>
<td>0.994</td>
<td>0.997</td>
</tr>
<tr>
<td>RMSEA</td>
<td>0.0540</td>
<td>0.0384</td>
<td>0.0497</td>
<td>0.0344</td>
</tr>
<tr>
<td>Δχ²</td>
<td>0.471</td>
<td>2.612</td>
<td>3.080</td>
<td></td>
</tr>
<tr>
<td>Δdf</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Significance</td>
<td>0.925</td>
<td>0.455</td>
<td>0.799</td>
<td></td>
</tr>
</tbody>
</table>

Independence model: $\chi^2 = 909.808$ with 66 degrees of freedom
**Full Model Results**

The complete results of the full SEM model can be found in the tables below. As can be seen from this analysis the path between variables in different years is always significant.

**Table 17: Standardized Estimates of Full SEM model**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variable</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility (t=1)</td>
<td>Diversity (t=0)</td>
<td>0.021</td>
<td>0.053</td>
<td>0.391</td>
</tr>
<tr>
<td>Flexibility (t=1)</td>
<td>Flexibility (t=0)</td>
<td>0.657</td>
<td>0.078</td>
<td>8.448***</td>
</tr>
<tr>
<td>Flexibility (t=2)</td>
<td>Diversity (t=1)</td>
<td>0.033</td>
<td>0.061</td>
<td>0.546</td>
</tr>
<tr>
<td>Flexibility (t=2)</td>
<td>Flexibility (t=1)</td>
<td>1.491</td>
<td>0.127</td>
<td>11.722***</td>
</tr>
<tr>
<td>Flexibility (t=3)</td>
<td>Diversity (t=2)</td>
<td>0.056</td>
<td>0.047</td>
<td>1.184</td>
</tr>
<tr>
<td>Flexibility (t=3)</td>
<td>Flexibility (t=2)</td>
<td>0.439</td>
<td>0.058</td>
<td>7.633***</td>
</tr>
<tr>
<td>Diversity (t=1)</td>
<td>Flexibility (t=0)</td>
<td>-0.033</td>
<td>0.064</td>
<td>-0.512</td>
</tr>
<tr>
<td>Diversity (t=1)</td>
<td>Diversity (t=0)</td>
<td>0.860</td>
<td>0.053</td>
<td>16.160***</td>
</tr>
<tr>
<td>Diversity (t=2)</td>
<td>Flexibility (t=1)</td>
<td>-0.021</td>
<td>0.062</td>
<td>-0.335</td>
</tr>
<tr>
<td>Diversity (t=2)</td>
<td>Diversity (t=1)</td>
<td>0.880</td>
<td>0.054</td>
<td>16.323***</td>
</tr>
<tr>
<td>Diversity (t=3)</td>
<td>Flexibility (t=2)</td>
<td>-0.001</td>
<td>0.050</td>
<td>-0.028</td>
</tr>
<tr>
<td>Diversity (t=3)</td>
<td>Diversity (t=2)</td>
<td>0.888</td>
<td>0.062</td>
<td>14.329***</td>
</tr>
<tr>
<td>Size (t=2)</td>
<td>Diversity (t=1)</td>
<td>-0.002</td>
<td>0.015</td>
<td>-0.145</td>
</tr>
<tr>
<td>Size (t=2)</td>
<td>Flexibility (t=1)</td>
<td>-0.011</td>
<td>0.019</td>
<td>-0.608</td>
</tr>
<tr>
<td>Size (t=2)</td>
<td>Size (t=1)</td>
<td>0.859</td>
<td>0.043</td>
<td>20.030***</td>
</tr>
<tr>
<td>Size (t=3)</td>
<td>Diversity (t=2)</td>
<td>0.018</td>
<td>0.016</td>
<td>1.101</td>
</tr>
<tr>
<td>Size (t=3)</td>
<td>Flexibility (t=2)</td>
<td>-0.018</td>
<td>0.015</td>
<td>-1.179</td>
</tr>
<tr>
<td>Size (t=3)</td>
<td>Size (t=2)</td>
<td>0.815</td>
<td>0.051</td>
<td>15.919***</td>
</tr>
<tr>
<td>Size (t=4)</td>
<td>Diversity (t=3)</td>
<td>0.006</td>
<td>0.013</td>
<td>0.439</td>
</tr>
<tr>
<td>Size (t=4)</td>
<td>Flexibility (t=3)</td>
<td>-0.009</td>
<td>0.018</td>
<td>-0.487</td>
</tr>
<tr>
<td>Size (t=4)</td>
<td>Size (t=3)</td>
<td>0.938</td>
<td>0.048</td>
<td>19.620***</td>
</tr>
</tbody>
</table>

*p < 0.001 Critical t-value 3.356 (df = 33, α = 0.001)

**Table 18: Error Covariances of Full SEM model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity (t=1)</td>
<td>Diversity (t=2)</td>
<td>-0.269</td>
<td>0.273</td>
<td>-0.984</td>
</tr>
<tr>
<td>Diversity (t=1)</td>
<td>Diversity (t=3)</td>
<td>-0.007</td>
<td>0.268</td>
<td>-0.025</td>
</tr>
<tr>
<td>Diversity (t=2)</td>
<td>Diversity (t=3)</td>
<td>-0.211</td>
<td>0.235</td>
<td>-0.901</td>
</tr>
<tr>
<td>Flexibility (t=1)</td>
<td>Flexibility (t=2)</td>
<td>-2.730</td>
<td>0.693</td>
<td>-3.939***</td>
</tr>
<tr>
<td>Flexibility (t=1)</td>
<td>Flexibility (t=3)</td>
<td>1.332</td>
<td>0.361</td>
<td>3.688***</td>
</tr>
<tr>
<td>Flexibility (t=2)</td>
<td>Flexibility (t=3)</td>
<td>-1.000</td>
<td>0.385</td>
<td>-2.594*</td>
</tr>
<tr>
<td>Size (t=2)</td>
<td>Size (t=3)</td>
<td>0.081</td>
<td>0.025</td>
<td>3.225***</td>
</tr>
<tr>
<td>Size (t=2)</td>
<td>Size (t=4)</td>
<td>0.039</td>
<td>0.020</td>
<td>1.985*</td>
</tr>
<tr>
<td>Size (t=3)</td>
<td>Size (t=4)</td>
<td>0.047</td>
<td>0.022</td>
<td>2.192*</td>
</tr>
</tbody>
</table>

*p < 0.05 Critical t-value 1.692 (df = 33, α = 0.05)

***p < 0.001 Critical t-value 3.356 (df = 33, α = 0.001)
Appendix G – Standards Organizations

This research project has used a sample of 103 standards organizations from the ANS database. Two standards organizations (Bluetooth Special Interest Group and SEMI) have been excluded from the analysis because their amount of members was much larger than the amount of members from the other standards organizations.

<table>
<thead>
<tr>
<th>Table 19: List of Standards Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
</tr>
<tr>
<td>10 Gigabit Ethernet Alliance</td>
</tr>
<tr>
<td>1394 Trade Association</td>
</tr>
<tr>
<td>3D Industry Forum</td>
</tr>
<tr>
<td>3D@Home Consortium</td>
</tr>
<tr>
<td>Advanced Media Workflow Association</td>
</tr>
<tr>
<td>Advanced Television Systems Committee</td>
</tr>
<tr>
<td>ARCNENET Trade Association</td>
</tr>
<tr>
<td>ASI SIG</td>
</tr>
<tr>
<td>ATM forum</td>
</tr>
<tr>
<td>AXle Consortium</td>
</tr>
<tr>
<td>Blu-ray Disc Association</td>
</tr>
<tr>
<td>BPMI</td>
</tr>
<tr>
<td>Cable Television Laboratories</td>
</tr>
<tr>
<td>CE Powerline Communication Alliance</td>
</tr>
<tr>
<td>CEBus Industry Council</td>
</tr>
<tr>
<td>CompactFlash Association</td>
</tr>
<tr>
<td>Content Reference Forum</td>
</tr>
<tr>
<td>DICOM</td>
</tr>
<tr>
<td>Digital display working group</td>
</tr>
<tr>
<td>Digital Living Network Alliance</td>
</tr>
<tr>
<td>Digital Video Broadcasting Project</td>
</tr>
<tr>
<td>dsl forum</td>
</tr>
<tr>
<td>DVD Forum</td>
</tr>
<tr>
<td>DVD+RW Alliance</td>
</tr>
<tr>
<td>Echonet Consortium</td>
</tr>
<tr>
<td>EIB Association</td>
</tr>
<tr>
<td>EMerge Alliance</td>
</tr>
<tr>
<td>Enhanced Wireless Consortium</td>
</tr>
<tr>
<td>Enterprise Grid Alliance</td>
</tr>
<tr>
<td>Ethernet User Alliance</td>
</tr>
<tr>
<td>Fiber To The Home Council</td>
</tr>
<tr>
<td>GlobalPlatform</td>
</tr>
<tr>
<td>GSM association</td>
</tr>
<tr>
<td>HAVi Consortium</td>
</tr>
<tr>
<td>HDMI</td>
</tr>
<tr>
<td>High-Definition Audio-Video Network</td>
</tr>
<tr>
<td>Alliance</td>
</tr>
<tr>
<td>HiperLAN2 Global Forum</td>
</tr>
<tr>
<td>Home Gateway Initiative</td>
</tr>
<tr>
<td>HomeGrid Forum</td>
</tr>
<tr>
<td>Alliance/Group</td>
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<tr>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>HomePNA Alliance</td>
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<tr>
<td>HomeRF workgroup</td>
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<tr>
<td>I3A</td>
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<tr>
<td>IMTC</td>
</tr>
<tr>
<td>infrared data association</td>
</tr>
<tr>
<td>Internet Engineering Task Force</td>
</tr>
<tr>
<td>Internet Streaming Media Alliance</td>
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<tr>
<td>IPSO Alliance</td>
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<tr>
<td>IPV6 forum</td>
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<td>JEDEC</td>
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<td>Khronos Group</td>
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<td>Konnex Association</td>
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