IMPACT OF CO-AUTHORSHIP STRATEGIES ON RESEARCH PRODUCTIVITY: A SOCIAL-NETWORK ANALYSIS OF PUBLICATIONS IN RUSSIAN CARDIOLOGY

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DEDICATION

This dissertation is dedicated to the three most important people in my life – my daughter Asiya, my husband Iskander and my mother Zinaida.

ABSTRACT

This study explores how the choice of a co-authorship strategy determines individual research productivity measured in terms of quantity of publications. The exploration is conducted in the specific context of Russian cardiologic research.

The concept of social capital is used to explain the relationship between co-authorship and increased research productivity. The methodology for theoretical classification and empirical determination of co-authorship strategies is based on theoretical and methodological foundations borrowed from social network analysis. Two competing theories explaining the relationship between social network structure and social capital by Coleman (1988) and Burt (1992) are used to classify and to determine empirically co-authorship strategies.

The study is conducted in three phases. First, social network analysis is used to determine the co-authorship strategy of each researcher in the study. Second, analysis of variance is applied to determine the effect of co-authorship strategies on individual research productivity. Third, sensitivity analysis is conducted to determine whether the results hold under different assumptions.

The results indicate that co-authorship strategies have differential effects on research productivity and that the bridging strategy, in which a researcher serves as a broker between other researchers, is the most productive in Russian cardiologic research. This finding is consistent with the results of a prior study on the effect of co-authorship strategies on individual research productivity in the US research in higher education (Rumsey-Wairepo, 2006). The study supports Burt's (1992) theory of structural holes in explaining how social network structure creates social capital.

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CHAPTER 1: INTRODUCTION

This chapter highlights the essence of the study. First, it provides background to the research problems addressed in this paper by summarizing existing research on co-authorship and identifying the research gap that the study is intended to fill. Second, it states the two main purposes of the study. Third, a summary of the approach to the study is provided. Fourth, a list of research questions for the study is presented. Fifth, the significance of the study is discussed. Finally, this chapter provides an overview of the rest of the dissertation.

1.1. Background of the study

Co-authorship is a formal manifestation of intellectual collaboration in scientific research (Acedo et al., 2006). Ideally, it represents the participation of two or more authors in the production of a publishable study (Acedo et al., 2006)[1]. In the first half of the twentieth century, scientific papers written by more than one author were rare (Acedo et al., 2006). In recent decades, there is a growing trend for co-authorship in scientific publication. The trend has attracted much attention from researchers and there are many studies exploring the incidence and causes of the phenomenon.

The widely spread explanation of the increasing trend of co-authorship is that co-authorship has an advantage over independent solo publication strategy because collaborative work increases research productivity both in terms of quality and quantity

[1] It should be noted that co-authorship is no more than a partial representation of collaboration. Many researchers (Katz & Martin, 1997; Smith, 1958; Subramanyan, 1983) noticed the imperfect nature of the representation. Sometimes, an author might be included in the list of collaborators for honorary purposes. In some adverse cases, researchers are including each others' names in their individual works without actually collaborating in order to look more productive. Some contributors (eg.: graduate assistants) are not included as co-authors. Also, not all collaborations result in publication.

of publications. The assumption is that productivity rises because co-authorship creates various benefits at a relatively low cost (Duque et al., 2005; He, 2009).

The review of literature for this study has demonstrated that existing research on co-authorship is focused on answering three primary questions. First, some researchers are analyzing the empirical data to understand the extent to which co-authorship is represented among other publication strategies, and whether there are any differences in the observed patterns determined by various factors, such as discipline, geographic region, gender, age and experience of the researcher. Other studies investigate the various costs and benefits (outputs) of co-authorship. The research problem addressed by the third group of studies is concerned with empirically testing the positive association between co-authorship and quality and quantity of research output or, to put it differently, on supporting the idea that co-authorship increases research productivity. This study is of the third type.

The studies concerned with empirical tests of the relationship between research productivity and co-authorship have been criticized on a number of grounds. The research gap addressed by this study is a combination of three of the criticisms. First, prior studies have not made much progress in understanding the relationship between co-authorship strategy and research productivity (Bozeman & Corley, 2004; Katz & Martin, 1997). Second, prior studies explored co-authorship in scientifically advanced countries and did not pay sufficient attention to empirical explorations of the effect of co-authorship on research productivity in countries with different levels of science and technology capacity (Duque et al., 2005). Finally, very few of the prior studies tested

whether the effect of co-authorship on productivity depends on the disciplinary affiliation of a researcher (Bozeman & Lee, 2003).

1.2. Purposes of the Study

This study pursued two major goals. First, it investigated the relationship between co-authorship and individual research productivity. In doing so, the study addressed a gap in research identified in the previous section. The study explored the relationship between different types of co-authorship strategy and individual research productivity in the field of cardiology and in the context of Russia, which is considered a less scientifically advanced country.

The second goal of the study was to test a conceptual and methodological approach for assessing the effect of co-authorship strategy on research productivity, which was suggested and previously used by Rumsey-Wairepo (2006). Drawing on the concept of social capital and social network theory and analysis, Rumsey-Wairepo developed a categorization of co-authorship strategies and a method for testing their effect on productivity in the field of higher education research in the US. This study drew on the same approach. However, in addition to the steps suggested by Rumsey-Wairepo (2006), it included a sensitivity analysis of the approach by testing whether results of the study would hold under different assumptions.

1.3. Summary of the Approach

The conceptual framework of the study was based on the application of the concept of social capital in the context of the social network paradigm. The concept of social capital is most generically defined "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or

less institutionalised relationships of mutual acquaintance and recognition" (Bourdieu & Wacquant, 1992, p.119). Productivity gains from co-authorship could be explained by the social capital accruing from interaction with other researchers.

Social network paradigm and analysis have been widely used in sociology, management, economics and other disciplines to represent and to reconstruct social structures, as well as to explore the influences of the social structures on an individual (Borgatti & Foster 2003; Freeman, 2006). Serving as a methodological tool for revealing the social capital arising from different social structures, social network analysis has been successfully applied in exploration of co-authorships.

Two theories in the social network paradigm are especially relevant for this research. The two theories explain the sources of social capital in the social structure. One theory (Coleman, 1988) posits that social capital arises primarily from cohesion, which facilitates trust and cooperation among individuals. Another theory (Burt, 1992), suggests that social capital results from the brokerage opportunities created by diverse ties.

Using the two theories and a set of social network analysis measures developed by Burt (1992), Rumsey-Wairepo (2006) designed a methodology to classify co-authorship strategies, which she applied in a study of the effects of co-authorship strategies on research productivity in higher education research in the US. This study largely adopted the methodology, which is described in detail in the methods section. The methodology includes two main phases. Phase I involved the application of social network analysis to empirically determine co-authorship strategies. Phase II used several statistical methods (limited to analysis of variance and correlational analysis for this

study) to explore the effect of co-authorship strategies on research productivity as measured by the number of publications. This study also included Phase III, which utilized sensitivity tests of Rumsey-Wairepo's (2006) methods under different assumptions. Specifically, the goal of the sensitivity analysis was to test whether results obtained using Rumsey-Waipero's (20060 would hold if, instead of estimating productivity as the total number of publications of an author in a selected set of journals for a specific period of time, one estimates productivity from the total publication record of a researcher.

1.4. Research Questions

The study answered the following three research questions:

1. To what extent are various co-authorship strategies present in the field of cardiologic research in Russia?
2. How do these co-authorship strategies affect the research productivity of the authors measured by the total number of publications?
    (a) Is there any significant difference in research productivity between authors using different co-authorship strategies?
    (b) How does each of the strategies perform in terms of its effect on research productivity compared with other strategies?
3. To what extent do the results of the study depend on the assumptions and the method used for reconstructing the network?
    (a) What is the extent of publishing in other domestic and international journals for researchers included in the study, who are using different co-authorship strategies and having different levels of productivity?

(b) How is productivity of researchers using different strategies and having different productivity domestically changed when their publications in international and other domestic journals are taken into account?

1.5. Significance of the study

The study is expected to make several research and policy contributions. First, it will advance existing understanding in three research domains: (a) the field of research exploring factors affecting research productivity; (b) the field of research exploring the effects of co-authorship; (c) the interdisciplinary research on social capital, specifically the theoretical argument attempting to explain how social network structure creates social capital. Specifically, research on productivity will benefit from learning whether co-authorship in general and co-authorship strategy in particular have a positive effect on individual research productivity. Research on co-authorship strategy will be expanded by additional knowledge on (1) how co-authorship strategy affects productivity, (2) whether science and technology capacity of the country where research is conducted has an effect on the relationship between co-authorship and co-authorship strategy on productivity, (3) whether the relationship between co-authorship and co-authorship strategy differs between disciplines. Finally, research on social capital will benefit because by using two dominant theories of social capital (by Coleman (1988) and Burt (1992)) as a conceptual basis, the study provided support in favor of one or the other, thus explaining what social network structure might be responsible for the creation of social capital.

Second, the study will improve the existing methodological approach since it tests an earlier approach to the study of the effects of co-authorship strategies on individual research productivity. Specifically, it tested the methodology for a different discipline and for a country with less advanced science and technology capacity.

Third, the study offers practical implications for individual researchers and policy makers. Knowing how co-authorship strategies compare with one another in terms of their effects on productivity, Russian researchers in cardiology would be able to improve their research portfolio by strategically choosing whether and how to co-author with others. In addition to that, having better understanding of the relationship between co-authorship strategy and productivity, policy makers in Russia and at the international level would be able to apply incentives appropriately in order to increase individual research productivity via co-authorship.

1.6. Overview of the Paper

The rest of the dissertation is organized in the following way. Chapter two provides the review of the literature. Specifically, it summarizes prior studies on co-authorship and productivity to configure the research gap addressed by this study. In addition to that, it provides an overview of the conceptual framework and explains why it is appropriate for the study. Chapter three describes study design. Specifically, based on the previously identified research gap, it states the research questions addressed by the study. Further, it explains why Russian cardiologic research was chosen as a setting for the study. It provides details of the methodological approach used by Rumsey-Wairepo (2006) and explicates the phases in which this study was implemented. Chapter four presents the results of the analysis organized by research questions. Chapter five provides

the discussion of the findings, suggests future research and practical implications, as well as lists limitations of the study, which should be taken into consideration in interpretation and application of the results.

CHAPTER 2: REVIEW OF THE LITERATURE

This chapter reviews prior literature related to the topic of this paper and it is organized in four main sections. The first section reviews the results of the key studies of co-authorship relevant for this study and identifies the targeted research gap. The second section provides an overview of literature related to the conceptual framework. Specifically, it discusses the concept of social capital and introduces the social network paradigm and analysis. The third section is an overview of previous studies that applied the concept of social capital and social network analysis to the study of co-authorship. In the fourth section, literature-based justification for the choice of Russian cardiology as settings for this study is provided. The chapter concludes with specification of this study's contribution to existing research.

2.1. Current State of Research on Co-authorship

2.1.1. Descriptive Studies of Co-authorship. Co-authorship is a formal manifestation of intellectual collaboration in scientific research (Acedo et al., 2006). Ideally, it represents the participation of two or more authors in the production of a publishable study (Acedo et al., 2006)[2]. In the first half of the twentieth century scientific papers written by more than one authors were rare (Acedo et al., 2006). In recent decades, there is a growing trend for co-authorship in scientific publication. The trend has

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attracted much attention from researchers and there are many studies exploring the incidence and causes of the phenomenon.

A substantial body of existing research is focused on estimating the commonality of co-authorship strategy among contemporary researchers. The descriptive studies demonstrate that co-authorship has increased in both natural sciences (Biagoli & Galison, 2002; Braun, et al., 2001; Cronin, 2001; Cronin et al., 2003, 2004; Glanzel & De Lange, 2002; Moody, 2004) and social sciences (Cronin, 2001; Cronin et al., 2003, 2004; Glanzel, 2001; Laband & Tollison, 2000; Moody, 2004); and that the trend is observed across the globe (Wagner et al., 2001). Not only the proportion of co-authored papers in the total number of publications has increased, but the number of authors per co-authored publication is growing (Cronin, 2001; Glanzel & De Lange, 1997; Smith, 1958; Wuchty et al., 2007). In some disciplines, such as experimental high-energy physics, author lists can reach hundreds or even thousands of people (Birnholtz, 2006; Newman, 2001c).

Descriptive studies of the phenomenon of growing co-authorship explore differences in the frequency of co-publishing among various groups of researchers. Co-authorship has been found to be more common for researchers in interdisciplinary, natural and basic sciences compared with researchers in social and applied fields (Laband & Tollison, 2000; Zuckerman & Merton, 1973). Prior studies have also shown that males co-author more frequently than females (Ferber & Teiman, 1980; McDowell & Smith, 1992). Furthermore, Pravdic and Oluic-Vukovic (1986) found that frequency of co-authorship increases with productivity, because researchers at all levels of productivity are interested in collaborating with highly productive authors and researchers of lower level of productivity are unlikely to collaborate with each other (or one another) unless a

highly productive co-author joins them. One other finding of prior studies is that domestic co-authorship decreases with geographic proximity of researchers (Katz, 1994).

As has been mentioned above, increasing incidence of co-authorship is observed globally. Several studies have been devoted to exploration of the phenomenon at the global level. These studies showed a steady rise in international co-authorship (Glanzel, & De Lange, 2002; Narin & Whitlow, 1990; Narin et al., 1991; Schubert & Braun, 1990). They also concluded that international co-authorship is less common in countries with lower science and technology capacity and that likelihood of international co-authorship increases as a country becomes more scientifically advanced (Wagner et al., 2001). Luukkonen and Sivertsen (1992) and Schubert and Braun (1990) found that international co-authorship is more common for researchers from smaller countries. Wagner et al. (2001), Beaver (2001), Glanzel and Schubert (2004), Callon (1991) and Luukkonen and Sivertsen (1992) pointed that international co-authorship patterns are influenced by geographic proximity, historical ties between countries and language. Incidence of international co-authorship is greater for countries, which are co-located, speak the same language or are connected via common history. International co-authorship rates vary by discipline (Frame & Carpenter, 1973; Luukkonen & Sivertsen, 1992) with cross-border co-authorship being more common for researchers in natural sciences and basic research since their studies do not deal with variation in human cultures and are relevant for broader contexts. Greater international collaboration is also characteristic of fields that require international collaboration of resources, efforts and equipment, such as oceanography, seismology and climate research (Luukkonen & Sivertsen, 1992).

In summary, prior descriptive studies of co-authorship indicate that co-authorship is increasing across research disciplines and national borders and there are differences in the incidence of co-authorship among individual researchers conditioned by their disciplinary affiliation, gender, experience, and geographic location. In addition to that, frequency of co-authorship increases as the person productively engages in co-authorship collaborations; so that the more a researcher publishes as a result of collaboration, the more likely he/she is to involve in future collaborations.

2.1.2. Explanatory Studies of Co-authorship. The widely spread explanation of the increasing trend of co-authorship is that co-authorship has an advantage over independent solo publication strategy because collaborative work increases research productivity both in terms of quality and quantity of publications. The assumption is that productivity rises because co-authorship allows to gain some benefits at a relatively low cost (Duque et al., 2005; He et al., 2009). Much of the existing research tries to identify various benefits of co-authorship. Although less abundant, some research focuses on the costs associated with co-authorship. Finally, some studies test the assumption by empirical exploration whether co-authorship actually increases quality of quantity of publications.

2.1.2.1. Studies of Costs and Benefits. The most widely recognized benefits produced by co-authorship arise from changes in the contemporary research environment. Two of the most important environmental changes, are increasing specialization within disciplines (Hudson, 1996; Katz & Martin, 1997; Laband & Tollison, 2000; McDowell & Melvin, 1983; Piette & Ross, 1992) and division of labor, which are both driven by the continual expansion of the stock of knowledge (Barnett et al., 1988). As the stock of

knowledge expands, theories are becoming more numerous and methods more complicated to be mastered within the lifespan of a single researcher. A corresponding benefit of co-authorship consists in the fact that it allows researchers to expand their narrow conceptual and methodological expertise with the expertise of their collaborator (Beaver, 2001; Goffman & Warren, 1980; Katz & Martin, 1997; Maanten, 1970; Melin, 2000). In fact, in many fields, especially in the natural sciences, engineering and interdisciplinary research, problems have become so complex, that they could be resolved only by drawing on collaborative expertise of a team of researchers (Beaver, 2001; Goffman & Warren, 1980; Maanten, 1970).

Another widely cited environmental condition underlying the increase in co-authorship is the growing cost of conducting research for a solitary researcher (Duque et al., 2005; Laband & Tollison, 2000). As equipment becomes more complicated and expensive, government and institutional funding cannot catch up with the increasing costs. Hence, competition for the limited funding increases. Researchers face the need to bring additional financial resources to be able to complete publishable studies. A corresponding benefit of co-authorships, which addresses this challenge, is that it allows researchers to pull together limited funds and to improve access to costly equipment (Beaver, 2001; Clarke, 1967; Heffner, 1981; Meadows, 1974; Meadows & O'Connor, 1971; Melin, 2000; Smith, 1958).

One other environmental driver of the observed increase in co-authorship is the growing dependence of the status and salaries of researchers on the number and the quality of articles that they publish (Cronin, 1996; Hamermesh et al., 1982; Sauer, 1988). The corresponding benefits of co-authorship are that it increases the number of studies

that can be undertaken due to efficiency arising from the division of labor and that it provides an opportunity for rigorous peer review, which improves article quality and increases the probability that an author's work will be accepted for publication in a journal (Barnett et al., 1988; Rigby & Edler, 2005). In addition to that, co-authorship has been found to be beneficial for researcher's prestige and visibility in the environments, which values co-authorship as a value in itself (Beaver, 2001; Beaver & Rosen, 1978, 1979a, 1979b; Crane, 1972; Katz & Martin, 1997).

Certain benefits of co-authorship arise from the nature of the research process. Although scientific knowledge is frequently regarded as public because it is available in the form of publications, an important part of the knowledge, especially the one related to the methodology, is inextricably tacit and stored in the minds of individual scientists (He et al, 2009). This tacit knowledge is frequently the key for success in the field because it is concerned about the most recent developments, knowledge of which provides competitive advantage (He et al., 2009). The best way to acquire the tacit knowledge is to jointly experience problem-solving (He et al., 2009). Hence, an important benefit of co-authorship is that it allows a researcher to gain from their partner information about techniques, which is otherwise inaccessible (Beaver, 2001; Beaver & Rosen, 1978, 1979a, 1979b; Katz & Martin, 1997).

The solitary nature of the research process gives rise to another benefit of co-authorship: co-authorship creates a companionship, which helps researchers to sustain motivation (Fox & Faver, 1984). In a study based on the results of interviews with researchers, Fox and Faver (1984) noted that co-authorship also increases motivation to

conduct research by creating a sense of mutual responsibility, which helps researchers to keep to goals and schedules.

Finally, an important feature of scientific production is that it "depends largely on a few stars, whose work shapes the short-run course of a discipline" (Moody, 2004, p. 2). These "stars" exercise greatest influence and attract most of research funding. They comprise a community, entrance to which is key to success in the field. One benefit of co-authorship is that it provides scientists with an access to such communities of researchers (Laband, 1985; McDowell & Amacher, 1986; Piette & Ross, 1992). This access allows the collaborators to capture valuable information on research opportunities and find potential collaborators for subsequent research (He et al., 2009).

Most prior studies focus on benefits of co-authorship in explaining its productivity effects. These studies assume that co-authorship has more benefits compared with solo publication and hence leads to greater productivity. Several researchers note, however, that a full picture of reality requires consideration of costs (Duque et al., 2005; He et al., 2009). They argue that co-authorship is a more productive approach to publication not merely because it has more benefits than solo publication approach, but because its benefits exceed those of solo publication after both have been adjusted for costs. Hence, they argue, it is important to understand the costs of co-authorship.

The studies of costs of co-authorship revealed that most important are transaction costs (including time, energy and money) associated with working with others (Landry & Amara, 1998). Finding and assessing research partners, establishing an agreement to organize collaboration and allocate the credit of expected research output, staying in touch by various media, waiting for others to comment, respond or do their part of the

research, social ingratiation—these are just some of the factors taking time and energy even in the best collaborative relationships (Bozeman & Lee, 2003; Duque et al., 2005; He et al., 2009). Time must be spent clarifying roles and responsibilities at the beginning and throughout implementation of the project as it evolves (Katz & Martin, 1997). Due to these costs, most active collaborators have had projects that never led to collaborative publications because one or more of the collaborators did not live up to expectations (Landry & Amara,1998).

In addition to transaction costs, there are also many outcome costs associated with co-authorship (Fox & Faver, 1984). Co-authorship may create a problem in evaluation and allocation of the credit for the collaborative work. This cost is especially important for junior faculty, whose career advancement may be impeded if most of his/her work has been collaborative and his/her individual effort is underappreciated. In co-authorship between a junior and a senior researcher the "Mathew Effect" may also operate, whereby greater recognition accrues to the researcher with greater reputation (Merton, 1968). Although most frequently it is argued that co-authorship increases the quality of research, Fox and Faver (1984) discovered that some researchers prefer not to collaborate for exactly the opposite reason: co-authorship, in their view, creates barriers to quality control, where the desire to maintain positive relationship or reliance on others may undermine the rigor of the review.

Duque et al. (2005) argue that the common assumption that international co-authorship might be more advantageous in terms of productivity that the domestic co-authorship might be erroneous. The assumption takes into consideration only benefits of international co-authorship, specifically, the fact that international co-authorship allows

researchers to get access to more diverse ideas and expertise. He points out that international collaboration incurs additional costs, which vary by location (Duque et al., 2005). These costs arise because collaborators are at dispersed locations and extra time and money is necessary for travelling. Transaction costs might also be higher due to cultural and linguistic barriers and differences in access to information-communication technologies.

As an optimistic note, many researchers indicate that some costs of co-authorship are decreasing, which may explain why the incidence of co-authorship is growing (Katz & Martin, 1997; Laband & Tollison, 2000). Improved methods of communication facilitate collaboration of geographically separated authors (Katz & Martin, 1997; Laband & Tollison, 2000). In addition to that, travel has become easier and less expensive for collaborators to maintain occasional face-to-face contact (Duque et al., 2005). In addition to that, the number of researchers, and, consequently, potential collaborators is increasing. This increase creates a more fierce competition in the publication process raising quality standards for the submitted articles, but, at the same time, improves the chances and, consequently, reduces the cost of finding a partner with complimentary expertise (Hudson, 1996; McDowell & Melvin, 1983).

In summary, despite the costs of collaboration, co-authorship seems to produce a lot of benefits, which may explain why many contemporary researchers choose to collaborate. The types of costs and benefits, as well as the ratio of costs to benefits have been shown to vary with time and geographic location of the researchers.

2.1.2.2. Studies of Productivity Effects and their limitations. A body of research on co-authorship is concerned with empirical tests of the assumption that co-authorship

increases research productivity. The belief that co-authorship is positively related to research productivity is empirically supported with the results of some studies. The studies have demonstrated that co-authorship is linked to increased research productivity.

Co-authoring researchers have been shown to be able to publish more articles over the course of their career (Crane, 1972; Meadows, 1974; Pao, 1982; Pravdic & Oluic-Vucovic, 1986; Zuckerman, 1967), thus making a greater contribution to the field in terms of quantity. In addition to that, some studies show that articles produced in co-authorship are of greater quality, i.e. are more likely to be accepted for publication, to be published in leading journals and to be cited by other researchers for a longer period of time (Barnett et al., 1988; Bayer & Smart, 1991; Beaver, 2004; Glanzel & Schubert, 2001; Gordon, 1980; Katz & Hicks, 1997; Laband & Tollison, 2000; Narin et al., 1991; Presser, 1980).

Not only empirical studies demonstrated the positive relation between co-authorship and productivity, but they have also shown that gains from co-authorship are higher for males, for researchers specializing in natural sciences, as well as for those involved in international collaborations (Glanzel, 2001; Glanzel & De Lange, 2002; Glanzel & Schubert, 2001; He et al., 2009; Narin et al., 1991; Narin & Whitlow, 1990). Most of the studies of the effects of co-authorship on productivity used data from single fields or from fields representing one larger domain, such as sciences. In addition to that, researchers utilized a variety of approaches to estimate the effects of co-authorships, frequently reporting only graphic representations of data or general conclusions in the form of results of statistic tests of differences in the mean levels of productivity among co-authoring authors and authors publishing alone. No comprehensive studies comparing

the effect of co-authorship on individual productivity across disciplines and reporting estimates of the effects have been identified.

Despite the optimistic results of the studies listed above, the positive association between co-authorship and research productivity is not well established. First, as Bozeman and Lee (2003) noted, that there are not enough studies accurately controlling to claim the presence of the association with confidence. More studies have to be conducted to test the association in various disciplines.

Importantly for this study, Duque et al. (2005) noted the dearth of studies on productivity effects of co-authorship in countries with lower levels of science and technology capacity. The existing research on co-authorship is often based on data from ISI Web of Science or other similar databases, which cover mostly authors and journals from developed countries. Most studies also concentrate on productivity gains from co-authorships for researchers from scientifically-developed countries. Hence, it is not clear whether domestic or international co-authorship is as beneficial for productivity in the context of scientifically-developing, lagging, and proficient countries.

In addition to that, many of the studies had methodological flaws (Bozeman & Lee, 2003). Most flaws could be explained by difficulties in measuring productivity (Bozeman & Lee, 2003). Productivity is calculated as a ratio of output to input (Swiss, 1991). However, many studies do not explicitly include inputs in their calculations and productivity is often measured by "average publication rate for individuals (the total number of publication divided by the number of years) or a per capita publication rate for group (the total number of publications divided by the total number of authors)" (Bozeman & Lee, 2003, p.11).

Another difficulty in measuring productivity arises from the problem of distributing credit for co-authored works (Bozeman & Lee, 2003). There are several methods to assign credit (assigning full credit only to the first author, assigning full credit to each of the authors and assigning proportional credit based on the number of authors co-authoring the article) (Bozeman & Lee, 2003). All these methods have their limitations and affect the results of productivity calculations.

Finally, an important criticism of studies of the association between co-authorship and research productivity is that many of the studies do not take into consideration possible interaction effects with other variables (Bozeman & Lee, 2003). These variables include age, rank and status of the researchers, grant or contractual organization of collaboration, gender, marital status, citizenship, perceived discrimination, job satisfaction and co-authorship strategy.

Most general studies of productivity (Lehman, 1953; Levin & Stephan, 1991; Pelz & Andrews, 1976) showed that productivity of researchers tends to decline with age. Based on the studies, Bozeman and Lee (2003) hypothesized that rank and status might have an effect on the relationship between co-authorship and productivity. Tenured and senior researchers, as well as project leaders, might benefit more than non-tenured and junior researchers, as well as graduate students because of potential exploitation and greater experience with collaboration.

Another variable that might be responsible for interaction effect is organization of the research activity with grants or contracts (Bozeman & Lee, 2003). Many co-authored publications result from grant or contract-covered activities. Grants or contracts may have an effect on the association between co-authorship and productivity because they

motivate participating researchers to sustain effort and to meet set contract or grant objectives and schedules.

The higher productivity of co-authoring males compared with females could be explained by the interaction of marital status (Bozeman & Lee, 2003). Females are less likely to engage in co-authorship and to be productive because they are more likely to have child-caring responsibilities and less likely to have a full-time home-stay spouse.

Bozeman and Lee (2003) also identified the potential effect on the association of co-authorship and productivity of such variables as citizenship of researchers, job satisfaction and perceived discrimination. Citizenship might affect the ability of a researcher to collaborate via language proficiency. Those with poor proficiency tend to have difficulty finding potential co-authors. Job satisfaction might make an individual more motivated to seek collaboration with others, while perceived discrimination might have an opposite effect.

Importantly for this study, Bozeman and Lee (2003) indicated the potential conditional effects of co-authorship strategy. As an example, they mentioned that those seeking collaboration with more productive researchers might be more productive than those co-authoring with their equals or juniors.

The importance of considering co-authorship strategy has also been noted earlier by Katz and Martin (1997). Although Bozeman and Lee (2003) were able to indicate a positive link between co-authorship and productivity even after taking into consideration most of the above mentioned variables (age, rank, grant or contractual organization of the research activity, gender, marital status, job satisfaction, perceived discrimination and

collaboration strategy). However, the results of the study cannot be considered conclusive unless they are repeated in a series of similar studies.

He et al. (2006) mentioned that the studies linking co-authorship to research productivity often disregard intellectual ability of the co-authoring researchers as a potential confounding variable. It is possible that greater productivity results from co-authorship merely because participation in co-authorship is competitive and only the most talented are able to find a collaborator.

Many of the limitations of the productivity studies enumerated above are determined by the constraints imposed by data collection method frequently utilized in the studies of co-authorship. Specifically, most studies utilize ISI Web of Science to analyze co-authorship patterns and the association between co-authorship and productivity. ISI Web of Science, however, contains only basic information about researchers, including institutional affiliation, funding agency, and language of the publication. Other important information, for example about researcher's gender, rank, or country of origin cannot be directly inferred from ISI Web of Science.

In summary, the assumption that co-authorship leads to increased research productivity requires further empirical exploration. Although many prior studies seem to indicate that co-authorship is indeed associated with higher productivity, the studies failed to explore the relationship between co-authorship and productivity in presence of potential confounding variables. One particularly grey area is the relationship between various co-authorship strategies and productivity. In addition, not enough advances have been made in understanding of the relationship between co-authorship strategy and

productivity in the context of less developed countries, as well as in a variety of research disciplines.

2.1.3. Studies of Negative Effects of Co-authorship. Despite their limitations, the studies that demonstrated the positive relation between co-authorship and productivity played an important role in turning co-authorship into "a value in itself" Duque et al. (2005) and He et al. (2009). More researchers, especially in the natural sciences, choose to co-author because they believe that co-authorship increases research productivity, measured in terms of quality and quantity of publications, and because they are encouraged to co-author via incentives from their institutions and governments acting upon the same belief.

Policy makers have started to look at co-authorship as a mechanism for increasing national research productivity, which, in its turn, has been shown to stimulate economic growth (Lucas, 1988; Romer, 1986). Some institutions (in Germany) have started to introduce co-authorship as a performance measure (Schmoch & Schubert, 2008). In the US, a number of agencies funding research in natural sciences and medicine indirectly increase the number of co-authored publications by giving preferences to multidisciplinary, multi-institutional and multi-national teams in grant-awarding decisions (Katz & Martin, 1997). At the global level, policies exist that encourage multinational collaboration and, consequently, co-authorship (eg: programs of Eurocomission) (Narin et al., 1991; Narin &Whitlow, 1990; REIST-2, 1997).

In the midst of optimism about co-authorship's beneficial effect on productivity, some researchers pointed to and explored the possible negative effects of dissemination of co-authorship on the scientific enterprise (Benett & Taylor, 2003; Huth, 1986; Rennie,

1994, 1997; Shapiro et al., 1994; Slone, 1996; Smith, 1994). These effects are twofold. First, co-authorship has introduced some complications in interpretation of a researcher's effort for evaluation purposes (Benett & Taylor, 2003). This complication may have an indirect negative effect on research because inaccurate evaluation creates difficulty in effective distribution of research funding in such a way that the most productive researchers are reinforced. Second, it might be accountable for the appearance of novel types of research misconduct associated with assigning credit to people who did not make any or made only marginal contribution to research, as well as with failure to assign credit to those, who contribution was significant (Benett & Taylor, 2003). The types of research misconduct also lead to ineffective distribution of funds aimed at increasing research productivity by reinforcing the most productive researchers. The remaining part of the section is limited to a cursory overview of the main complications created by co-authorship, which are relevant to the research focus of this dissertation.

The issue of interpretation of contribution is linked to the order of authors in co-authored papers. Studies of the relation of the order of authors and author contribution have shown (1) that first authors normally make the greatest effort in writing of the paper (Schapiro et al., 1994); (2) that middle authors normally contribute substantially less work to a manuscript, although they still contribute a majority of the time to each task involved in a paper except for conception and design (Shapiro et al., 1994; Rennie, 1997); and (3) that the last position in the authors line typically indicates either the person, who contributed least of all, or the senior member of the team, who contributed resources rather than time in the production of the paper (Shapiro et al., 1993).

However, the conventional pattern of contribution in relation to the order of authors in the author line is not always observed. Sometimes, middle and last authors make significant contributions to the paper, while the first position in the order of authors could be taken by the senior member of the team (Shapiro et al., 1994). Hence, evaluation of author contribution based on the order of authorship might not be accurate.

In case when authors are listed alphabetically, evaluation of a researcher's effort might be obscured if the author's name always occurs at the end of articles with long lists of authors because their family name starts with one of the later occurring letters of the alphabet (Benett & Taylor, 2003). Journals may have restrictions on the number of authors included in citations and the names of authors at the end of author lists might not be included in subsequent citations by other authors (Benett & Taylor, 2003). Conversely, authors with names starting with letters occurring in the alphabet earlier might benefit from being cited more frequently than their counterparts.

The spread of co-authorship has also given rise to novel types of research misconduct. One such misconduct is commonly known *gift* (*honorary, guest, unjustified) authorship*. According to Benett and Taylor (2003), it is defined as "inclusion, among the authors, of an individual who does not fulfill the requirements for authorship" (p.266). Guest authors do not help write the paper, may not have seen the final draft submitted to the journal and cannot publicly defend the content of the article (Benett & Taylor, 2003, p. 266). A variation of guest authorship is *pressured authorship*, which takes place when "a person uses their position of authority to apply pressure upon staff more junior to them to include them as an author even though they do not qualify" (Benett & Taylor, 2003, p.266).

Benett and Taylor (2003) listed the most common reasons for guest authorship. One such reason is the desire to increase likelihood of publication by including the name of a more recognized expert in the field. Researchers may also include a non-author to their publications because of perceived obligation to repay a favor. Examples of such favors vary from referral of a patient (in clinical studies) to adverse cases of reciprocity, when researchers mutually cite each other in their works to boost their publication record. Technical personnel employed and paid for support purposes on clinical research projects may also be included at times for motivational purposes.

Ghost authorship is a reverse of guest authorship and takes place when "an individual is not listed as an author but could have either made contributions worthy of authorship or participated in the writing" (Benett & Taylor, 2003, p. 267). This type of abuse commonly affects graduate assistants, who might significantly contribute to a study without receiving a credit for their contribution (Benett & Taylor, 2003).

The negative effects of co-authorship have some impact on the exploration of the relationship between co-authorship and productivity. First, the ambiguity of the link between author order and contribution makes it impossible to incorporate the sequence of authorship in the estimation of productivity. Second, the measurement of productivity can be obscured by the new types of research misconduct, i.e. guest authors might seem productive without being actively involved in either research or collaboration, while ghost authors might seem unproductive despite in actuality being so.

In summary, co-authorship has been shown to create complications in evaluation of individual contribution of researchers and to elicit novel types of research misconduct associated with distribution of credit for contribution. Apart from increasing the

efficiency of distribution of research funding, these negative might distort results of studies of the relationship between co-authorship and research productivity.

2.1.4. Summary of the Research Gap. The review of prior research on co-authorship has shown that there is sufficient evidence of the increasing trend in co-authorship across research disciplines and national borders. Some evidence has been gathered to demonstrate differential effects on co-authorship incidence of researcher's gender, rank, disciplinary affiliation, and geographic proximity. Previous research has also generated rather good understanding of the benefits and, to a less extent, costs associated with co-authorship.

However, additional empirical evidence is necessary to confirm that co-authorship has beneficial effects on quality and quantity of individual research. Prior research on productivity effects of co-authorship failed to account for some potential interaction effects. The unaccounted potential interaction variables include age, rank and status of the researchers, grant or contractual organization of collaboration, gender, marital status, citizenship, perceived discrimination, job satisfaction and co-authorship strategy. Very few studies have been conducted to explore the relationship between productivity and co-authorship in countries with lower levels of research capacity.

This study will contribute to the growing body of research on co-authorship by having explored the relationship between co-authorship and individual research productivity. Specifically, it explored the effect of one of the potential interaction variables - the co-authorship strategy utilized by a researcher. In addition to that it analyzed the relationship between productivity and co-authorship strategy in the context of a country with less scientific capacity and in the field of cardiology. It provided

addition evidence to support the conclusions made by a prior study of the interaction between co-authorship strategy and productivity in higher education research in the US.

2.2. Social Network and Social Capital Framework

In this study the effect of co-authorship strategies on productivity was be explored using the concept of social capital and social network analysis, briefly reviewed in the next two sections. This section introduces the concept of social capital, provides an overview of social network paradigm and analysis, and explains why the conceptual framework based on the concept of social capital and social network analysis is an appropriate strategy in the study of co-authorship.

2.2.1. The Concept of Social Capital. The idea of social capital is very old in sociology. In some form or another it was explored by Tocqueville, Mill, Toennies, Durkheim, Weber, Locke, Rousseau, Simmel and Marx (Bankston & Zhou 2002; Labonte, 1999; Lazega & Pattison, 2001; Portes, 1998; Portes & Sensenbrenner, 1993; Putnam, 1995).

The contemporary understanding of the concept was introduced by French sociologist Pierre Bourdieu. Although barely relying on empirical data (Adam & Roncevic, 2003), Bourdieu's analysis remains the most systematic and comprehensive treatment of social capital (Portes, 1998).

In American sociology, the concept of social capital was introduced by Coleman, who was a sociologist with links to economics (Jackman & Miller, 1998; Li et al., 2003; Schuller et al., 2000). Coleman's most important contribution consisted in a shift from Bourdieu's egocentric dimension (social capital outcomes for individual) to sociocentric (socio capital's outcomes for groups) dimension (Adam & Roncevic, 2003; Cusack,

1999; McClenaghan, 2000). Unlike that of Bourdieu, Coleman's analysis was empirically grounded (Schuller et al., 2000).

Bourdieu defined social capital as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition"(Bourdieu, 1985, p. 248). Although the study will be based on this original definition by Bourdieu, it is important to mention that other authors provided different definitions of social capital, depending on their discipline, ideology and other substantive reasons (Dolfsma & Dannreuther, 2003; Foley & Edwards, 1997).

One way to understand the concept of social capital is by comparing it with other forms of capital. The general notion of capital was introduced by Karl Marx (2008). Marx's classical theory of capital defines capital as having two important characteristics. First, capital is a surplus value or stock and, second, it represents a result of an investment with expected returns (Lin, 1999).

Several types of capital have been identified and are widely recognized in the contemporary social sciences. *Economic capital* conventionally refers to *real or physical capital*, which means material goods that can help produce other goods in the future (Boldizzoni, 2008). It refers to machines, roads, factories, schools, infrastructure, and office buildings which humans have produced in order to produce goods and services. In financial economics, real capital is expressed in the form of the *financial capital,* i.e. monetary sums raised to operate and expand a business (Boldizzoni, 2008). In Marx's

(2008) terms, economic capital is the material surplus of production resulting from investment in the production and circulation of commodities (Lin, 1999).

Human capital was conceptualized by Schultz (1961) and Becker (1964). It represents the stock of individual competences, knowledge and personality attributes embodied in the ability to perform labor so as to produce economic value (Lin, 1999). It is accumulated via investment in technical skills and knowledge via education and experience (Lin, 1999).

Cultural capital was conceptualized by Bourdieau (1985). It refers to a stock of social competencies, i.e. knowledge of dominant cultural beliefs and values, which might promote social mobility beyond economic means. They are acquired as a result of investment in knowledge and behavioral skills as a result of socialization.

Redefining the concept of social capital using Marx's (2008) generic approach to capital, social capital represents the stock of valuable resources, such as information, influence, social credentials and reinforcement, which is formed as a result of investment of time and effort in constructing social relations (or social networks) (Lin, 1999).

Like other forms of capital, social capital can be invested with the expectation of future returns (Adler & Kwon, 2002), is appropriable (Coleman, 1988), is convertible (Bourdieu, 1985), and requires maintenance (Gant et al., 2002). Unlike economic capital, social capital is intangible in nature (Portes, 1998). While economic capital resides in people's bank accounts and other material investments and human capital is inside their heads, social capital resides in the structure of their relationships (Portes, 1998, p. 7). Further, social capital cannot be traded by individuals on an open market like other forms of capital (Gant et al., 2002; Glaeser et al., 2002). Social capital could be ultimately

reduced to economic capital (Bourdieu, 1985). Through social capital individuals can gain direct access to economic resources (eg: subsidized loans, investment tips, protected markets); or they can increase their economic capital indirectly by improving their human capital through contacts with experts or through affiliation with institutions granting credentials (Portes, 1998).

Gaining access to social capital requires deliberate investment of human and economic resources via a process, which is not formalized (contractual) and economic in its nature since it is less transparent and more uncertain (Bourdieu, 1985). The process is characterized by frequently unspecified obligations, uncertain time horizons and unguaranteed outcomes (Portes, 1998). Coleman (1988) emphasized the importance of closure for the formation of ties producing social capital. Closure means the existence of sufficient ties between a certain number of people to guarantee the observance of norms and ostracism in case of their violation (Portes, 1998). These norms are observed by all the members of the community without the need to recourse to cumbersome legal contracts (Coleman, 1988, p.99).

In his review of social capital research Portes (1998) identified four mechanisms in which social capital is formed. First, social capital emerges when one individual is willing to provide some sort of economic resource (for example, money) to another in a non-economic transaction relying on the existence of established social norms, which guarantee the return of the resource in a timely manner. In this case, the motive underlying the action of the grantor is economic in nature since he expects to obtain some economic return from the transaction.

Second, a grantor may be willing to provide access to his human or economic capital for the recipient relying on the norms of reciprocity existing among mutually familiar individuals. In this case, the motivation is not necessarily economic, the grantor may expect an unquantifiable non-economic resource (may be the one he/she is in lack of) to be returned in the future.

Third, the grantor may provide access to his resources for the recipient out of "bounded solidarity", which emerges in groups, which are bound by common fate (eg: members of an oppressed minority). In this case the motivation of the grantor is the feeling of identification with one's own group and the return is not necessarily expected.

Finally, a grantor may grant access to resources to an unfamiliar recipient because of their mere belonging to the same social structure. In this case, the motivation of the grantor is instrumental since he may expect the return to be paid back to the group and a personal benefit being derived from other members of the group in the form of prestige, status or recognition.

Claridge (2004) reviewed prior literature to identify main types of social capital. The most common distinction is between *bonding* and *bridging* social capital. Bonding is capital localized and exists within the same community between equal members (Dolfsma & Dannreuther, 2003; Narayan, 2002; Narayan & Pritchett, 1999), between members of adjacent communities or between adjacent communities (Wallis, 1998; Wallis et al., 1998). It is characterized by thick trust (Anheier & Kendall, 2002). Bridging capital is distant and emerges between distant communities or their members (Wallis, 1998; Wallis et al., 1998), as well as between unequal members of the same community

(Dolfsma & Dannreuther, 2003; Narayan, 2002; Narayan & Pritchett, 1999). It is built on thin trust (Anheier & Kendall, 2002).

Another distinction is drawn between *cognitive* and *structural* social capital (Grootaert & Van Bastelaer 2002; Uphoff & Wijayaratna, 2000). Structural social capital arises from established roles and social networks supplemented by rules, procedures and precedents (Hitt et al., 2002). Cognitive social capital emerges from shared norms, values, attitudes, and beliefs (Krishna & Uphoff, 2002; Uphoff, 1999).

The concept of social capital could be very helpful in explaining productivity gains arising from co-authorship. Co-authorship is a social relation, which can be treated as investment leading to the formation of the stock of resources comprised of the benefits of co-authorship listed above. The benefits of co-authorship cannot be freely traded on the market because they reside in the relationship itself. However, they could be transformed to economic gains in the form of higher faculty salaries.

Social capital arising as a result of co-authorship is most likely formed via the second and fourth mechanisms described by Portes (1998). If researchers are familiar from prior interactions, the second mechanism can be at play. Researchers may be willing to provide access to each others' human and economic capital (equipment and funding) in expectation of returns ensured by familiarity and trust. When the researchers are not familiar, the fourth mechanism might be used, whereby mere belonging to the same disciplinary field with its informally imposed norms and values may create trust leading to reciprocal access to each others' human and economic capital.

Since collaboration is possible within and between disciplines, as well as between previously formed tight and novel loose units of researchers, both bonding and bridging

social capital can be formed as a result of co-authorship. In addition to that, co-authorship probably involves both structural and cognitive social capital. The structural capital may arise from formalized relationships regulated by publication process prescribed by publishing venues. The cognitive capital arises from the shared norms and values of the disciplinary community.

2.2.2. Social Network Paradigm and Analysis. In social science, the *social network paradigm* emerged as a structuralist response to criticism of positivist paradigm. Unlike the earlier positivist approach in social sciences, social network approach tried to explain individual behavior as situated within and largely determined by the social context (Borgatti & Foster 2003; Freeman, 2006). Social network paradigm tries to understand human behavior not by dissecting the society into individual beings and linking the behavior to individual attributes of the participants of social interactions, but viewing the behavior as a result of complex relations among individuals (Borgatti & Foster, 2003; Freeman, 2006). It does this by reconstructing and then analyzing social networks consisting of individuals and relationships among them (Freeman, 2006), the process called *social network analysis*.

Modern social network analysis, started with the publication in1934 of Jacob L. Moreno's pioneering book on sociometry, Who Shall Survive? (Alba, 1982; Degenne & Forsé, 1994, p. 31; Freeman, 1989, p.17; Wasserman & Faust, 1994, p. 12). There had been, however, many precursors, whose contribution was extensively described by Freeman (2006). Subsequently, scholars such as S.D. Berkowitz, Stephen Borgatti, Ronald Burt, Kathleen Carley, Martin Everett, Katherine Faust, Linton Freeman, Mark Granovetter, David Knoke, David Krackhardt, Peter Marsden, Nicholas Mullins, Anatol

Rapoport, Stanley Wasserman, Barry Wellman, Douglas R. White, and Harrison White expanded the use of systematic network analysis in social sciences (Freeman, 2006).

Since social network analysis has been applied to a variety of social phenomena at various levels, a comprehensive review of its concepts, metrics and approaches would be impossible within the limits of a dissertation chapter. Several books have been previously published to fulfill the role (Carrington et al., 2005; Degenne & Force, 1999; De Nooy, 2005; Freeman, 2007; Hanneman & Riddle, 2005; Knoke & Young, 2007; Scott, 2000; Wasserman & Faust, 1994; Wasserman & Galaskiewicz, 1994). Further, only the basic concepts, metrics and methods, necessary for understanding of the research approach of this study are presented.

The object of the study in social network analysis is social behavior in the context in which it occurs. This context is conceptualized as a *social network*, defined as any bounded set of connected social units. This definition highlights three important elements of social networks: (1) social units comprising it, (2) actual or potential relations among members of the network; and (3) boundaries, delineated on the basis of some explicit criterion (Streeter & Gillespie, 1992).

Because social network analysis is concerned with relations among social units, rather than attributes of individual social units, it cannot draw independent samples, where observed individuals could be treated as representative of other individuals (Hanneman & Riddle, 2005). Observations in network analysis are relational and, consequently, are not independent of one another. Hence, network analysis utilizes census rather than sampling (Hanneman & Riddle, 2005). Network analysts can expand

the scope of their studies by replicating populations or by the inclusion of multiple levels of analysis (Hanneman & Riddle, 2005).

Social network analysis concentrates on the study of two sets of properties of social networks: structural properties and relational properties. There are some generic metrics, which are used to describe the properties in social network analysis in various trends of social research (Figure 1).

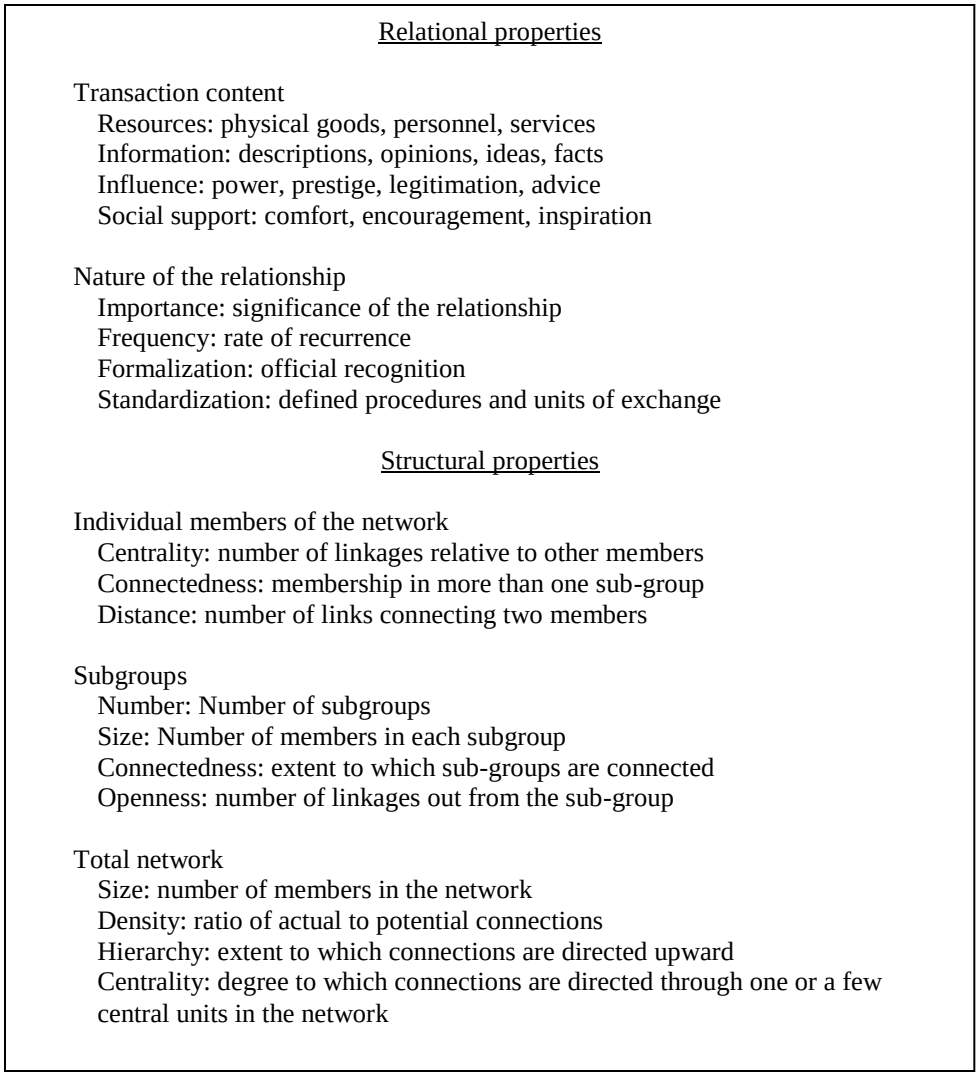

*Figure 1***.** Basic Properties and Measures of Social Networks (Streeter & Gillespie, 1992)

Relational properties focus on the content and the form of the relationship between network members (Streeter & Gillespie, 1992). Two aspects of relational properties have been studied: transaction content, and the nature of relationships (Streeter & Gillespie, 1992). Transaction content refers to what is exchanged in networks: resources, information, influence, and social support. The nature of relationships refers to the qualities of the relationship between members of the network.

Structural characteristics of networks are explored at three levels of analysis: individual members (egocentric), subgroups, and total networks (Streeter & Gillespie, 1992). Measures of individual members describe differences in the individual's connections to other members of the network and are used to define individual roles, such as star, liaison, bridge, and gatekeeper. Measures with subgroups as the unit of analysis represent the structural characteristics of clusters within the total network. Measures of total network describe the overall pattern of relations among all members of the network.[3]

Social network analysis utilizes many different methodological approaches to study the transaction and the relational properties (Streeter & Gillespie, 1992). Several authors have provided excellent reviews of various approaches to network analysis (Knoke & Kuklinski, 1982; DiMaggio, 1986; Paulson, 1985). The most generic distinction can be drawn between approaches based on graph models and matrix models (Streeter & Gillespie, 1992).

Most graphic models of networks are presented as sociograms (Figure 2), which display the relations among network members in two-dimensional space (Streeter &

[3] Figure 1 presents basic measures of social network properties for each level of analysis, as well as their definition.

Gillespie, 1992). Members of the network are represented as points or *nodes*, with lines drawn between pairs of nodes to show a relationship or *tie* between them (Streeter & Gillespie, 1992). An arrow could be used to show the direction of flow in a relationship (the graph is called directional in this case) (Streeter & Gillespie, 1992).

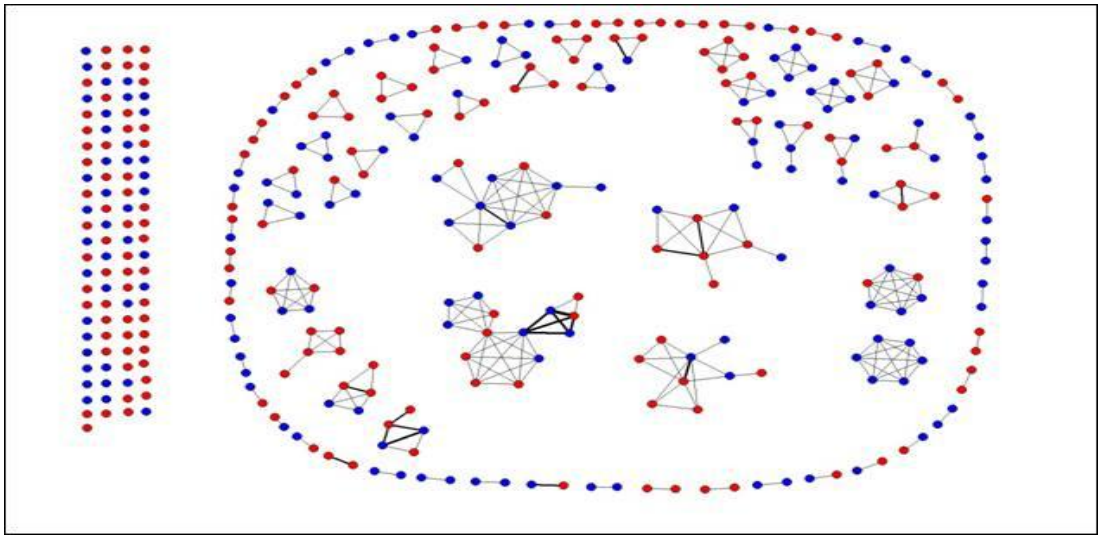

Figure 2. Sociogram (graph) of co-authorships in a journal.
Dots (nodes) represent authors. Links between dots represent co-authorship relations. Gender distinctions are represented with different dot colors. Strength of co-authorship relations (number of occurrences) is represented with the width of links.

Graphs are the most natural, visually comprehensive way to portray social structures (Klovdahl, 1981). Their main limitation, which restricted their use in this study, is that for large networks, visual displays may become so complex that they will complicate understanding of the network structure (Streeter & Gillespie, 1992).

A matrix approach, which was the main approach in this study, has recently become the dominant approach to network analysis (Streeter & Gillespie, 1992). This happened in part due to the development of computer software that makes it possible to

manipulate larger matrices (McEvoy & Freeman, 1987). A matrix (Figure 3) presents a network in the form of an array of units arranged in rows and columns. The rows represent network members and the columns represent the same set of members in identical sequence. Each cell in the matrix contains a number that represents the relationship between two members of the network.

	S.Smith	B.Brown	G.Green	W.White
S.Smith	0	2	0	4
B.Brown		0	5	1
G.Green			0	0
W.White				0

Figure 3. Example of a simple matrix representing a co-authorship network

In the same way as graphs, matrices can be used to represent not only non-directional, but also directional relations. While a matrix does not stimulate the kind of intuitive understanding that a simple graph model does, it is able to express all file information pictured in a graph model and it allows more extensive quantitative analyses (Streeter & Gillespie, 1992).

Social network paradigm is a very appropriate approach for the analysis of co-authorship. A complete picture of the publication behavior of each of the collaborating authors comes from consideration of both the individual characteristics of the co-authors

(positivist perspective), as well as from consideration of the nature of the relationships with each other and the rest of the research community (social network perspective).

Social network in co-authorship studies is the combination of all authors whether co-authoring or not, who can be treated as a population of some sort, as well as all instances of relations among them. The boundaries of the network (or population criteria) could be drawn in terms of geographic location of researchers, disciplinary fields, journals within the fields or individual institutions or departments. The networks could be graphically visualized as a set of nodes representing authors and connected with ties representing incidence of co-authorship among the authors. The ties could be numbered to reflect incidents of multiple co-authorships among authors. In addition to that matrices could also be used to represent co-authorship networks. In the matrices, rows and columns would list individual authors and numbers in cells would reflect number of collaborations among them.

Social capital interpretation of co-authorship is also compatible with social network paradigm. Social capital resulting from co-authorship can be viewed as transactional content of a social network, which is exchanged as a result of social relations among co-authors.

Finally, co-authorship relations can be studied at all three levels used in social network analysis. At the individual level of analysis, the part of the social network comprising all ties leading to and nodes linked to an individual researcher can be analyzed to understand the role that the individual plays in the field, as well as to explore the overall picture of the individual's relations with others. At the subgroup level, one might conduct an analysis to determine groupings in the network to identify key schools

of thought, subfields within a discipline, or individual, institutional, interdisciplinary, or international linkages. Finally, at the level of the total network one might explore the composition, diversity, and the generic pattern of relations for a department, journal, field, or a country.

2.3. Prior Applications of Social Network Analysis to the Study of Co-authorship

2.3.1. Social Network Analyses of Co-authorship Relations. Co-authorship has been explored using social network analysis in a number of previous studies. The studies are of four major categories defined by the applications of the findings. The categories are not clear-cut since the findings of the majority of the studies could be applied in various fields for different purposes. However, they take a different methodological and conceptual stance depending on the primary readership.

The first category of studies uses co-authorship networks to investigate general properties of networks sought by network science, a new discipline developing a unified theory of networks for a variety of fields ranging from engineering to biology. The second group of studies utilizes social network analysis of co-authorships to make conclusions for library and information science about publication and citation patterns, use of information and scholarly communication. The third category of studies applies social network analysis of co-authorships to understand various social relations to make conclusions for social sciences. The three categories of studies, explained above, are not interested in understanding of co-authorship itself; rather co-authorship is used as a proxy of social relations under investigation. For the fourth category of studies co-authorship is the focus of attention. These studies investigate co-authorship to inform science and technology and higher education policy.

Co-authorship networks are of interest for network science because they represent a prototypical case of complex evolving networks. Their analysis allows understanding of general topological features and dynamics of complex networks, the task, which is central for network science (Barabasi et al., 2002; Newman, 2001a, 2001b, 2001c; Watts & Strogatz, 1998). Newman (2001a; 2001b; 2001c; 2003) is generally cited as the first researcher, who explored general network properties using the case of co-authorship networks. Barabasi et al. (2002) and Borner et al. (2005) studied co-authorship networks to understand the changes in the topology of the type of network over time.

Social network analysis of co-authorship is widely used in library and information science, an interdisciplinary field primarily concerned with the analysis, collection, classification, manipulation, storage, retrieval and dissemination of information. Co-authorship networks were studied in the field to understand general topology, generic properties and dynamics of large information networks (Kretschmer, 2004; Liu et al., 2005; Nascimento et al., 2003; Otte & Rousseau, 2002; Rodriguez & Pepe, 2008; Yin et al., 2007). The analysis allows researchers in information science to identify emerging disciplines, to determine key journals and researchers, to draw conclusions about characteristics of individual journals, such as the geographic distribution of contributors, as well as to infer database design principles. Few studies in this category (Li-chun et al., 2006; Yan & Ding, 2009) explored co-authorship networks at the micro level to capture the features of the individual actors in order to apply them for impact analysis.

Social network analysis of co-authorship has been also used in social sciences with the goal to understand social phenomena. One example is Fafchamps et al. (2006) investigation of co-authorship network in economics in search of insights for

understanding of the production of knowledge externalities via collaboration, which is important in the field of growth economics. Menezes et al (2009) utilized social network analysis of global co-authorship network in computer science to explain the formation of disciplinary subfields and to draw conclusions for sociology of science. Moody's (2004) explored co-authorship network in sociology with a similar purpose in mind.

Social network analysis has been previously used to understand co-authorship itself as a type of research collaboration. Co-authorship networks were used to analyze collaboration at the individual, disciplinary, national, and multinational levels.

At the disciplinary level, Eaton et al. (1999) examined the relation between author productivity and the network structure of co-authorship in global consumer behavior research. The analysis revealed a positive link between co-authorship and author productivity and reconstructed a macro network of most influential and less influential authors. The study, however, did not control for important variables, including gender, rank, access to grant funding, and age. Further analysis showed a relation between publication productivity and an author's position in the macro network. Lorigo and Pellacini (2007) conducted a similar analysis for physics, while Acedo al. (2006) implemented such an analysis for management.

At the multinational level, Wagner and Leydesdorff (2003), as well as Glanzel and Schubert (2004) used international co-authorship data to map co-authorship relations between nations. The authors mapped the network to determine core members (countries) in the global network, to identify regional networks and emerging hubs within them.

At the national level, Gossart and Ozman (2007) used social network analysis to

explore co-authorship patterns for a specific country - Turkey. Durbach et al. (2008) reconstructed co-authorship networks for chemistry and mathematics in South Africa.

As has been mentioned previously, few studies have been conducted that would explore the effect of co-authorship strategies on the association between co-authorship and research productivity. Among the studies utilizing social-network analysis, only three papers were directly or indirectly concerned with the role of co-authorship strategies.

Although not using social network analysis explicitly, Porac et al. (2004) essentially used social network paradigm and many of the ideas from the previous studies of scientific collaboration from the social-network perspective to analyze the effect of the type of collaboration within a team on research productivity. In other words, their paper did not directly assess individual co-authorship strategy and its effect on research productivity, but it did this indirectly by exploring the effect of team structure on team productivity. The researchers implemented a mixed-method case study of two research teams, which represented two ends of a theoretical continuum: dense homogenous teams, which included individuals from similar disciplines and prior experience of work with one another; and loose heterogeneous teams, which included individuals from diverse fields with no prior research collaboration experience with one another. The study provided clear evidence that the second type of teams is characterized by greater research productivity measured in terms of number of publications.

Rumsey-Wairepo (2006) completed a doctoral dissertation explicitly addressing the question of how different co-authorship strategies affect productivity. She assumed that a co-authorship strategy would correspond to a network structure (a specific configuration of ties and nodes) in network analysis. Based on a literature review, she

then identified two competing social network structures that she referred to as "the structure of cohesion" and "the structure of structural holes", which have been theorized to create social capital. The nature of collaboration in the structures is similar to collaboration in the two types of teams in Porac et al. (2004). Using social network measures of constraint and efficiency, which are used to identify the structures, she hypothesized seven co-authorship strategies. She then explored to what extent the strategies are present in the co-authorship networks in higher education research in the US and tested the effects of each of the strategies on research productivity.[4] The finding was consistent with the finding of Porac et al. (2004): the structure of structural holes, which was characterized by relations similar to the ones in loose heterogeneous teams, was more productive than the structure of cohesion.

Most recently, Hill (2008) tried to investigate the relationship between social network structures in co-authorship network and research productivity. Based on the review of prior literature in social network analysis, she chose the measures of eigenvector centrality (extent of being connected to influential members of the network), betweenness centrality (extent of importance in connecting other members of the network), as well as the E-I Index (measure of dominance of external over internal ties in organizational subunits) to describe potential structures in co-authorship network. She then used publication data from tenured faculty in a computer science department in a US university and statistically tested the association between each of the measures and research productivity. Hill (2006) found that E-I index and betweenness centrality are significant predictors of publication rate. Given the fact that both these measures

[4] More details of the study are provided in the next section.

correspond to the bridging strategy, the results are consistent with findings by Rumsey-Waipero (2006). The main limitations of Hill's (2008) study is that unlike Rumsey-Waipero (2008), she did not explicitly classified strategies based on the network measures.

In summary, social-network analysis and the concept of social capital have been successfully used in the analysis of co-authorship in the past, which provides additional evidence that the conceptual framework is appropriate for a study of the relationship between co-authorship strategy and research productivity. However, only one study by Rumsey-Wairepo (2006) has attempted to apply the conceptual framework to explore the relationship between co-authorship strategy and research productivity directly. The study was based on a novel approach applying social network measures to classify and empirically identify co-authorship strategies; hence, the conclusions of the study have to be re-tested by other studies based on a similar methodology.

In this study, the approach developed by Rumsey-Wairepo's (2006) for the analysis of the impact of co-authorship strategies on individual productivity of researchers in higher education in the US will be applied to a different field (cardiologic research) and/or context (Russia). The study will test whether the relationship between certain types of co-authorship strategies and individual productivity is the same fpor cardiologic research in Russia. In addition to that, the study will conduct a sensitivity analysis for Rumsey-Waipero's (2006) methodology.

The next section provides details of Rumsey-Wairepo's (2006) methodology for classification and empirical identification of co-authorship strategies and is followed by a

section providing justification for the choice of Russian cardiologic research as a setting for re-testing Rumsey-Wairepo's (2006) approach.

2.3.2. Ramsey-Wairepo's (2006) Method for Classification and Empirical Identification of Co-authorship Strategies. Rumsey-Wairepo's (2006) exploration of the effect of various co-authorship strategies on research productivity is based on the assumption that the strategies correspond to the structure of ties that characterize an egocentric network, i.e. a network of an individual authors. She noted that such structures might be unconsciously constructed by the majority of authors; however, if the authors learn about the differential effects of the structures on research productivity, they could strategically choose the structures in building their co-authorship portfolio.

Reviewing prior literature on social network analysis, which is summarized further, Rumsey-Wairepo (2006) noticed that although sufficient evidence has been collected by now to demonstrate the importance of social ties for an individual, there is much less agreement about what kind of ties or their configurations (or network structures) are most productive in creating social capital. Specifically, there seem to be two competing views on the matter.

Coleman (1988) argued that social capital arises primarily from cohesion, which facilitates trust and cooperation between individuals. Social capital arises in cohesive communities through such processes as establishing obligations, expectations and trustworthiness, creating channels for information, and setting norms backed by efficient sanctions (Coleman, 1988).

A cohesive network (Figure 4) is characterized by several social network measures developed by Burt (1992). First, it has high density, meaning ego (or an

individual focal node (Hanneman & Riddle, 2005) is connected to others who are also connected to one another. It is also characterized by high mean strength of ties, i.e. two egos tend to have multiple contacts with one another using the same tie. Finally, the cohesive network includes a small number of nodes. Cohesion is also characterized by high constrain, a complex social network measure, developed by Burt (1992), which is taking into consideration all the preceding measures.

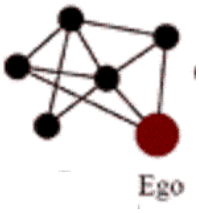

Figure 4. Ego network with cohesive (strong) ties

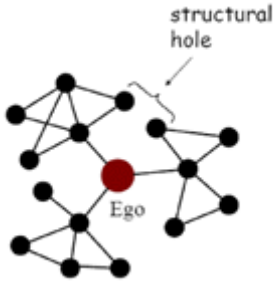

Figure 5. Ego network with weak ties

In the case of co-authorship networks, cohesion might exist in small groups of co-authors, who regularly write papers with one another. Greater research productivity may arise in such groups because, as a result of multiple co-authorships, members of the group know each others' strengths and weaknesses and can effectively distribute responsibilities, as well as because they can trust each others' judgment in fulfilling the assigned task, thus saving effort and time in the process of mutual review. In addition to that, being a part of a closely knit circle with informal norms of communication prevents free-riding and encourages mutually beneficial behavior, such as citing each others' work in publications. Finally, repetitive co-writing creates clear and efficient communication

channels among the researchers, thus also saving effort and time on maintaining contacts and clarification of ideas and approaches.

Coleman's (1988) view was criticized in subsequent research by Granovetter (1973), Portes (1998), Burt (2000) and Baron et al. (2000). These authors believe that cohesive, also referred to as strong ties have a number of disadvantages, including lowered flexibility, which undermines innovativeness, as well as the extra effort, time and money, which they require for maintenance. In addition to that, strong ties result in social capital when they are relatively stable and their stability decreases as additional players are added to the social structure.

As an alternative to Coleman's (1988) explanation, Burt (1992) suggested that social capital results from the brokerage opportunities created by diverse weak ties. An individual who has an ego network with weak ties bridges a multiplicity of structural holes, i.e. places in the network, where potential ties do not exist. Hence, he/she serves as a buffer or insulator in electric circuits in which actors are not connected. As a result, the network structure is full of non-redundant contacts, which provide additive rather than overlapping benefits (Burt, 1992).

Several advantages characterize an ego network with weak ties. Having extended ties allows the individual bridging structural holes to have better access to information, diverse human and financial capital of other people, and opportunities. Moreover, a person bridging structural holes connects people, who otherwise would not have access to each other, and, hence, derives power and influence from serving the buffer role. Being exposed to a variety of contacts also results in greater visibility of the individual, and, consequently, a greater chance that he/she would be recalled and called for at the right

moment and will have useful information very early, thus receiving a competitive advantage (Burt, 1992). Benefits are also found in that more innovative solutions are to be expected from the social capital of bridge relationships (Burt, 2000). Burt (1992) also notes that having weaker ties with many different actors, can alleviate some of the relational investment necessary to sustain the level of closeness necessary for cohesion.

Burt (2001) does acknowledge one drawback of weak ties in that there can be more difficulty with team communication and coordination. Structural holes between people in a group can weaken in-group communication and coordination, which also weakens the group's ability to take advantage of brokerage beyond the group (Rumsey-Wairepo, 2006).

In terms of structural characteristics, a network with many structural holes (Figure 5) is characterized by a lower density and a lower mean strength of co-authorship ties (Burt, 1992). It also includes ties from the ego (person under analysis) to multiple other co-authors, i.e. it is large in size (Burt, 1992). Finally, a network with structural holes has a high value of efficiency (or non-redundancy), another Burt's (1992) complex measure taking into consideration size, density and mean strength of ties to identify the extent of presence of structural holes. It is important to mention here that by efficiency, Burt understood non-redundancy of ties that an individual under analysis built with other members of the social network.

A researcher demonstrating an egocentric network of structural holes would have an extended network of contacts with whom he/she co-authors only once. The researcher's co-authors would be expected to be very different in their conceptual and methodological background, sometimes from related rather than the same fields and lines

of inquiry. It could be hypothesized that researchers with egocentric networks with many structural holes would have greater productivity compared to researchers with fewer structural holes, because they would be more likely to come across very novel ideas or work in interdisciplinary areas bringing together a co-authoring team with diverse backgrounds. They would also have greater productivity because they would be cited by a large number of contacts publishing in diverse journals, thus increasing the researcher's visibility and the chances that the work will be cited by people outside the network. They would also have better access to resources and innovative ideas because of their extended set of contacts.

Relying on the two prototypical types of tie configuration, which have been hypothesized to be accountable for the creation of social capital, as well as on the social network measures of constraint and efficiency developed by Burt (1992), Rumsey-Wairepo (2006) developed a classification of co-authorship strategies (Figure 6). Overall, seven strategies were suggested (Table 1). The *isolate strategy* is used by researchers, who always publish alone. *Dyadic strategy* is used by researchers working exclusively in pairs with the same researcher or different researchers each time. These two strategies had to be treated as separate categories because Burt's (1992) measures can be applied only to social networks involving more than two individuals. Rumsey-Waipero (2006) defined c*ohesive strategy* as one characterized by a high value of constraint and low value of efficiency. *The* s*tructural holes* strategy was defined as the one characterized by low constraint and high efficiency. *The independent strategy* was defined as being characteristic for configuration of ties with low values for both measures, while *the complex strategy* referred to a strategy characteristic for tie

configurations with high values of both measures. *The middle strategy* was defined as the middle ground, where the configuration is average in both efficiency and constraint.

Table 1.

Characteristics of strategies

Strategy	**Characteristics**	**Type and amount of social capital**	**Network measures**
Isolate	Researchers who always write articles alone	No social capital	Not applied
Dyadic	Researchers who write articles exclusively with one other exclusive author	Much bonding social capital	Not applied
Bonding	Researchers who write exclusively with a relatively small exclusive group of authors	Much bonding social capital	High constraint and low efficiency
Bridging	Researchers who write with as many different authors as possible serving as a broker, i.e. write in such a way that via the co-author they obtain a non-redundant access to new groups	Much bridging social capital	Low constraint and high efficiency
Independent	Researchers who write with others, but seldom with the same people and often with several people belonging to the same group	Neither bonding nor bridging, but some other type	Low constraint and low efficiency
Middle	Researchers who write with others in such a way that at times co-authorship with an exclusive group may occur several times, though less frequently than is typical for other members of the group, and who sometimes may serve as a broker	Some bonding and some bridging	Medium constraint and medium efficiency
Combination	Researchers who are simultaneously active members of an exclusive group(s) and also actively engage in brokerage.	Much bonding and much bridging	High constraint and high efficiency

In her study, Rumsey-Wairepo tested to what extent each of the hypothesized strategies are present in the co-authorship network in higher education research in the United States and also explored the association of each of the strategies with research productivity of individual authors measured in terms of number of publications . She found that each of the hypothesized strategies are possible, although most authors chose

to write alone, in pairs or in cohesive groups. Figure 7 below presents the actual distribution of authors across strategies found as a result of her study.

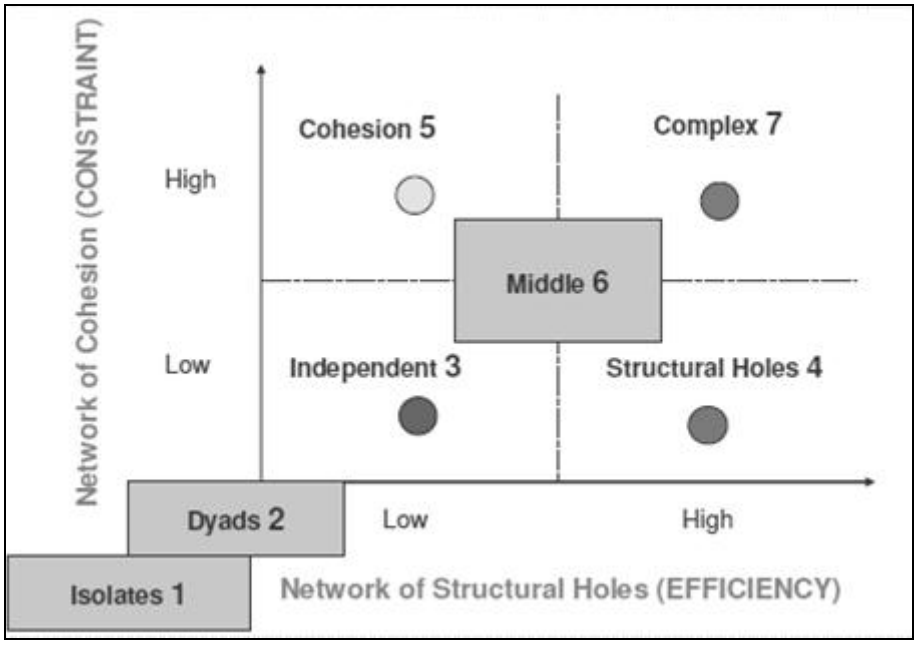

*Figure 6***.** Co-authorship network structures *(Rumsey-Wairepo, 2006)*

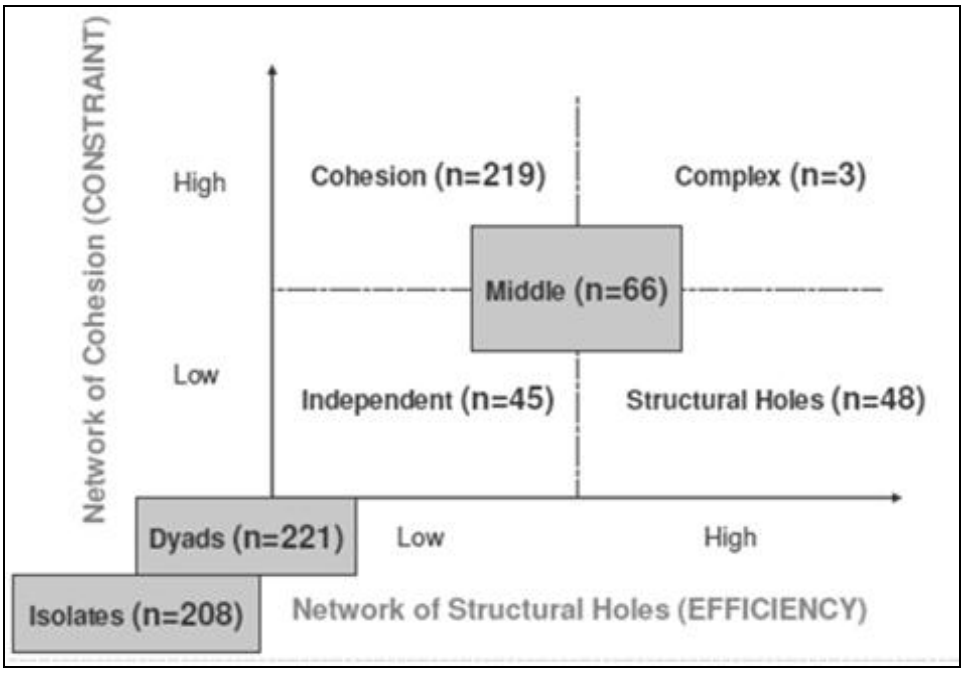

Figure 7. Distribution of authors in co-authorship network structures found in Rumsey-Wairepo (2006)

With regards to the productivity effects of various co-authorship structures, Rumsey-Wairepo (2006) concluded that the most productive strategy is complex, however, it is also the most challenging in implementation, judging from the number of authors that actually utilize it. The data suggested that maintaining close contact with some of the authors was important for realizing the potential buried in structural holes (Burt, 2001). The second productive strategy is that of structural holes.

Although it should be acknowledged that Rumsey-Wairepo's (2006) strategy succeeded in incorporating the competing social network theories explaining the sources of social capital, it could benefit from minor corrections. Specifically, the use of the labels "bonding" and "bridging" is suggested for cohesive and structural holes strategies correspondingly, which would correspond to two types of social capital created by the

strategies. The problem with the labels used by Rumsey-Wairepo (2006) originates from the fact that Burt (1992) has not suggested a parallel alternative to Coleman's (1988) "cohesion". While Coleman (1988) used the term "cohesive" to describe the nature of social ties, the word "structural holes" is used by Burt (1992) to describe absence of such ties in a social network. Hence, the two labels used by Rumsey-Wairepo (2006) are not parallel. The problem is resolved by replacing them with existing parallel labels, used to describe corresponding types of social capital created by the competing configuration of ties. The label "complex" has also been replaced with the label "combination" because, according to Rumsey-Wairepo (2006), a researcher using this strategy combines bonding and bridging strategies. Figure 8 summarizes the adapted visual representation of strategies based on Rumsey-Wairepo (2006), which was used in this study. Table 1 provides a lay description of the characteristics of the strategies.

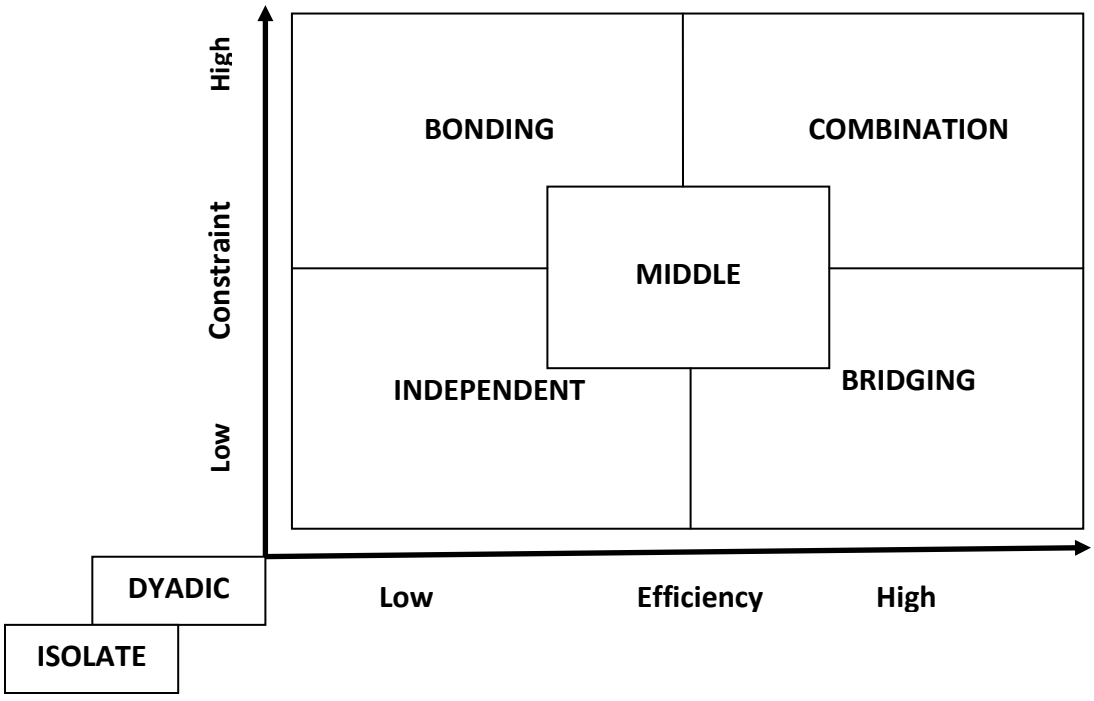

Figure 8. Adapted classification of co-authorship strategies

2.4. Justification for the Choice of Russian Cardiology as Settings for the Study

Given the need to re-test Rumsey-Wairepo's findings in the context of a different country and for a different research field, this study will explore social network of co-authorship in the field of cardiologic research in Russia. The choice of the country and of the research field was not accidental. The reasons for the choice are provided below.

Russia represented an interesting case for the analysis for several reasons. Russia is recognized as a scientifically-proficient country with an advanced scientific expertise in many disciplines at the basic and applied level (Wagner, et. al., 2001). It has developed a research publication industry. In 2007, Russia was ninth in the world in number of research journals (Ryabchuk, 2007). These characteristics of Russia imply that, first, Russia has a high level of research activity and, consequently, large co-authorship networks in many fields and a potential for manifestation of the complete set of the theoretically proposed co-authorship strategies. The second implication is that due to availability of recognized journals in the country, a substantial number of researchers could be expected to publish domestically rather than submit their publications abroad.

The second rationale for the choice of Russia was connected with the high probability that the co-authorship networks in the country are relatively complete and representative of the pool of researchers in the country. In case of other scientifically proficient countries, such as India or China, the fear was that a large share of talented researchers would prefer submitting their articles to journals abroad. As a result, even if they submitted some of their articles to the local journals, their productivity would be underestimated by using the total number of their publications in the local journals. The Russian scientific enterprise is still relatively closed and underfunded at the individual

level and in many fields Russian researchers do not actively submit their articles to journals outside the country (Russian science, 2007; Schiermeier, 2007). In addition to that, among BRIC countries, Russia is ahead of only Brazil in terms of number of publications in international scientific journals (Radio Free Europe, 2010).

The choice of cardiologic research can be justified on three grounds. One reason was the desire to look at the relationship between co-authorship and productivity in a field where such relationship has not been explored before. In fact, to our knowledge, no prior studies have been conducted on the effect of co-authorship on individual productivity in any of the medical fields. Hence, investigation of the relationship in cardiologic research would provide an insight in the medical domain in general.

Second, the decision to investigate the relationship in the medical field was determined by the desire to test the framework developed by Rumsey-Wairepo (2006) on a field, where the relationship between co-authorship and productivity could potentially play out differently from the way they work in higher education research representing the social sciences domain. As has been explained before, prior research showed that scientists in natural sciences have different characteristics from those in the social sciences in terms of preference for co-authorships, an average number of co-authoring contributors per article citation, and frequency of participation in international collaborations (Frame & Carpenter, 1973; Laband & Tollison, 2000; Luukkonen & Sivertsen, 1992; Zuckerman & Merton, 1973). It was assumed that the medical domain would more similar to natural sciences domain in this respect and would, therefore, represent a good counterexample to social sciences in testing Rumsey-Wairepo's (2006) framework.

In addition to that, one of the methodological requirements for social network analysis is boundedness of the analyzed population. In the context of research on co-authorship, this would mean that the set of publications/researchers included in the analysis would be complete for the field analyzed. If not all publications or researchers are included, one cannot be sure that the included publications accurately represent an author's productivity. For example, if researchers in a country actively publish abroad, one cannot accurately represent their productivity by including only domestic publications because very productive researchers could publish predominantly abroad/ There is prior evidence that medical fields of research are relatively closed in Russia due to nationally specific methodological approaches and lack of knowledge of the English language among the researchers (Goldberg et al., 1997). Based on this evidence, it would be safe to assume that a social network of cardiologic research in Russian would be complete and would generate accurate estimations of productivity.

2.5. Summary of Chapter Two

This chapter has presented a review of the literature on co-authorship as a collaborative research strategy. The review indicates that prior research has provided strong empirical evidence that co-authorship is becoming an important approach to research publication across disciplines and geographic boundaries. Sufficient understanding has been achieved of the costs and benefits of co-authorship. However, not much evidence has been collected in support of the dominant explanation of the phenomenon of growing co-authorship: the assumption that co-authorship increases research productivity has been supported by very few studies. Critics of the studies on the effects of co-authorship on research productivity have also indicated that the studies fail

to consider the effects of various interaction variables that might confound the relationships between co-authorship and productivity.

This chapter has also introduced the concept of social capital and social network paradigm and analysis, as well as explained how they could be used to explain and explore the co-authorship's effect on research productivity. In short, benefits of co-authorship could be viewed as social capital arising from social interactions among co-authors.

Social network paradigm and analysis have been used before to explore the structure of social relations and to account for various amounts of social capital. Some studies used social network analysis to explore social capital arising from co-authorship. However, only one study by Rumsey-Wairepo (2006) has adapted social network analysis methodology to study the difference in the amount of social capital arising from different co-authorship strategies. This study explored the difference in the context of higher education research in the US.

Research on co-authorship would benefit if Rumsey-Wairepo's (2006) approach was utilzed in other studies, exploring the relationship between co-authorship strategies and research productivity in different geographic contexts and disciplinary fields. This chapter has provided some evidence indicating that Russia would be an interesting context for the exploration of the effect of co-authorship on research productivity. It also showed why cardiologic field in Russia presents an interesting disciplinary context.

In general, the review of prior literature summarized in this chapter provided evidence of the timeliness and importance of this study, which explored the effect of various co-authorship strategies on individual research productivity in Russian

cardiologic research using social network analysis and the concept of social capital. It also allowed formulating the following research questions addressed by the study:

1. To what extent are various co-authorship strategies present in the field of cardiologic research in Russia?
2. How do these co-authorship strategies affect the research productivity of the authors measured by the total number of publications in selected Russian journals?
    (a) Is there any significant difference in research productivity between authors using different co-authorship strategies?
    (b) How each of the strategies performs in terms of its effect on research productivity compared with other strategies?
3. To what extent do the results of the study depend on the assumptions and the method used for reconstructing the network?
    (a) What is the extent of publishing in other domestic and international journals for researchers included in the study, who are using different co-authorship strategies and having different levels of productivity?
    (b) How is productivity of researchers using different strategies and having different productivity domestically changed when their publications in international and other domestic journals are taken into account?

CHAPTER 3: METHODOLOGY

This chapter describes the design of this dissertation research, i.e. it provides a description of the data sources, of the sampling procedure, and of the data collection and data analysis methods. In general, the study was organized in three phases, which have different goals, answer different research questions, and utilize different data collection and data analysis approaches. Therefore, the chapter is organized in three sections, each presenting a description of goals, stating relevant research questions, and presenting the methods for one of three phases of research.

3.1. Overall Study Design

The approach used to answer the research questions of the study drew from the methodological approach employed by Rumsey-Wairepo (2006). The methodology was modified to reflect (1) a different source of data (Information about co-authorships was obtained by searching records on pre-selected Russian journals in the Web of Science vs. by searching actual journal publications); (2) a different field of research (cardiology vs. higher education) represented by an alternative set of journals; (3) a different research context (Russian vs. the US) represented by an alternative set of journals; and (4) the addition of the third research question pertaining to sensitivity of the method to different set of assumptions.

The study was conducted in three phases. During the first phase, social network analysis was used to reproduce the co-authorship network in cardiologic research in Russia with the goal to identify co-authorship strategies of each of the authors, and, thus to collect data for the second phase.

During the second phase, statistical analysis was used. The statistic analysis had two goals. First, descriptive statistics were obtained to determine the distribution of researchers across co-authorships strategies. Second inferential methods were applied to examine the relationship between various co-authorship strategies (represented by co-authorship network structures identified during the first stage) and research productivity measured as the number of publications by researchers. The second phase was intended to answer the first two research questions.

During the third phase, sensitivity analysis was performed with the goal to determine whether strategies identified during social network analysis phase would hold under a different set of assumptions. The third phase was intended to answer the third research question.

3.2. Phase I: Social Network Analysis

The goals of the first phase was to reproduce the co-authorship network present in the top cardiologic journals in Russia, to determine the types of co-authorship structures for each of the authors in the network and, thus, to collect data necessary for the second stage of the analysis.

The boundary of the target population of cardiologic researchers was determined by identifying top peer-reviewed journals in cardiologic research in Russia. Three journals were chosen for inclusion: *Cardiology* (Kardiologiya), *Cardiovascular Therapy and Prevention* (Kardiovaskylyarnaya Terapiya i Profilaktika), and *Russian Journal of Cardiology* (Russkii Zhurnal Kardiologiyi). These three journals were selected because they were identified as top publications in cardiologic research in Russia by the ISI Web of Science and were also listed as the key journals for publication of research articles on

the website of the Russian Scientific Society of Cardiologists (Vserossiiskoe Nauchnoe Obshestvo Kardiologov) *http://www.cardiosite.ru.*

The authors and co-authorships for inclusion in the network were selected using the ISI Web of Science. Specifically, the advanced search option was used to select all articles from the three journals for the period of six years (2004-2009), which was assumed to be sufficient for researchers to demonstrate their co-authorship strategy. Only scholarly articles and articles indicating Russia as the country of origin were included in the analysis. Subsequently, the list of authors and articles was imported to a Microsoft ACCESS database in the form of a text file.

In the ACCESS database, several queries were run on the table produced from the exported text file containing lists of authors and publications. The main goal of the queries was to determine each of the author's productivity (count of articles) and an edgelist, i.e. a table recording absence or presence of co-authorship ties (representing an instance of co-authorship) between all possible pairs of authors in the database. The resulting edgelist was imported in the form of a text file into the UCINet software (Borgatti & Everett, 2006), which is a special software used for analysis of network structures.

Data analysis in the UCINET was focused on egocentric network structures of each of the authors in the study. The analysis was aimed to determine which of the seven co-authorship structure types adapted from Rumsey-Wairepo (2006) (Figure 8) each of

the authors in the study had.[5] These network structures were categorized into types using measures of constraint and efficiency, representing cohesion and structural holes respectively.

Constraint is a special measure developed by Burt (1992) to determine the extent to which a person's contacts are redundant (Burt, 1992) or connected to others who are also connected to one another. Burt (1992) developed the measure of constraint based on the observation that in cohesive network structures actors who have many ties to others may actually lose freedom of action rather than gain it or, in other words, become constrained -- depending on the relationships among the other actors (Hanneman & Riddle, 2005). Therefore, "more constraint means fewer structural holes" and "more network closure" (Burt, 1997, p. 347) or cohesion.

Efficiency is another measure developed by Burt (1992). This measure is an indicator of structural holes. It determines the extent to which an actor's ties are non-redundant or not connected to the actor's other contacts. Greater efficiency represents a greater extent of bridging structural holes and less cohesion.

Categorization of co-authorship network structures into seven hypothesized strategies was done in the following way. First, using the edgelist (table of ties between researchers) imported from the Excel file, UCINET automatically reconstructed individual social networks (egonetworks) of each researcher. After application of a set of specialized instructions, the program then produced a set of network measures, including

[5] As has been noted in the preceding chapter, Rumsey-Wairepo's (2006) labels of the co-authorship strategies have been slightly modified based on prior research, so that cohesive strategy was renamed into bonding strategy and structural holes strategy was renamed into bridging strategy.

size, constraint and efficiency of all ego networks. [6] The resulting UCINET output was imported to Microsoft Excel in the form of a text file and the results were further compiled into a single table containing information about author's name, network size, and the measures of constraint and efficiency.

Further, several manipulations were made with the Excel table to obtain the list of authors and their strategies. First, all isolates and dyads were identified using special queries in ACCESS and extracted from the Excel table. These lists of authors were saved in a separate spreadsheet as isolates and dyads respectively.

Second, a list of authors using Middle strategy was generated by (1) trichotomizing the range of constraint and efficiency (calculated by the UCINET program) into Low, Middle and High with "percentile" formula in Excel; (2) filtering out all records with the values of constraint and efficiency falling in the second third (Middle) of the corresponding ranges. The resulting list was then copied to a separate sheet, containing a list of resulting strategies, and all records of authors with middle strategy were removed from the original Excel table, which was used for analysis.

Finally, to determine who of the remaining authors used independent, complex, bonding and bridging strategies, the following procedures were run in Excel. First, using the original table, containing isolates, dyads, and the middle strategy, the middle of the ranges for constraint and efficiency were calculated using "median" formula in Excel. Second, the values of constraint and efficiency were then recoded using a logical formula in Excel into "Low" or "High" depending on whether they fell below or above the middle

[6] Specifically, Network->Ego Network ->Basic Measures path of computer commands was used to obtain the size of ego networks of each individual author; and Network->Ego Network-> Structural Holes command was used to determine the measures of constraint and efficiency.

of the range. The records remaining in the Excel table without isolates, dyads and the middle strategy were then sorted into the remaining four strategies using filters on constraint and efficiency columns. The settings of the filter "Equals Low" for both measures corresponded to independent co-authorship strategy. The settings "Equals High" for both measures corresponded to complex co-authorship strategy. The settings "Equals Low" for efficiency and "Equals High" for constraint corresponded to bonding co-authorship strategy, while the reversed filter settings were used to determine authors with bridging strategy. The lists of authors produced by filtering were then copied to separate spreadsheets. Finally, the duplicate spreadsheets containing lists of authors in each strategy were compiled into a single file listing all authors, their strategies, social network measures and productivity. This sheet was used in the statistic analysis during Phase II.

In addition, to increase the validity of the categorization, a graphic analysis of the ego networks was implemented for randomly selected 50 authors (out of the total of 2,666) using E-Net software (Borgatti, 2006). The software visualized egonetworks of individual researchers. The network shape, size (number of nodes) and density of ties were visually assessed to determine to what extent the visual representation resembled a prototypical isolate, dyadic, bonding or bridging structure (or a combination of the two).

3.3. Phase II: Statistic Analysis

The goal of the statistic analysis was to answer the first two research questions of the study. The first research question - *To what extent are various co-authorship strategies present in the field of cardiologic research in Russia?* - was answered by

analyzing descriptive statistics. The primary descriptive statistics of interests was the number of authors utilizing each of the proposed co-authorship strategies.

The second research question - *How do these co-authorship strategies affect research productivity of the authors measured by the total number of publications?* – was originally planned to be answered by utilizing the classical analysis of variance (ANOVA) with post hoc multiple comparisons. The dependent variable in the ANOVA model would be mean number of publications in the groups utilizing different co-authorship strategies (measure of research productivity). The main independent (or treatment) variable would be types of co-authorship structures (or strategies)[7] identified during Phase I.

The originally planned ANOVA analysis included two stages. The first part of the research question - *Is there any significant difference in research productivity between authors using different co-authorship strategies?*- was supposed to be answered with an omnibus test, testing the complete null hypothesis stating that there is no difference in the mean number of publications between groups of authors utilizing different co-authorship strategies.

The second part of the question - *How does each of the strategies perform in terms of its effect on research productivity compared with other strategies?*- was supposed to be answered with post-hoc multiple comparisons of mean numbers of publications of groups of authors utilizing various co-authorship strategies. The post-hoc procedure was chosen over a priori analysis because comparisons among all means were necessary for the purposes of this study and there was no prior information to determine

[7] The strategies were recoded into integers prior to the statistic analysis.

which of the means were most likely to differ (Rumsey-Wairepo findings were not informative for a different disciplinary and national context).

In reality, the data obtained as a result of Phase I were non-parametric. Specifically, it failed to meet both the normality and homogeneity of variance assumptions. As a basic strategy to deal with outliers the data were checked for errors during data entry and exporting from one software to another. No such errors were found.

The second alternative was to use robust ANOVA tests. However, the relevant robust tests - Welch for omnibus test and Tamhane2 for the post-hoc procedure - could produce inaccurate results since both normality and homogeneity assumptions are violated.

As a third step, several data transformations (square root, cube root, logarithmic, inverse, and sine) were attempted to achieve either normality or greater homogeneity. The data were found to be insensitive to the transformations.

Trimmed-means based procedures were considered as the next alternative. The alternative was discarded because (1) trimmed-means tests are considered controversial (Keselman & Zumbo, 1997; Mallows & Tukey, 1982); (2) "throwing away" some data points could result in the loss of the most interesting cases for this analysis – the most and the least productive researchers; (3) there was no reason to assume normality and homogeneity in the population distribution; moreover, due to the large size of the sample, it would be safer to assume that the population has the same distribution that the sample does.

Another alternative would be to use a non-parametric procedure - Kruskal-Wallis test for omnibus hypothesis combined with Mann-Whitney test for post-hoc pairwise

comparisons, in this case. This procedure required the data to be at least homogeneous in variance, and, therefore, was thought to be less appropriate than a resampling approach.

The inferential strategy, which was identified as the most appropriate for the nature of the data was resampling, specifically, bootstrap ANOVA (Efron, 1979, 1981, 1982). The procedure does not make normality and homogeneity of variance assumptions about the underlying population. Instead, it approximates the actual population by resampling with replacement from the original sample and makes inferences based on this approximated population. Although bootstrap ANOVA would be the best approach for the data obtained, in practice, robust ANOVA, non-parametric ANOVA and bootstrap ANOVA were conducted and results were compared to validate the results.

3.4. Phase III: Sensitivity Analysis

The nature of social network analysis requires the use of bounded populations. In this study the population was bounded by including only articles from the three cardiologic journals and with Russia as the country of origin. As a result of such an approach, the publication profile and the co-authorship strategy of some of the authors publishing in other cardiologic journals inside and outside of Russia might not be accurately reflected. Some researches might demonstrate one strategy publishing domestically or when publishing in the three chosen journals and another strategy when involved in international collaboration or when submitting articles to other domestic journals. In addition to that, some authors shown as unproductive using Rumsey-Wairepo (2006) methodology might be very productive when their complete publication profile in all domestic and international journals is considered.

Unfortunately, it would be impossible to check whether co-authorship strategy changes if one considers complete publication profile of all the authors. Since each author publishes in a different set of journals, the complete set of journals to be included in the social network analysis would be very large. If the researcher network were constructed from all the journals, its size would be unmanageable for social network analysis software.

The goal of the sensitivity analysis conducted during Phase III was to test whether results obtained using Rumsey-Wairepo's (2006) method would hold if, instead of estimating productivity as the total number of publications of an author in the three cardiologic journals during the period of six years, one estimates productivity from the total publication record of a researcher. Pursuing the goal, the third phase of the research intended to answer the third research question of the study - *To what extent do the results of the study depend on the assumptions and the method used for reconstructing the network?*

The analysis was conducted in the following way. First, a new small sample was created from the original social network population, which included authors with different strategies and levels of productivity. In each co-authorship strategy group, authors were divided into those with high and low productivity levels. In order to do that, median productivity was calculated using the Excel file from Phase I. Productivity value was then recoded into "High", if it was above the median, and into "Low, if it was below the median. Ten researchers were randomly selected in each co-authorship strategy group in such a way that five of the researchers were from the low productivity group and five researchers were from the high productivity group. The total number of the resulting

random sample was expected to be 70 researchers (7 strategies X 2 levels of productivity X five researchers), however the final sample consisted of 68 researchers because in two strategies there were fewer than five authors with certain levels of productivity. The size of the sample was relatively small compared to the number of researchers in the bounded population. The size of the sample was limited due to the time consuming nature of exploring individual profiles. It was assumed, however, that the random nature and the stratified structure of the sample will produce results that would be representative of the larger population.

A search was then implemented in the ISI Web of Science for each of the authors in the new sample to obtain their complete cardiologic publication record. The results of the search were extracted to Excel file and combined with the data on productivity and publication strategy obtained during Phase I.

To answer the first part of the research question - *What is the extent of publishing in other international and domestic journals for researchers using different co-authorship strategies and having different levels of productivity domestically?* – separate counts of additional publications in the journals included in the analysis, as well as counts of other international and domestic journals were obtained for each author in the sample. The counts were then compared between researchers using different co-authorship strategies and between researchers with different levels of productivity domestically. In addition to that, the counts of international publications were also compared with the counts of other domestic publications for each researcher; while both types of counts were also compared with the counts of publications in the journals included in the analysis.

To answer the second part of the question - *How is productivity of researchers using different strategies and having different productivity domestically changed when their publications in international and other domestic journals are taken into account? –* the total count of additional publications was obtained first for each researcher in the sample. This total was treated as change in publication profile produced as a result of change in assumptions. The share of researchers with no change in the publication profile was compared with the share of researchers for whom the profile changed. The change was then analyzed separately for authors who published only international articles and for authors, who published only in domestic journals not included in the original analysis. In addition to that, the share of researchers whose profile has changed over the years not included in the original analysis was calculated.

For researchers with the greatest change in productivity, average productivity was calculated by dividing the change in publication profile by the number of years (excluding the period in the original analysis) during which the change was produced. This average productivity was compared with average productivity of the author during the years included in the analysis, while the overall change in publication record was compared with the original number of publications obtained during Phase I. Special attention was paid to the co-authorship strategy of the researcher during the analysis.

Table 1 provides a summary of the study design, aligning study phases, research questions, data courses and methods of analysis.

Table 1

Study design

Phase	Goal	Research question	Subquestion	Data source	Sample	Analysis method
I Social network analysis	To collect data for Phase II (to identify strategies)	None	None	Web of Science	2,666	Ego network analysis
II Statistical analysis	To explore the extent of empirical representation and the effect of co-authorship strategies on individual research productivity	1. To what extent are various co-authorship strategies present in cardiologic research in Russia?	None	Data from Phase I	2,666	Descriptive statistics
		2. How do these co-authorship strategies affect the research productivity of the authors measured by the total number of publications?	(a) Is there any significant difference in research productivity between authors using different co-authorship strategies?			Omnibus tests: Robust ANOVA (Welch), Non-parametric ANOVA (Kruscal-Wallis)
			(b) How each of the strategies performs in terms of its effect on research productivity compared with other strategies?			Post-hoc tests: Robust ANOVA (Tamhane 2), Non-parametric ANOVA (Mann-Whitney test), Bootstrap ANOVA
III Sensi-tivity analysis	To test the method under different assumptions	3. To what extent do the results of the study depend on the assumptions and the method used for reconstructing the network?	(a) What is the extent of publishing in other domestic and international journals for researchers with different co-authorship strategies and levels of productivity?	Data from Phase I and	70	Descriptive statistics
			(b) How is domestic productivity of researchers changed when their publications in international and other domestic journals are considered?	Web of Science		Descriptive statistics

CHAPTER 4: RESULTS

This chapter presents the results of the study. The results are organized by the research question. The discussion of the results pertaining to each of the research questions is preceded by a section presenting the results of the exploratory analysis summarizing characteristics of the study population..

4.1. Exploratory Descriptive Analysis

This section summarizes the results of the analysis of the data obtained from ISI Web of Science, which was conducted prior to network, statistical, and sensitivity analyses to determine characteristics of the population. Two characteristics were explored in particular to characterize the background for the subsequent analyses: those pertaining to the articles and those pertaining to the researchers.

The total number of 1,241 records or articles was extracted from the Web of Science for the period 2004-2009 using the advanced search option described in the methods section. Seven hundred forty seven articles (60%) were from the journal *Kardiologiya*, 319 (26%) - from *Cardiovascular Therapy and Prevention*, and 175 (14%) – from *Russian Journal of Cardiology*. In terms of year of publication (Table 2), the largest number of articles (336 or 27%) was from year 2007, while the smallest number of articles (118 or 10%) was from year 2006. Table 3 shows that very few articles in the sample were cited by other articles. Only 22 articles (less than 2%) were cited more than once, and only 71 (6%) of articles were cited at least once.

Table 2

Distribution of articles across years of publication

	Year					
Articles	2004	2005	2006	2007	2008	2009
Number	138	151	118	336	262	236
Percent	11	12	10	27	21	19

Table 3

Distribution of articles by impact measured as number of times cited

	Articles	
Times cited	Number	Percent
Five	1	< 1%
Four	1	< 1%
Three	4	< 1%
Two	16	1%
One	71	6%
Zero	1,148	92%

The total number of authors, who published in the three journals during the period 2004-2009 was 2,666. Using the gender inflection at the end of the Russian-origin family names, it was possible to determine gender for 2,106 (78%) researchers. Of the

researchers with identifiable gender, 809 (30%) were males and 1,282 (48%) were females. This does not necessary imply gender imbalance in the sample. If the majority of researchers for which gender was not identified were males, the sample could still be relatively balanced in terms of gender.

Table 4 shows how many authors of each gender contributed to all three, two or only one of the journals in the sample. From the table it is clear that for both genders most of the authors (85%) contributed to only one journal. Only 18 males and 15 females contributed to all three journals. This conclusion would not be affected by the number of individuals in the unknown category.

Table 4

Distribution of authors by gender in terms of number of journals contributed to

	Males		Females		Unknown		Total	
Number of journals	Number	Percent	Number	Percent	Number	Percent	Number	Percent
One	693	86	1,100	86	466	83	2, 259	85
Two	113	13	167	13	84	15	364	14
Three	18	<1	15	<1	10	2	43	1

Three most productive authors in the sample published 36 articles each. The next ten authors in terms of productivity contributed from 19 to 32 articles. Most of the authors (1,790 or 67%) published only once in the three journals during the period of 2004-2009. Mean number of articles published by an individual author in the three

journals during 2004-2009 was 1.95 with the standard deviation of 2.58. Median productivity for all authors was equal to 1.

Fourteen or 56 percent of the 25 most productive authors in the sample were identifiable males. Three individuals or twelve percent of the authors were females and the remaining eight (32%) authors were uncategorized. Again, no gender imbalance can be assumed in this case because of the significant representation of the uncategorized individuals, which could affect the size of both gender categories.

4.2. Results Pertaining to Research Question 1

The extent to which each of the theoretically hypothesized co-authorship strategies were present in Russian cardiologic research was determined with descriptive statistics. After the list of researchers for each strategy was obtained as a result of the social network analysis stage of the study, the total number of researchers listed under each strategy was calculated and represented in terms of percentage from the total number of researchers in the population.

Table 5 presents distribution of authors across the hypothesized co-authorship strategies. As could be seen from the table, the most preferred strategy among the authors publishing in the Russian cardiologic journals was the middle ground strategy, which was used by 26 percent of the authors. The independent, complex and bridging strategies were fairly well and relatively equally represented (21%, 18%, and 19%, respectively). The bonding, dyadic and isolate strategies were less represented and were utilized by 231 (9%), 135 (5%) and 39 (1%) researchers respectively. The data was not further broken down by gender because the share of unknown authors was very high in each strategy and, therefore, it would not allow for an unequivocal interpretation of the results.

Table 5

Distribution of authors across co-authorship strategies

Strategy	Number	Percent
Middle	683	27
Independent	559	21
Bridging	512	19
Complex	507	18
Bonding	231	9
Dyadic	135	5
Isolate	39	1

4.3. Results Pertaining to Research Question 2

The second research questions assessed whether co-authorship strategies have differential effects on individual research productivity. Specifically, this study attempted to determine (1) whether there is a difference in the mean number of articles published by authors using different co-authorship strategies; and (2) (if there was a difference) how co-authorship strategies compared in terms of their effect on the mean number of publications.

The originally planned approach was to use the classical ANOVA omnibus test and a post-hoc procedure to answer each of the respective sub-questions. However, the data obtained as a result of social-network analysis was non-parametric and insensitive to various conventional transformations. Because the data did not meet homogeneity of variance assumption, the use of a robust or a non-parametric procedure alone could

produce inaccurate results. Therefore, the best approach would be to use resampling. Specifically, bootstrap ANOVA was implemented using a command available in the most recent version of SPSS (PASW 18). The robust and non-parametric procedures were also conducted to compare the results obtained from the three methods in order to ensure validity.

Before implementing ANOVA, preliminary analysis was conducted using descriptive statistics. Specifically, for each co-authorship strategy, the number of articles published by all researchers utilizing the strategy was calculated. In addition to that, strategies preferred by the top 25 most productive researchers were identified. Finally, for all strategies, the mean number and standard deviation of articles published by all researchers utilizing the strategy was calculated.

Table 6 summarizes the distribution of the publications across various co-authorships strategies. Looking at the total pool of authors in the network, the co-authorship strategy of structural holes was most productive since the authors in the group produced almost fifty percent of all publications in the three journals during 2004-2009. In the aggregate, the second most productive strategy was the middle ground, which was responsible for 17% of all publications. Authors utilizing the independent strategy and the complex strategy produced relatively equal amount of articles totaling 25% of the pool. The three other strategies together were responsible for less than 10% of all publications, with the cohesive strategy being the most productive (5%). As in Table 4, the data in Table 5 is not broken down by gender due to the potential effect of the *Unknown* category on the interpretation.

Table 6.

Distribution of articles across co-authorship strategies

Strategy	Number	Percent
Bridging	2,520	49
Middle	885	17
Independent	678	13
Combination	634	12
Bonding	258	5
Dyadic	137	2
Isolate	39	1

Note: the percentages do not sum up to 100 due to rounding

Due to the unbalanced distribution of authors across co-authorship strategies it is impossible to establish a link between the aggregate productivity of a group and aggregate productivity of individuals within the groups. The aggregate productivity could be high due to a large number of authors in the group, even if the average individual productivity within the group is low.

The results presented in Table 7 are more informative. The table lists the identifiers for the top twenty five most productive authors in the network alongside their gender, co-authorship strategy, and total number of publications. The average number of publications for the top 25 authors is 21 articles. The majority of the top authors with identifiable gender are males (15 or 60% males vs. 3 or 13% females). This, however,

does not imply gender imbalance since there are seven more researchers, who could be females. Most importantly, all but two of the most productive authors utilize bridging co-authorship strategy. This result indicates that bridging strategy is probably most productive on the average, too.

Table 7

Gender, co-authorship strategy, and productivity of top 25 authors

Author ID	Gender	Strategy	Productivity
2145	Unknown	Bridging	36
430	Male	Bridging	36
210	Male	Bridging	36
367	Female	Bridging	32
1399	Unknown	Bridging	27
1628	Male	Bridging	27
1189	Unknown	Bridging	26
914	Male	Bridging	24
2040	Female	Bridging	24
1770	Female	Bridging	21
2346	Unknown	Bridging	20
1023	Unknown	Bridging	19
1327	Male	Bridging	19
757	Male	Bridging	18
1356	Male	Bridging	17
713	Male	Complex	16
1549	Male	Bonding	16
105	Male	Bridging	15
1818	Male	Bridging	15
912	Male	Bridging	15
647	Unknown	Bridging	14
1878	Unknown	Bridging	14
30	Male	Bridging	14
2616	Male	Bridging	14

The fact that bridging strategy is ahead of all other strategies in terms of its effect on productivity (number of articles) is also evident even more from Table 8. As should be clear from the table, authors utilizing bridging co-authorship strategy have an average productivity of five articles, while the average for all other strategies is one article.

Table 8

Mean and standard deviation of productivity (number of articles) by strategy

Strategy	*M*	*SD*
Isolate	1.10	0.31
Dyadic	1.16	0.50
Independent	1.20	0.54
Combination	1.20	0.53
Bonding	1.07	0.28
Bridging	4.82	4.63
Middle	1.35	0.88
Totals	1.95	2.58

Prior to implementation of the ANOVA procedures, the data were assessed for compliance with model assumptions. As has been indicated above, the assumption of normality and homogeneity of variances were not met and conventional transformations did not normalize the data. Below, relevant evidence is presented.

Figure 9 presents Normal Q-Q plot of the quantiles of the residuals against the quintiles of the normal distribution. Figure 10 presents a histogram of the residuals

compared with the normal plot. Both graphs shows that the distribution of the residuals does not fit the theoretical normal distribution, providing the evidence that the normality assumption is violated. Kolmogorov – Smirnov test apporpriaste for large datasets also failed to confirm the null hypothesis that the residuals are normally distributed (D(2,666) = 0.32, p<0.01). The descriptive statistics command produced a value of skewness for the residuals, which is equal to 7.27, and the value of kurtosis, which is equal to 82.26. The positive values indicate a high degree of right skewness of the residuals and leptokurtic distribution. The data also failed to meet the assumption of homogeneity of variance, which was tested using the Levene's test (W(6; 2,659)=153,44; p<0.01).

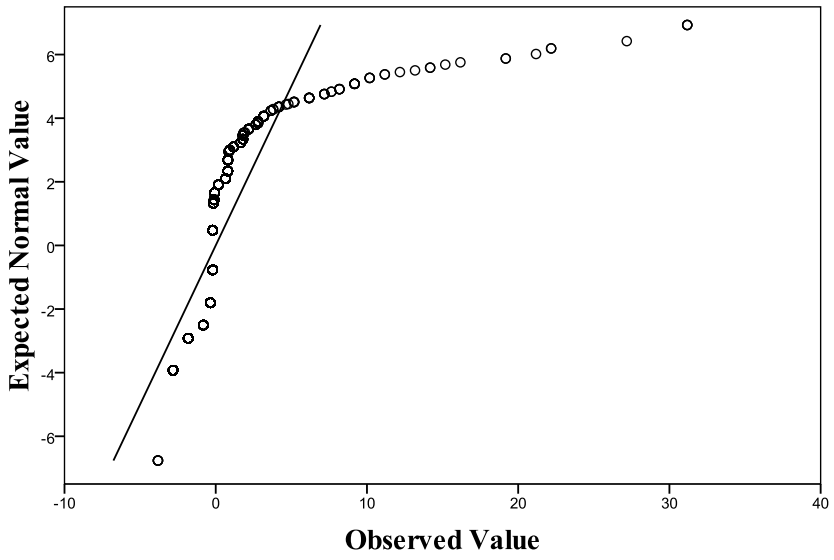

Figure 9. Normal Q-Q plot of the residuals

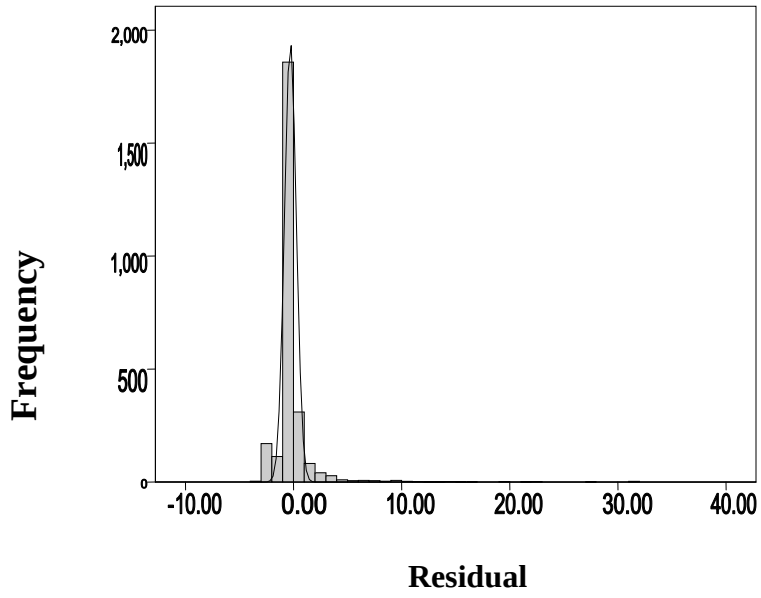

Figure 10. Histogram of the residuals

Prior to the implementation of further procedures, the data was checked for errors during data entry and exporting from one software to another. No errors were identified and the conclusion was made that mere discarding of outliers would be unacceptable.

Three conventional transformations (square root, logarithmic, and inverse) of the data were implemented to reduce skeweness and two transformations (cube root and sine) were conducted to reduce positive kurtosis. Figures 11, 12, 13, 14, and 15 below present Normal Q-Q plots of the distributions of the residuals for the model using the transformed productivity variable. The plots compare the quintiles of the theoretical normal and empirical distributions against each other. As should be clear from the plots, none of the transformations resulted in a normal or approximately normal distribution of residuals.

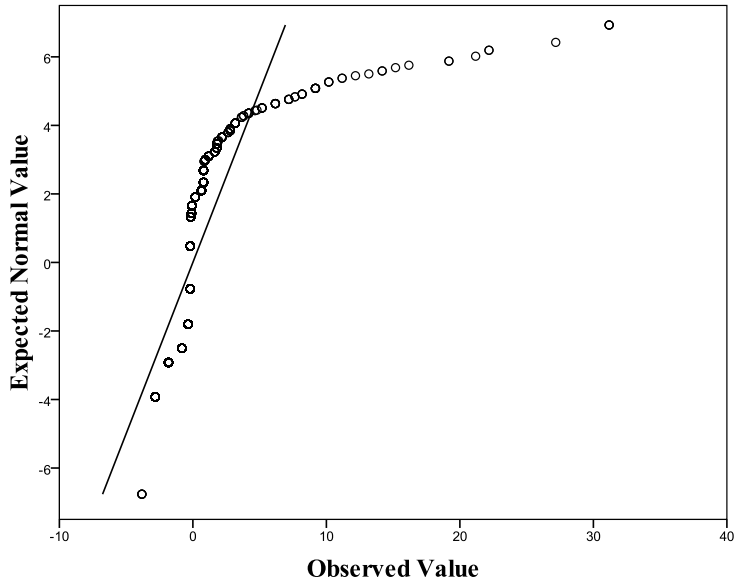

Figure 11. Normal Q-Q plot of residuals (square root transformation)

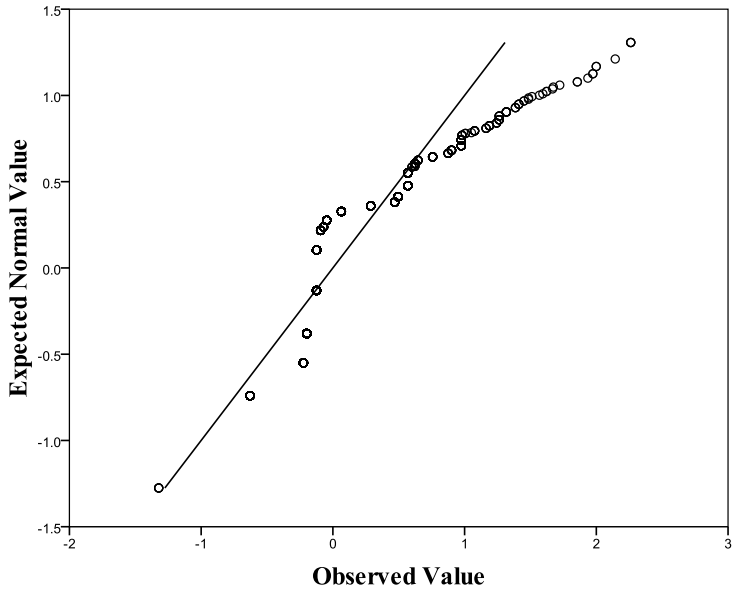

Figure 12. Normal Q-Q plot of residuals (ln transformation)

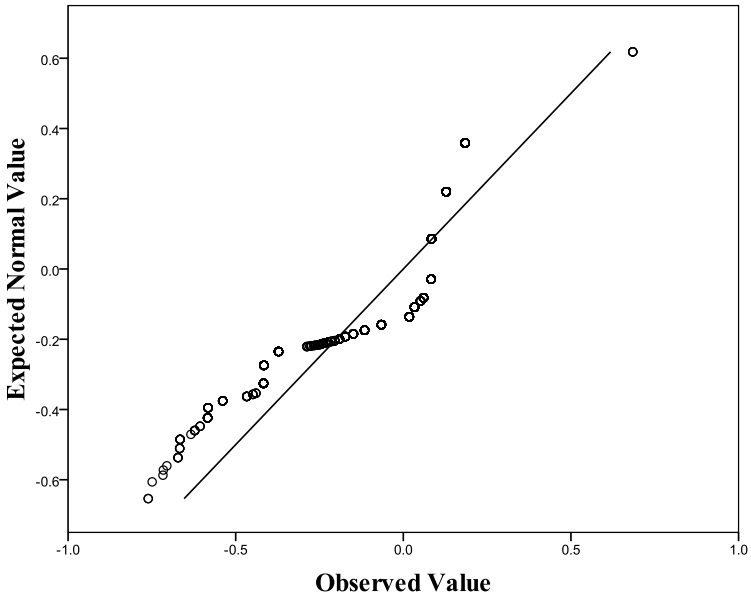

Figure 13. Normal Q-Q plot of residuals (inverse transformation)

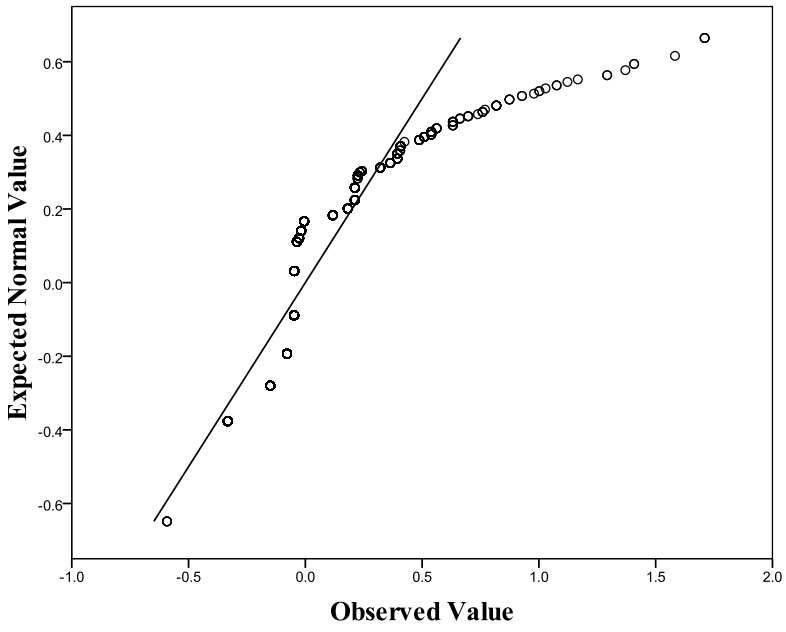

Figure 14. Normal Q-Q plot of residuals (cube root transformation)

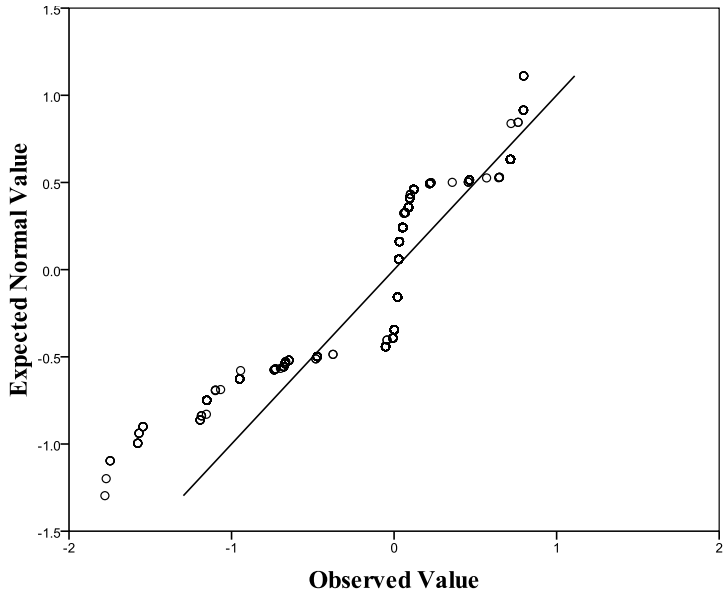

Figure 15. Normal Q-Q plot of residuals (sine transformation)

Table 9 presents results of the Levene's tests implemented as a part of ANOVA procedures run on each of the transformed data. The table demonstrates that neither of the transformations resulted in distributions with homogeneous variances.

Table 9.

Results of Levene's tests of homogeneity of variance implemented as part of ANOVA procedure on the transformed data.

Transformation	*W*	*DF1*	*DF2*	*p*
Square root	171.13	6	2,659	<0.01
Logarithmic	103.69	6	2,659	<0.01
Inverse	24.71	6	2,659	<0.01
Cube Root	151.41	6	2,659	<0.01
Sine	396.37	6	2,659	<0.01

As has been mentioned in the Methods section, such approaches as trimming and the use of non-parametric test was also considered as a way to deal with nonparametric data. Since no additional descriptive statistics or assumptions tests pertain to these two analysis, no further discussion of the two procedures is necessary in this section.

The inferential strategy, which was eventually implemented in practice was bootstrap ANOVA. As has been mentioned in the methods section, the procedure was chosen because bootstrap method does not make normality and homogeneity of variance assumptions about the underlying population. Instead, it approximates the actual population by resampling with replacement from the original sample and makes inferences based on this approximated population. The remainder of the section reports the results of bootsrapped ANOVA and, for comparison purposes, the results of robust ANOVA and the non-parametric Kruscal-Wallis procedure.

ANOVA results. Since the data failed to meet both the normality and the homogeneity assumptions, the ANOVA omnibus test was conducted using Welch's variance—weighted procedure, which is considered both powerful in protecting against Type I errors and robust to violations of both assumptions (Kohr & Games, 1974; Keselman et al., 1979). At the 0.05 level of significance, the test failed to confirm the omnibus hypothesis that there is no difference among mean individual productivities of researchers using different co-authorship strategies ($F''(6, 322) = 61.84$, $p<0.01$, $\acute{\omega}^2 = 0.31$), indicating that co-authorship strategy has a large effect on the level of individual research productivity.

In order to determine how various strategies compare with one another in terms of their effect on individual productivity, post-hoc tests were conducted. Tamhane 2

procedure was used because it is considered a very conservative test appropriate for situations when homogeneity of variance assumption is violated (Tamhane AC ,1977).

Table 10 summarizes the results of the Tamhane 2 procedure and Figure 16 presents the plot of means, which was used in interpretation of the results. The Tamhane's 2 test revealed that there is no significant difference in mean number of articles produced by researchers using isolate (M=1.10, SD = 0.31) and bonding (M= 1.07, SD = 0.28) strategy. Significant difference was found between the mean number of articles published by researchers in each of the strategies and the mean number of articles published by researchers utilizing combination (M= 1.20, SD = 0.53) strategy. The mean number of articles published by researchers in dyadic (M=1.16, SD= 0.50), strategy was not significantly different from the mean number of publications in either the isolate or bonding strategy or the combination strategy. Mean productivities of researchers in combination, independent (M=1.20, SD= 0.54), and middle (M=1.35, SD= 0.88) strategies were all significantly different from each other and from means of both isolate and bonding strategies. Finally, mean productivity of researchers in the bridging (M=4.82, SD= 4.63), strategy was significantly different from productivity of all other strategies. Figure 17 summarizes the ranking of strategies in terms of their effect on productivity based on the Tamhane 2 procedure.

Table 10

Post-hoc Comparisons with Tamhane 2 Procedure

Pairs of strategies					$CI_{.95}$	
A	B	M_a-M_b	*SE*	*p*	Lower Bound	Upper Bound
Isolate	Dyadic	-.05	.08	1.00	-.30	.20
	Middle	-.25	.06	<.01	-.45	-.05
	Independent	-.10	.05	.79	-.27	.07
	Combination	-.10	.05	.79	-.27	.07
	Bonding	.03	.06	1.00	-.14	.21
	Bridging	-3.72	.21	<.01	-4.34	-3.09
Dyadic	Middle	-.20	.08	.20	-.44	.04
	Independent	-.05	.07	1.00	-.26	.17
	Combination	-.05	.07	1.00	-.26	.17
	Bonding	.08	.07	1.00	-.13	.30
	Bridging	-3.67	.21	<.01	-4.30	-3.03
Middle	Independent	.15	.05	.03	.01	.29
	Combination	.15	.05	.02	.02	.29
	Bonding	.28	.05	<.01	.14	.43
	Bridging	-3.47	.20	<.01	-4.09	-2.85
Independent	Combination	.01	.03	1.00	-.09	.09
	Bonding	.13	.03	<.01	.03	.23
	Bridging	-3.62	.20	<.01	-4.23	-3.01
Combination	Bonding	.13	.03	<.01	.04	.22
	Bridging	-3.62	.20	<.01	-4.23	-3.01
Bonding	Bridging	-3.75	.20	<.01	-4.36	-3.14

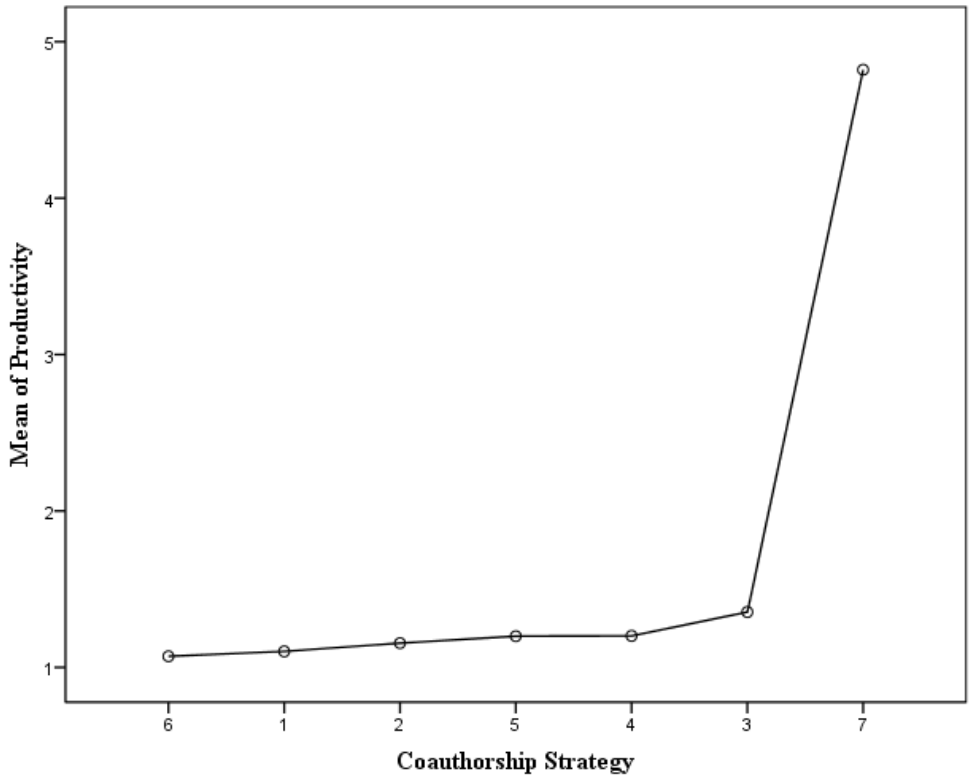

Figure 16. Plot of Mean Productivity of Co-authorship Strategies
Values on the Co-authorship strategy axis: 1-isolate, 2- dyadic, 3-middle, 4-independent, 5-combination, 6-bonding, 7-bridging

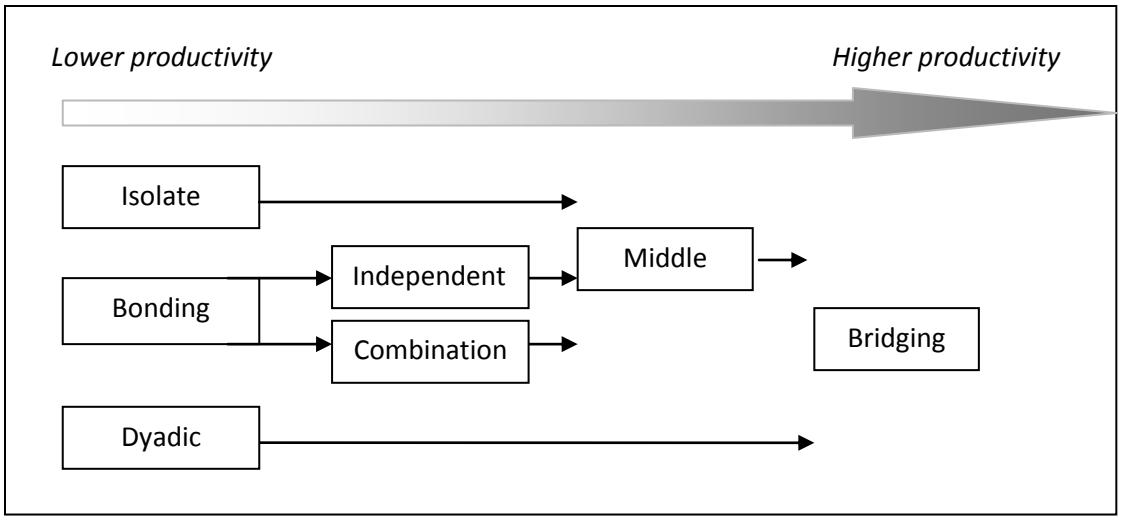

Figure 17. Ranking of co-authorship strategies in terms of their effect on individual productivity (based on Tamhane 2)

Kruscal-Wallis results. In the Kruskal-Wallis H test, the null hypothesis was that the groups of authors with different co-authorship strategies do not differ in mean rank for their research productivity. The test failed to confirm the omnibus hypothesis ($H(6) = 1563.36$, $p<0.01$, $\eta^2 = 0.59$) at the $\alpha = 0.05$ level, indicating that co-authorship strategy has a large effect on the median productivity of researchers. Table 11 reports the mean ranks for each of the strategy resulting from the omnibus test.

Table 11

Mean ranks for co-authorship strategies based on Kruscal-Wallis test

Strategy	Mean Rank
Isolate	1,009.50
Dyadic	1,026.00
Middle	1,172.72
Independent	1,076.58
Combination	1,079.81
Bonding	968.57
Bridging	2,307.04

Because the Kruscal-Wallis test failed to reject the null hypothesis, pairwise post-hoc test were conducted using Mann-Whitney test to determine whether the productivity ranks for pairs of co-authorship strategies were significantly different. Significant difference was adjusted using Bonferonni adjustment, i.e. the 0.05 level of significance

was divided by 21 comparisons with the resulting 0.002 level of significance used in post-hoc comparisons. Table 12 presents the results of pairwise comparisons using Mann-Whitney test.

As a result of the pairwise comparisons using Mann-Whitney test, significant difference was found between isolate and bridging (U=426.00, z=-10.21, p<0.001), dyadic and bridging (U=1,062.50, z=-11.88, p<0.001), middle and independent (U=122, 960.50, z=-3.20, p=0.001), middle and combination (U=177,753.00, z=-3,32, p=0.001), middle and bonding (U=26,557.50, z=-4.39, p<0.001), middle and bridging (U=15,686.50, z=-24.39, p<0.001), independent and bridging (U=12,841.00, z=-28.12, p<0.001), combination and bridging (U=17,797.50, z=-31.39, p<0.001), bonding and bridging (U=1206.50, z=-18.00, p<0.001) strategies.

The ranking of strategies resulting from Mann-Whitney test is different from the ranking produced by the Tamhane 2 procedure. This is evident by comparing Figure 17 with Figure 18.

Table 12

Results of pairwise comparisons of mean productivities between strategies using Mann-Whitney test

Pairs of strategies		*U*	*Z*	*P*
Isolate	Dyadic	1,124.00	-0.10	0.920
	Middle	7,653.50	-1.90	0.060
	Independent	10,901.50	-0.90	0.370
	Combination	15,631.50	-0.96	0.340
	Bonding	2,645.00	-0.81	0.420
	Bridging	426.00	-10.21	*<0.001*
Dyadic	Middle	11,528.00	-2.09	0.040
	Independent	16,353.00	-0.91	0.370
	Combination	23,454.00	-0.99	0.320
	Bonding	3,916.50	-1.02	0.310
	Bridging	1,062.50	-11.88	*<0.001*
Middle	Independent	122, 960.50	-3.20	*0.001*
	Combination	177,753.00	-3.32	*0.001*
	Bonding	26,557.50	-4.39	*<0.001*
	Bridging	15,686.50	-24.39	*<0.001*
Independent	Combination	2,499.77	-0.20	0.840
	Bonding	37,909.50	-2.77	0.006
	Bridging	12,841.00	-28.12	*<0.001*
Combination	Bonding	54,323.00	-2.93	0.003
	Bridging	17,797.50	-31.39	*<0.001*
Bonding	Bridging	1206.50	-18.00	*<0.001*

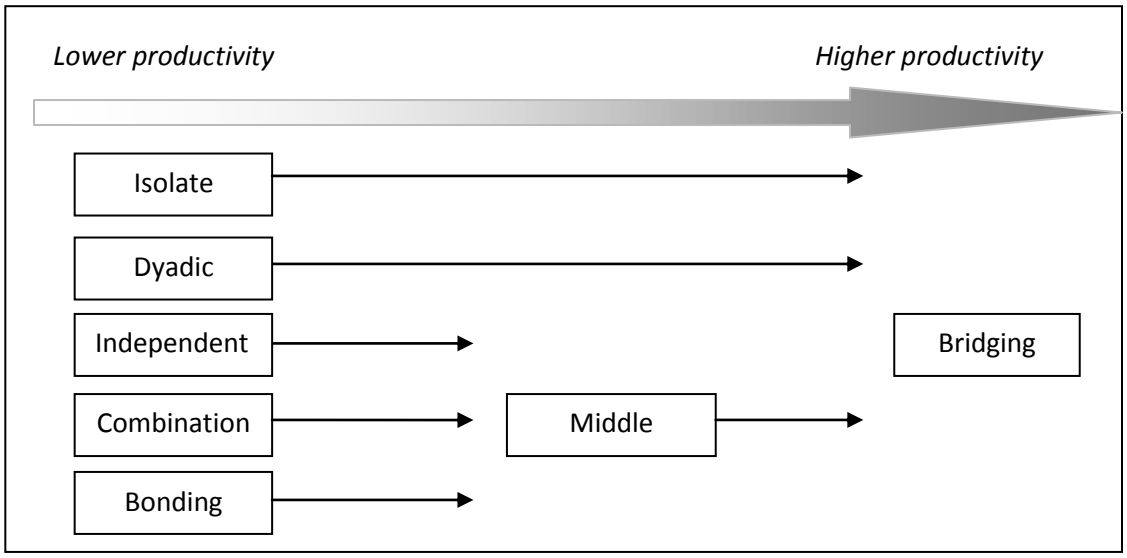

Figure 18. Ranking of co-authorship strategies in terms of theiir effect on individual productivity (based on Mann-Whitney)

Bootstrapping results. Bootstrap was based on 5,000 resamplings. The seed was set at 2,000,000. Nighty-five percent bias-corrected accelerated interval (BCa) was used in order to correct for bias and skeweness. Mean difference for the bootstrap procedure was obtained from Tamhane 2 test.

As should be clear from Table 10 for 12 comparisons the bootstrap confidence interval did not include M_a-M_b=0. This implies that for the twelve comparisons, for which confidence interval is italicized in the table, a significant difference in the mean productivity was found.

Figure 19 summarizes the results of the analysis by presenting the ranking of strategies in terms of their effect on productivity.

Table 10.

Results of Bootstrap for multiple comparisons in ANOVA using Tamhane 2 procedure

Pairs of Strategies			Bootstrap results			
A	B				CI_{BCa}	
		M_a-M_b	Bias	*SE*	Lower	Upper
Isolate	Dyadic	- .05	.00	.08	-.22	.10
	Middle	- .25	.00	.06	*-.38*	*-.12*
	Independent	- .10	.00	.05	-.19	.01
	Combination	- .10	.00	.05	-.19	.01
	Bonding	.03	.00	.05	-.07	.14
	Bridging	-3.72	.00	.20	*-4.14*	*-3.32*
Dyadic	Middle	- .20	.00	.08	*-.34*	*-.045*
	Independent	- .05	.00	.07	-.16	.09
	Combination	- .05	.00	.07	-.16	.09
	Bonding	.08	.00	.07	-.03	.22
	Bridging	-3.67	.00	.21	*-4.10*	*-3.26*
Middle	Independent	.15	.00	.05	*.06*	*.25*
	Combination	.15	.00	.05	*.07*	*.24*
	Bonding	.28	.00	.05	*.19*	*.38*
	Bridging	-3.46	.00	.20	*-3.90*	*-3.08*
Independent	Combination	.00	.00	.03	-.05	.06
	Bonding	.13	.00	.03	*.06*	*.20*
	Bridging	-3.62	.00	.20	*-4.03*	*-3.23*
Combination	Bonding	.13	.00	.03	*.07*	*.19*
	Bridging	-3.62	.00	.20	*-4.04*	*-3.23*

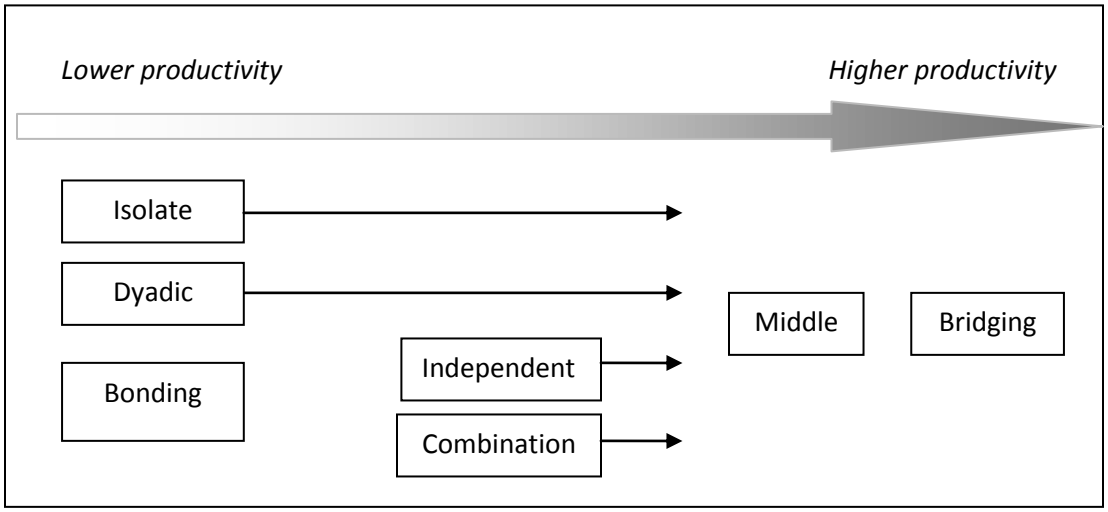

Figure 19. Ranking of co-authorship strategies in terms of their effect on individual productivity (based bootstrap confidence intervals for differences in means estimated in Tamhane 2)

The comparison of the rankings of strategies produced by the three tests (Figure 17, 18, and 19) demonstrates that (1) robust Anova with Tamhane 2 was unable to track the significant difference between dyadic and middle strategies; (2) non-parametric Kruscal-Wallis test was unable to track the significant difference between isolate and middle and dyadic and middle strategies; and (3) only the bootstrap procedure based on confidence intervals for differences in means estimated in Tamhane 2 was able to track both differences. Hence, the final result corresponds to the ranking produced by the bootstrap procedure (Figure 19).

According to this ranking the most productive strategy is Bridging. The second most productive strategy is Middle. All other strategies are less productive than Middle

strategy. In addition to that, Independent and Combination strategies are more productive than Bonding strategy.

4.4. Results Pertaining to Research Question 3

This section presents the results of the third phase of the analysis which intended to check the sensitivity of the results of the previous section to the assumptions of the methodological approach. The results are organized by subquestion.

What is the extent of publishing in other international and domestic journals for researchers using different co-authorship strategies and having different levels of productivity domestically?

Overall, 12 researchers out of 68 or 18% had single international publications when their complete publication profile for all years of publishing was considered. Only one of the twelve researchers published four articles in international journals during his/her whole career. When only the 2004-2009 period was considered, the publication profile has changed for only three researchers out of 68 when their international publications were included. Teach of the researchers published only one article abroad during this period.

These results indicate that Russian cardiologic researchers rarely publish abroad. Specifically, they did not publish much abroad during the period included in the original analysis. This finding is consistent with the literature on characteristics of Russian cardiologic research summarized in the literature review section. As has been mentioned in the section, Russian cardiology is a relatively closed field, where most of the researchers publish domestically. It supports the original decision to choose Russian cardiologic research for its isolation from the international research in order to obtain

accurate measures of productivity using the method based on a population bounded by country.

In addition, based on the results there does not seem to be any relationship between co-authorship strategy and tendency to publish abroad. Individuals who had international publications came from a variety of strategies. Four of the researchers utilized isolate strategy, three of the researchers utilized dyadic strategy, two researchers – independent and bonding strategies and one researcher used middle strategy. Although not all strategies were represented in the small sample among authors publishing abroad, it could be due to the size of the sample. At the same time, none of the represented strategies dominates the others. The results also seem to indicate that international publication is more characteristics of researchers with lower levels of productivity domestically.

None of the authors published in other domestic journals during the analyzed period of 2004-2009. When all years during which a person published were considered, 32 researchers (48%) changed their publication profile as a result of publication in other domestic journals. This result could have been expected because not all researchers could publish in the selective key journals and some researchers could be expected to publish their works in other domestic publications. On the average, the publication profile has changed by seven articles, which implies that on the average about half of the researchers (48%) publish seven articles in non-key journals over the course of their career.Overal, the result indicates that the extent of publication in other domestic journals is greater than the extent of publication in international journals. At least half of the researchers publish in other domestic journals, while a very small proportion of researchers publish abroad.

Researches who published in other domestic journals came from a variety of strategies. Isolate, middle and independent strategies were used by four researchers publishing in other domestic journals each. Eight researchers used dyadic strategy and seven researchers used bonding strategy. Combination and bridging strategies were utilized by three researchers each. The results might that there might be a relationship between using a dyadic and, especially, bonding strategy and the tendency to publish non-key domestic journals. If this is the case, then the productivity levels of those using bonding and dyadic strategy might be underestimated when only publication in key journals is considered. One reason this may not be the case is the fact that all, but one, researcher using bonding strategy had a high level of productivity as determined the method based on publications in key journals during 2004-2009. Similarly, all but one researchers using dyadic strategy had a high level of productivity as determined by the restricted method.

Only one of the researchers who had overseas publications had a high level of productivity. Most of the researchers who had international publications had a low original level of productivity (two articles and below). Given the small number of researchers in the sample, it is impossible to make any conclusions about the relationship between the level of productivity and the tendency to publish abroad. Eighteen out of 32 researchers, who had additional domestic publications, had a high level of productivity as determined by the method based on publications from key journals during 2004-2009. The rest of the researchers had a low level of productivity. The result indicate that there does not seem to be a relationship between the level of productivity and the tendency to publish in non-key journals domestically.

To summarize, the results of the sensitivity analysis indicate that Russian researchers in cardiology rarely publish abroad. At the same time, researchers do publish in other domestic journals. Also, in case of international publications, it is not clear whether the tendency to publish abroad is associated with higher levels of productivity or specific strategies for publishing due to sample constraints. In case of publications in other domestic journals, there does not seem to be a relationship between the tendency to publish in non-key domestic journals and affiliation with any particular strategy or having a specific level of productivity.

How is productivity of researchers using different strategies and having different productivity domestically changed when their publications in international and other domestic journals are taken into account?

Overall for all years publication profile has changed for 33 authors out of 68 or for 49% of researchers in the small sample. On the average these authors, who published additional articles abroad, domestically in non-key journals and prior to the period under consideration, published about one additional article in two years. As a result, only 5 authors have moved from L to H category, when their complete publication profile was considered. This implies that the method based on restricted sample of articles from key journals and selected years produces relatively accurately estimate of the overall level of productivity (low, middle or high).

For 21 researchers (31%) their publication profile has changed merely as a result of inclusion of different years. These researchers published additional articles only in three journals included in the original analysis. The author, for whom productivity

changed most (44 additional publications), started their career 21 years before the period under analysis. The person had average annual productivity of about two articles over the period not included in the analysis. This average productivity was the same as the productivity observed during the period included in the analysis indicating that the person continues to actively publish and maintains relatively stable level of productivity over the years. Interestingly, the most productive individual during the period excluded from analysis used bridging co-authorship strategy. Two other individuals with notable changes in productivity (25 and 22 additional articles) also started their careers long before the period included in the analysis and had average annual productivity of two articles. However, their recent productivity observed during the period of analysis was relatively low, indicating that the researchers might be retiring from the field. Other individuals with notable changes in the total number of articles published over the span of their career had low average annual productivity both during the period included in and excluded from the analysis.

The results summarized above indicate that the format of the original analysis is not very sensitive to the change in assumptions. The productivity profile of researchers has not changed significantly as a result of inclusion of publications in other domestic and international journals. In fact, during the period included in the analysis, addition of international and domestic journals has left the outlook of productivity almost intact. None of the researchers increased their productivity profile by additional domestic publications and only three researchers published in international journals an average of one article. For other periods, publication in the key domestic, international and non-key domestic journals has

not resulted in significant gains in productivity, either. For only two researchers publication profile has significantly changed as a result of inclusion of the whole publication lifespan and publications in international and other domestic journals.

CHAPTER 5: DISCUSSION

This chapter summarizes key findings of this study and discusses practical implications arising from the results. In addition, the chapter makes transparent some limitations of the study design and identifies potential directions for future research.

5.1. Findings

One important finding of the study is that researchers in Russian cardiology are not normally distributed in terms of their productivity level. The majority of researchers have published only one article in one of the key cardiologic journals in Russia during the period of six years. On the other hand, there are outliers, who published extensively. The three most productive authors published 36 articles each. Not only Russian cardiologic researchers seem to demonstrate low productivity in terms of number of publications, but there are also indications that the quality of research is low because more than 90% of articles were not cited even once.

The finding, that Russian cardiologic research is characterized by low productivity, as measured by the number of publications, could be explained in several ways. One explanation is that article publication is not important for a career in Russian cardiology. Another explanation is that the key journals are not theoretical in scope and might publish articles intended for both practitioners and researchers. This could explain very well the non-normal distribution of productivity and the presence of outliers. Individuals, who publish in the journals, might come from two different populations – those with higher productivity could be researchers, for whom publication is very important; and those with lower levels might be practitioners, for whom publication is not important. Finally, the difference in productivity could be explained by active

participation in research of graduate students and laboratory personnel and technicians. Because not all graduate students might continue with a career in cardiology and support personnel might have a high degree of turnover, there might be a large number of "noise" in the sample, produced by individuals, who are not actual researchers and who are not active participants in research.

The finding that Russian cardiologic research is characterized by a low productivity as measured by the number of citations could be interpreted as an indication of low quality of research. An alternative interpretation is that Russian cardiologic field may have a research culture, where citation is not necessary in articles. This explanation is quite possible taking into consideration the widespread culture of plagiarism and poor enforcement of copyright in the country (Vlassov, 2010). In addition to that, Russian cardiologic research is relatively isolated with researchers barely publishing abroad. In such a context, Russian researchers might not be sufficiently exposed to members of the international research community via international journals to be adequately cited.

The second key finding of the study is that all co-authorship strategies hypothesized by Rumsey-Wairepo (2006) are present in the field of Russian cardiologic research, although to a different extent. The most preferred strategy among the authors publishing in the Russian cardiologic journals was the combination strategy. The independent, bridging and middle strategies were fairly well and relatively equally represented. The isolate, dyadic and bonding strategies were less represented with bonding strategy being most underused. The pattern of use of strategies indicates that overall strategies creating bridging social capital are preferred in Russian cardiology to isolate strategy or strategies based solely on bonding social capital. Combination strategy,

which is most preferred in Russian cardiologic research, does create the bonding capital, but only in combination with bridging capital.

The identified distribution could be explained in two ways. First, strategies based on bridging could be chosen by researchers because of the nature of training and the dominant culture in the field, in other words, researchers favor strategies based on bridging because they know no alternative or because the alternative is not an option. Second, strategies based on bridging might be more productive and are preferred by researchers in pursuit of the greater number of publications.

The third finding of this study provides an explanation why researchers in Russia tend to use strategies creating bridging social capital more frequently than others. Figure 19 presents a ranking of strategies in terms of their effect on productivity. According to this ranking the most productive strategy is bridging. The second most productive strategy is middle. All other strategies are less productive than middle strategy. In addition to that, independent and combination strategies are more productive than bonding strategy. In short, bridging and bonding strategies seem to be at the polar ends of a continuum describing the effect of co-authorship on productivity with bridging strategy being most productive.

The third finding of the study is consistent with prior research on social capital (Burt, 1992, 1997, 2000, 2001), which seems to indicate that bridging structural holes in social networks creates more social capital than maintaining cohesive ties. This finding also points to an explanation of preference of Russian cardiologic researchers for strategies based on bridging: bridging-based strategies are preferred because they are more productive. What the finding does not explain, however, is why distribution of

strategies does not match exactly the ranking of strategies in terms of their effect on productivity.

The difference between the ranking of strategies in terms of use in Russian cardiologic research and the ranking of strategies in terms of their effect on productivity could be explained by the difficulty in the use of strategies. Although bridging is the most productive strategy, it could be difficult to use; and, hence, it is not most preferred in terms of use. Searching for and establishing contact with many potential co-authors could be costly in terms of effort and money. Such contacts are frequently established during conferences and Russian cardiologists may not have money to attend many conferences or may not have time (due to involvement in practice) to do that.

It is important to mention that bonding is also costly. In case of bonding, much effort and money is expended on maintaining contact with co-authors. In view of the lowest frequency of use of bonding strategy and its lowest position in the productivity ranking, it is possible that the cost of bonding is more prohibitive than the cost of bridging in Russia. One possible explanation comes to mind: a researcher using bridging could invest in attendance of one conference and get many new contacts out of it, thus cutting some of the costs. Costs cannot be cut in such a way in case of bonding.

The dominant position of combination strategy in the ranking based on usage and the second position of the middle strategy in the ranking of productivity effects indicate that the best and most widely utilized strategy for cardiologic researchers in Russia is trying to combine both bonding and bridging. In such a combination a researcher invests efforts and financial resources to maintain close contact with an established group of

researchers, possibly conducting research of common interest, and simultaneously, tries to publish with people from other groups to expose oneself to novel ideas.

The finding of the study about the effect of various research strategies on individual research productivity is consistent with the findings of Rumsey-Wairepo (2006), who also came to the conclusion that, overall, strategies high in efficiency (based on bridging) are more productive than strategies high in constraint (based on bonding). In Rumsey-Wairepo's (2006) study, however, combination strategy was most frequently used. In this study, the most frequently used strategy was combination strategy, which was followed by bridging. Middle strategy was only third in rank in terms of effects on productivity and it performed worse than bridging strategy.

The fact that combination strategy was more widely used in higher education research in the US could be explained by the lower cost of using bonding strategy in the US compared with the cost of using the strategy in Russia. The cost could be lower due to a smaller number of co-authors per article in the social science field and better developed and less expensive communication services (especially the Internet), as well as higher level of research funding (covering overhead costs) in the US compared with Russia.

The lower cost of bonding strategy, combined with the lower cost of bridging in the US might also explain why combination strategy turned most productive in Rumsey-Wairepo's (2006) study: if the cost of bonding and bridging were both lower in the US higher education research than the cost of respective strategies in Russian cardiologic research, it would be easier for researchers to combine successfully both strategies and get the highest productivity effects from the combination. Higher costs of both bridging

and bonding in Russia might make them difficult to combine. As a result, middle strategy is more productive than combination strategy in Russia.

One key finding of at the theoretical and methodological level is that classification developed by Rumsey-Wairepo (2006) seems to represent accurately the types of co-authorship strategies existing in reality. All types of strategies identified in the classification were empirically found. Another key finding of the study at the theoretical and methodological level is that the approach for empiric identification of co-authorship strategies and exploration of the effect of strategies on research productivity produces stable results irrespective to the assumptions. In the Russian cardiology context, characterized by a high degree of isolation from the international research activity, addition of non-major domestic journals and international journals, as well as inclusion of all publications produced by researchers over time did not result in significant change in the results of the study. Thus, the use of Rumsey-Wairepo's (2006) approach bounding the population of articles included in the analysis by a sample of publication years and venues can produce relatively accurate results, which could be generalized to the complete publication profile of a researcher.

5.2. Limitations

This study has several limitations, which were impossible to address due to the nature of the data source, methodology and the scope of the study's attention. These limitations should be taken into consideration when interpreting study results and in using the result to inform practice.

One of the most important limitations of the study is in the way it has operationalized productivity. Only the quantity of publications was taken into

consideration in estimation of productivity. The results could be different if the quality of publications was also taken into account.

The study is also limited to the extent it did not take into consideration several potentially confounding variables. First, it does not explicitly address the potential confounding effect of a researcher's ability. Capable researchers could be both most productive and better at or more inclined to establishing bridging connections. A highly productive person may be attractive for many researchers from different subfields, while a less productive researcher might be able to establish contacts with only a certain circle of people.

Second, the study did not control for gender of the researcher. As indicated in the review of literature, including the study by Rumsey-Wairepo (2006), prior studies found that males and females have different preferences for the co-authorship strategies and demonstrate different levels of research productivity. It is possible that the effect of co-authorship on research productivity differs depending on gender of the researcher.

Third, the study did not control for academic rank of the researcher, which has been found to influence preference for co-authorship and productivity (Bozeman & Lee, 2003). Researchers may use one co-authorship strategy at the beginning of their career and another strategy later in their career. In addition to co-authorship strategies may have a different effect on productivity at different stages of a research career.

The study did not control for institutional affiliation of researchers. Both collaboration strategies and productivity could have been affected by the types of organization, where a researcher is employed. For example, affiliation of a researcher with the Russian Academy of Sciences could make a researcher more attractive as a

collaborator for researchers and could increase the likelihood of utilization of bridging strategy. In addition to that, famous researchers with higher levels of productivity could be more likely to be affiliated with central medical academies.

The study also did not control for the nature of research funding in this study. As has been noted in the literature review section, this potentially confounding variable has been ignored by previous studies (Bozeman & Lee, 2003). Meanwhile, the nature of research funding, especially the source of funding and grant requirements regarding co-authorship and publication might influence individual research productivity.

The study failed to take into consideration some important characteristics of cardiologic research and research publication in this field. First, it was assumed that journals included in the analysis were uniform in terms of types of articles that they published. In fact, the assumption was that the key journals publish papers most contributing to research, rather than to practice. It is quite possible, however, that the journals differed by the type of articles they published or published both types of articles. Not accounting for the specialization of the journal introduced a complication – the analyzed sample could have been composed of individuals from two different populations – researchers and occasionally publishing practitioners.

In addition to that, the study failed to take into consideration the nature of the collaborative work in clinical research. As has been mentioned before, it is possible that clinical research in Russian cardiology involves not only prototypical researchers, but also doctors, who recruit patients for the study, interns, and laboratory personnel and technicians. This conventionally explains the larger size of co-authorship teams in sciences compared with the size of the teams in social sciences. The pool of individuals

included in the sample could have included not only researchers, but also non-researchers. This would explain the non-normal character of distribution of individuals in terms of their productivity levels.

Finally, the study could not control for potential ethical violations in co-authorship. It is possible that the most productive researchers in the study benefited from honorary authorship. They could be administrators at research centers or people, who have influence in distribution of research funding. They could be simply historically famous figures in the field, whom other researchers might include as co-authors to increase the status of their papers; or journal editors, who make decisions on whether the article will be published. The confounding variable has not been mentioned by critics of prior research on co-authorship. However, it could be very relevant for the Russian context, where the culture of honorary authorship could be wide-spread.

Another limitation of the study is that its results might be period specific. Cardiologic research in Russia is most likely undergoing transformation like other aspects of life in the transitional economy. The costs determining productivity effects of various strategies might be period specific and a different set of strategies might become productive in a relatively short term as government in Russia continues to invest in research, as university and research center administrators realign incentives to stimulate higher productivity, and as Russian cardiology researchers and journals become more exposed to Western research practices.

In addition to that, the period of time could have been too short for complete manifestation of co-authorship strategies. Publication of an article is a time-taking process. It may take up to a year for a researcher, who submitted an article for

publication, to see the article in print. One can imagine that some articles that were published during the first year included in the analysis, led to formation of collaborative ties among researchers interested in the same or related areas of research. It would take about a year for collaborators to get in touch (for example at an annual conference) and to define a topic of common interest. Given the experimental character of research in cardiology, it may take two years for a collaborative research project to come to completion. It might take two more years for results to be summarized in an article and for an article to be published in a journal. The whole process would stretch over a period of time longer than the period included in the analysis. As a result, the extent of some novel collaborations could have been underestimated and co-authorship strategies of researchers could have been different from the ones determined from the estimates of ties from the period of five years.

5.3. Implications

Three sets of implications could be derived from the results of the study. These implications pertain to individual researchers in Russian cardiology, Russian policy makers in the field of science and technology and higher education, and researchers studying the relationship between co-authorship and individual research productivity.

Although incentives might not be present in Russian to increase productivity of research at this point, cardiologic researchers in the country should be concerned about increasing their productivity if they believe that Russian cardiology will gradually integrate with the international research community in the field. Individual research productivity in the field measured in terms of quantity is way below the average in countries with advanced science and technology capacity. To the extent the individual

researchers are not limited in foreign language proficiency; they should also try to publish abroad to gain from benefits of international collaboration such as greater visibility, cost-sharing and exposure to novel ideas.

In pursuit of greater productivity researchers in Russian cardiology should also try to follow one of the research strategies, which creates bridging social capital. This advice, however, is restricted to domestic collaborations only. Different costs could be involved in international collaborations and the strategies, which are more productive in Russia may not be as productive when collaboration with researchers abroad.

Policy makers in Russia should become concerned with the low productivity of research in Russian cardiology. Barriers should be identified and funding and incentives should be realigned to achieve greater research productivity in the field because international experience and economic research clearly demonstrate the link between research and economic productivity (see literature review section). Using the recent experience in countries with advanced science and technology capacity, policy makers in Russia should stimulate research collaboration as a cost-effective way to raise research productivity. In addition to that, recent research insights, including this study and the study of Rumsey-Wairepo (2006) indicate that it might be most effective to incentivize participation of researchers in certain types of research collaborations. Unfortunately, no prior policy experience exists that could be used as an example and some ingenuity will be in need.

Not only incentives should be realigned by policy-makers to induce greater collaboration and research productivity, but the nature of research education and training should be changed to cultivate appreciation of collaboration in research and to equip

future researchers with skills necessary for successful collaboration. Graduate students in cardiology should be provided more opportunities for teamwork, for apprenticeship research with established researchers, as well as for international experience during their studies. Similar measures should be taken as a part of professional development of faculty and research personnel.

Several implications follow from the study for future research. First, more studies need to be conducted to explore the effect of co-authorship strategies on research productivity. So far only two studies, including this one, addressed the relationship directly and their conclusions need to be confirmed by similar studies contextualized in a variety of research fields and countries with different level of science and technology capacity.

Second, to the extent possible future studies should attempt to control the potential confounding variables, which were indicated in the limitations section. Evidently, the use of the Web of Science as a source of data for compiling the study sample does not allow to collect sufficient information about the confounding variables. Hence, different sources of data might be utilized. Alternatively, the confounded variables could be accounted for indirectly. For example, a mixed method approach could be utilized, whereby a quantitative analysis would be supplemented with an interview, survey or document analysis to gain better understanding of the journals, the research field and the research activity in the field, including information about the extent of participation in research of practitioners, the types of articles published in the journals, and the costs involved in different types of research collaboration.

Despite its limitations, the study has made an important contribution to existing research. It advanced existing understanding about the relationship between co-authorship and productivity by exploring the role of co-authorship strategy, discipline and country context. It confirmed the findings of preceding studies that collaboration is more productive than conducting research in solitude, that co-authorship strategy does matter, and that bridging-based strategies are on the average more productive than bonding-based strategies.

An important implication of the study for future research is that it confirmed the reliability of the approach to the study of the effect of co-authorship strategies on productivity, which was suggested by Rumsey-Wairepo (2006). The consistency of the findings of this study with the findings of Rumsey-Wairepo (2006), as well as the stability of the results during the sensitivity analysis indicate that the approach could produce accurate results and could be successfully utilized in future studies.

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