

# Leader-member exchange, trust, and performance in national science foundation industry/university cooperative research centers

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Published online: 10 November 2009  
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**Abstract** This research examines the relationship between leader-member exchange, trust, and research center performance with satisfaction and commitment to the research center in all Industry/University Cooperative Research Centers supported by the National Science Foundation in the United States. University administrator ratings of center performance fully mediated the positive relationship between leader-member exchange and trust and the extent to which university administrators reported satisfaction with and commitment to the Industry/University Cooperative Research Center that reported to them. We discuss the manner in which leadership relationship and research center performance mutually reinforce each other and the importance of this in creating and transferring technology in industry-university research partnerships and the implications of this for science policy.

**Keywords** Research and development · Leadership · Innovation

**JEL Classification** D23 (organization behavior) · I23 (higher education research institutions) · M12 (personnel management) · O3 (technological change; research and development)

## 1 Introduction

Approximately two-thirds of award-winning innovations in the United States during the period 1970–2006 required some form of interorganizational collaboration (Block and Miller 2008). The high incidence of collaboration reflects the cooperation required to create complex innovations, the increased role of the private sector in funding earlier stages of the innovation process, and encouragement of collaborative research by federal

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funding agencies and universities (Block and Miller 2008). One unique form of industry-university research collaboration is the Industry/University Cooperative Research Center (I/UCRC) promoted and funded by the National Science Foundation (NSF; National Science Foundation 2008). I/UCRCs facilitate collaborative relationships involving industrial firms and universities through formalized mechanisms for developing and transferring new knowledge and technologies (Betz 1996). Industrial firms benefit from the alliance by gaining access to experts and leading-edge research facilities and technologies (Santoro and Chakrabarti 2001) as well as by enhancing their reputation from association with prominent academic institutions (Fombrun 1996). Universities benefit by receiving educational and employment opportunities for students and post-doctoral researchers as well as contributions of laboratory equipment and financial support from partner firms (National Science Board 2006; National Science Foundation 1982).

I/UCRCs are organizationally and administratively complex because they straddle multiple disciplines, multiple academic departments and multiple organizations and, as a result, have multiple groups of stakeholders that must be satisfied. Leaders of I/UCRCs can coordinate complexity and enhance technological innovation by removing boundaries and managing internal relationships at multiple levels of the organization as well as cultivating relationships with external collaborators (Davis 1995). Leaders must be skilled administrators to establish strong links through internal and external boundary spanning while simultaneously managing their own research teams (Van de Ven 1986). As leader of a research and development (R&D) organization, I/UCRC directors must create and sustain an organizational climate for innovation, acquire money and resources, develop effective internal relationships with superiors, colleagues and subordinates, and nurture effective external relationships with industry partners (Amabile 1988; Elkins and Keller 2003). Directors of I/UCRCs, despite being distinguished scientists and engineers, may be challenged by the leadership demands of such organizational complexity (Gray and Walters 1998).

This research examined all I/UCRCs in the United States that were operating in 2005. We studied the leadership relationship involving center directors and the university administrators to whom they reported. University administrators are important to the success of I/UCRCs because they can interpret university rules in a manner that is favorable to the center (e.g., choice of indirect cost rates), provide critical resources to support the center's operation (e.g., space, equipment, and administrative support), and remove barriers to center performance (e.g., ensure cooperation across university departments and colleges; Gray and Walters 1998). We examined two aspects of the leadership relationship involving I/UCRC directors and the university administrators to whom they reported—leader-member exchange and trust.

## 2 Leader-member exchange and leadership

Leader-member exchange (LMX) is a theory of leadership that emphasizes the role-making process involving leaders and work group members who report to them and the extent to which their relationship exhibits exchange and reciprocal influence (Yukl 2010). The role-making aspect of LMX theory has received greater research attention than its exchange aspect (Liden et al. 1997). Focus on leadership relationships rather than leader characteristics or leadership style distinguishes LMX theory from other leadership theories (House and Aditya 1997). Developed by Graen and colleagues (Dansereau et al. 1975; Graen 1976; Graen and Cashman 1975), the original formulation of LMX theory was

grounded in role theory (Kahn et al. 1964), which states that organizational members occupy roles that specify the work behavior that is expected of them. LMX theory emphasizes the importance of leaders in the role-making process (Graen 1976). As roles evolve, leaders provide desired outcomes in exchange for member contributions. Exchanges vary in quality across members on the basis of interpersonal compatibility and member performance, competence, and reliability. Members able to develop high quality exchange relationships receive desirable outcomes such as valued job assignments, promotion opportunities, delegation of greater responsibility, and pay increases as a result of their high LMX relationship. In exchange, members are expected to work harder, demonstrate loyalty to the leader, and share some of the leader's responsibilities. The relationship evolves and strengthens as both leader and member satisfy mutual expectations and needs, reward exchange behaviors and successfully influence each other, and as a result create a relationship that has high LMX quality (Graen and Scandura 1987). Member and leader ratings of LMX quality demonstrate only modest agreement, however, suggesting that each member of the dyad may pay attention to and value different aspects of the relationship (Deluga and Perry 1994; Gerstner and Day 1997; Liden et al. 1993; Scandura and Schriesheim 1994).

Early formulations of LMX theory emphasized that relationship quality varies across each leader-member dyad, with members divided into in-groups or out-groups based on the quality of exchange and the strength and closeness of the leader-member relationship. In-group members have high quality LMX relationships that are characterized by greater mutual influence, support, and trust that spur them to act beyond the requirements of their formal job descriptions (Graen and Uhl-Bien 1995; Liden and Graen 1980). In contrast, out-group members have lower quality exchanges that are characterized by less trust, mutual respect, and obligation that induce them to constrain their performance to meet only minimum requirements of the work role; their performance meets role expectations but does not exceed them (Graen and Uhl-Bien 1995; Liden et al. 1997). LMX theory has been reformulated to reduce the distinction between in-group and out-group members and advocates instead strengthening all leadership relationships (Graen and Uhl-Bien 1995). Consistent with this recommendation, we ignore the distinction between in-group and out-group membership in our analysis.

LMX theory has received extensive empirical support. Reviews of research show that LMX quality is related to meaningful organizational antecedents and outcomes (Erdogan and Liden 2002; Gerstner and Day 1997; Graen and Uhl-bien 1995; Liden et al. 1997; Schriesheim et al. 1999). Common antecedents of LMX quality include leader-member similarity in attitudes, values, and personality traits, as well as member competence, dependability, effort, and performance. Common outcomes of high LMX quality include increased job satisfaction, organization commitment, mentoring, open communication, role clarity, and high performance of members. Some variables such as performance may serve either as an antecedent or outcome of LMX quality. We discuss below how we examine performance as both antecedent and outcome.

Relevant to I/UCRCs, Graen and Scandura (1987) hypothesize that high quality LMX relationships empower subordinates to engage in innovative behavior. Scott and Bruce (1994, 1998) found that LMX quality is related to innovative behavior of R&D professionals engaged in product and process innovation, and that reciprocal influence processes inherent in strong LMX relationships are beneficial to innovation. Tierney et al. (1999) found that LMX quality was positively related to several measures of individual creativity among R&D employees. Moreover, the LMX relationship had an enabling effect for less creative employees who demonstrated greater creativity when they reported a high quality

LMX relationship with their leader. High quality LMX relationships are related to the following variables that may mediate creation and transfer of technological innovations: providing others with challenging tasks (Liden and Graen 1980) and recognition (Graen and Cashman 1975), support of risk-taking (Graen and Cashman 1975), successful resource acquisition (Graen and Scandura 1987), supportive advocacy (Duchon et al. 1986), and providing task and relationship support (Amabile et al. 2004).

We examined the center director-university administrator leadership relationship and its association with the attitudes that university administrators have toward the I/UCRC. Consistent with previous research, we expected to find that high quality LMX relationships between I/UCRC center directors and university administrators would be positively related to university administrator satisfaction with and commitment to the I/UCRC.

### 3 Trust and leadership

Mayer et al. (1995, p. 712) define trust as the "...willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor (the individual trusting), irrespective of the ability to monitor or control that other party." We used this definition of trust to guide our research as it is widely accepted in the organizational research literature (Rousseau et al. 1998).

Trust has cognitive and affective components (Lewis and Weigert 1985). Cognition-based trust results from rational evaluations of the other person's reliability and dependability, whereas affect-based trust results from emotional bonds or reciprocated interpersonal care and concern between both members of the relationship (Lewis and Weigert 1985; McAllister 1995). Although affective and cognitive components may be differentially related to outcomes, most research that examines the influence of trust in leadership combines both components and employs a single scale score to represent the construct (Dirks and Ferrin 2002). We combined cognitive and affective components to represent a single dimension of trust to simplify interpretation of our results and to make our results more easily comparable to the research of others.

Trust plays a central role in leadership relationships and influences desired outcomes such as satisfaction, commitment, and performance (Costigan et al. 1998; Dirks 1999). Dirks and Ferrin (2002), in a meta-analysis of the literature devoted to trust and leadership, found that trust is related to job satisfaction and performance, goal attainment, organizational commitment, intention to leave the organization, satisfaction with leader, and leader-member exchange. Trust is most strongly related to attitudes such as satisfaction and least strongly related to job performance (Dirks and Ferrin 2002). The importance of trust in leaders may be universal. Ratings from 60 societies/cultures reveal that trustworthy leaders are perceived around the globe to be more effective (Den Hartog et al. 1999).

Trust may be related to organization-level outcomes such as I/UCRC performance because it lowers agency and transaction costs (Jones 1995), promotes smooth and efficient market exchanges (Arrow 1974), and improves the organization's ability to adapt to complexity and change (Korsgaard et al. 1995; McAllister 1995). Trust also strengthens the type of industry-university collaboration required for successful I/UCRC performance (Santoro and Saporito 2003). We expected to find that university administrators who reported a high level of trust in the director of the I/UCRC that reported to them would also report greater satisfaction with and commitment to the I/UCRC.

LMX and trust are moderately related to each other (average uncorrected  $r = .59$ ; Dirks and Ferrin 2002), but the causal structure underlying this relationship is uncertain. Some

researchers distinguish between trust and LMX, most often treating trust as a correlate of LMX quality (Cunningham and MacGregor 2000). Other researchers treat trust as a component of the LMX construct. Brower et al. (2000) argue that LMX quality comprises two forms of trust that do not have to be balanced or reciprocated in leadership exchange—leader's trust in subordinate and subordinate's trust in leader. Moreover, trust is viewed by some to be a broader construct than LMX that may include additional aspects of trustworthiness, benevolence, openness, receptiveness, and the emotions related to trusting (Brower et al. 2000; Butler 1991; McAllister 1995). Because of its greater theoretical breadth, we expected that trust may be related differently than LMX with university administrator satisfaction with and commitment to the I/UCRC. In keeping with the Dirks and Ferrin (2002) interpretation of the literature and to allow more detailed interpretation of results, we treated LMX and trust as separate predictors in our analysis.

#### 4 LMX, trust, and performance

Ability, competence, and performance are positively related to LMX quality and trustworthiness in organizations (Dirks 2000; Mayer et al. 1995; McAllister 1995). Member performance is both an antecedent and outcome of LMX quality (Erdogan and Liden 2002; Gerstner and Day 1997; Liden et al. 1997; Schriesheim et al. 1999). The original formulation of LMX theory emphasized the role-making process for leaders and members at the beginning of their relationship (Graen 1976). Roles become routinized over time as leaders and members engage in exchange (Graen and Scandura 1987; Graen and Uhl-Bien 1995). High member performance early in the relationship leads to greater trust and higher quality leader-member exchange, which lead in turn to greater assistance and support provided by the leader, which then increase member performance (Graen and Scandura 1987). Hence, LMX, trust, and performance are reciprocally related and mutually reinforce each other over time. Longitudinal research required to test this reciprocal relationship has been rare and has yielded mixed results (Erdogan and Liden 2002; Liden et al. 1997). Leader ratings of member performance are positively correlated with trust and ratings of LMX quality, but the strength of this relationship depends on the type of performance measure that is used; subjective ratings of performance are more highly correlated than are objective measures of performance (Gerstner and Day 1997). Duarte et al. (1993, 1994) reported that performance ratings of low LMX members were related to objective measures of their performance, whereas high LMX members received high performance ratings that were unrelated to objective measures of performance. This pattern of correlations suggests that some inflation may exist in subjective ratings of performance for members who have a high LMX quality relationship with the leader.

We expected that I/UCRC performance would be positively associated with university administrator satisfaction with and commitment to the center as well as their perceptions of trust and LMX quality. Because performance may serve as both an antecedent and outcome of trust and LMX quality, we analyzed it both ways. We did this because the leadership relationships we studied were well established, existing on average for more than 3 years. This length of time is sufficient for center directors to demonstrate competence and achieve success for their center, which should in turn influence university administrator attitudes toward the center, which may then increase their support of the I/UCRC thus enhancing its performance. We examined two models of mediation by altering the position of I/UCRC performance in the equations: (1) I/UCRC performance as a mediator of the relationship between LMX and trust and university administrator satisfaction with and commitment to

the I/UCRC; (2) LMX and trust as mediators of the relationship between I/UCRC performance and university administrator satisfaction with and commitment to the I/UCRC.

## 5 Method

### 5.1 Participants and sampling procedures

The data reported here are part of a national study of leadership in NSF I/UCRCs. Directors of all I/UCRC sites in the United States were asked to participate in the study and provide contact information for the university administrator to whom they reported. Out of the population of 127 center and site directors invited to join the study, 105 directors agreed to participate (82.7% response rate). Of these, 96 I/UCRC directors provided complete questionnaire data and were asked to nominate the university administrator to whom they reported to participate in the study. Of 96 university administrators invited to participate in the study, 52 completed questionnaires (54.2% response rate). University administrators were typically department chairs, deans, or vice-presidents for research.

An email invitation was sent to each participant that described the purpose of the study. Upon joining the study, a unique password was sent to provide access to the questionnaire and participants were directed to the web site where the questionnaire was located. University administrators received weekly reminders via email until they completed the questionnaire. After 4 weeks, university administrators who had not completed the questionnaire were called by telephone and asked to participate. University administrators received up to 10 phone calls and 12 email reminders until they completed the questionnaire or they asked to be removed from the study. Most participants completed the questionnaire after receiving a small number of follow-up requests. Responses were confidential but not anonymous.

### 5.2 Measures

University administrators rated the quality of the leadership relationship involving center directors, their satisfaction with and commitment to the I/UCRC, and performance of the I/UCRC and its director. Leader ratings such as these are commonly used to study trust, LMX, and other aspects of the leadership relationship, and their association with other variables such as satisfaction, commitment, and performance (Dirks and Ferrin 2002; Erdogan and Liden 2002; Gerstner and Day 1997; Liden et al. 1997; Schriesheim et al. 1999).

#### 5.2.1 *Leader-member exchange*

Leader-member exchange quality was measured using the LMX-7 (Graen et al. 1982). The LMX-7 is recommended and used most widely to assess the quality of leader-member exchange and has the strongest psychometric properties (Gerstner and Day 1997; Graen and Uhl-bien 1995), although it may not represent the full range of the leader-member exchange construct (Liden and Maslyn 1998; Schriesheim et al. 1999). The LMX-7 consists of 7 items employing a five-choice response format with varied choices. Item wording reflected the relationship involving center directors and university administrators. University administrators rated the quality of leadership exchange involving the center director reporting to them. The coefficient alpha for this scale was .83.

Further evidence for reliability comes from examining agreement between university administrator and center director ratings of LMX quality ( $r = .38, p = .008$ ). The strength of this agreement is consistent with other research. The mean sample-weighted correlation between leader and member ratings of LMX quality is .29; the average correlation is .37 corrected for leader and member measurement unreliability (Gerstner and Day 1997). The extent of agreement is unrelated to the type of measure used to assess LMX quality.

### 5.2.2 *Trust*

We used a measure developed by McAllister (1995) to assess the extent to which university administrators trusted the center directors who reported to them. Using confirmatory factor analysis, McAllister (1995) validated a two-factor model of trust with a scale that had high reliability ( $\alpha = .91$  for cognition-based trust and  $\alpha = .89$  for affect-based trust) and demonstrated discriminant validity when compared to other measures. The scale measuring both factors consists of 11 items employing a seven-choice response format that ranges from strongly disagree (1) to strongly agree (7). The coefficient alpha for this scale was .92. Further evidence for the reliability of this measure comes from agreement between center director and university administrator ratings of trust ( $r = .46, p = .001$ ).

### 5.2.3 *Satisfaction with I/UCRC*

Fourteen items were adapted from Coberly (2004) and three additional items were created to assess university administrator satisfaction with the I/UCRC. Items used a five-choice response format that ranged from very dissatisfied (1) to very satisfied (5). Although items represented different facets of satisfaction, we combined them to form a single scale in order to reduce the number of variables in the equation due to our small sample size and to simplify presentation of the results. The reliability for this combined scale ( $\alpha = .94$ ) suggests that the single scale score adequately represents the content domain of the items.

### 5.2.4 *Commitment to I/UCRC*

Commitment to the I/UCRC was measured using 15 items adapted from the Organizational Commitment Questionnaire (Mowday et al. 1979; Porter et al. 1974), the instrument used most widely to assess organizational commitment (Meyer et al. 2002). Items employed a five-choice response format that ranged from strongly disagree (1) to strongly agree (5). The coefficient alpha for this scale was .91.

### 5.2.5 *I/UCRC performance*

University administrators were asked to rate five aspects of center performance. Items representing three aspects of center performance that focus on innovation and technology transfer were taken from the annual survey of I/UCRCs administered for NSF by North Carolina State University (Gray 2009). The first item assessed the extent to which research and development were enhanced via increased technical awareness, accelerated or new projects, or development of intellectual property in the partner organizations. The second item assessed the extent to which commercialization was enhanced via improvement of new products, processes, services, improved sales, or new or retained jobs. The third item assessed the extent to which professional networking was enhanced via improved ability to

recruit students, or increased cooperation with other industrial members and scientists outside the partner organizations. Each item employed a five-choice response format that ranged from no impact (1) to very high impact (5). We created two additional items to assess I/UCRC performance. One item asked administrators to rate performance of the I/UCRC compared to other research centers in the university that reported to them. A second item asked administrators to rate performance of the center director compared to other center directors at the university that reported to them. Both items employed a five choice response format that ranged from poor (1) to exceptional (5).

We used maximum likelihood factor analysis to assess the factor structure underlying the five performance items. A single factor was extracted that explained 70% of the variance. The lowest item loading (.68) represented commercialization. The highest item loading (.89) compared performance of the I/UCRC to other research centers reporting to the administrator. The internal consistency of the scale containing all five performance items supports their aggregation into a single scale (coefficient alpha = .89). We used the average rating of all items to represent university administrator perceptions of I/UCRC performance.

## 6 Results

Responses were examined for distributional violations and outliers. One case was more than 3 standard deviations from the mean on the LMX measure and was deleted as recommended when analyzing small samples (Tabachnik and Fidell 2001, p. 71). Means, standard deviations, correlations, and reliabilities for all variables are included in Table 1. The size of the correlation between LMX and trust ( $r = .68, p = .000$ ) reveals a moderate relationship with more than 50% non-overlapping variance, which is consistent with other research (Dirks and Ferrin 2002), and supports our decision to treat them independently in our analysis.

We used multiple regression to examine the relationship between university administrator perceptions of LMX, trust, and center performance with their satisfaction and commitment to the I/UCRC. Although structural equation modeling is the preferred method for analyzing mediation because of its ability to consider measurement error in parameter estimates, the minimum sample size of 100 required to employ this method argued against its use with our sample (Hoyle and Kenny 1999). Instead, we used a

**Table 1** Means, standard deviations, scale reliabilities, and correlations among variables

Variable	Mean	SD	LMX	Trust	I/UCRC performance	Satisfaction with I/UCRC	Commitment to I/UCRC
LMX	4.09	.54	(.83)				
Trust	5.81	1.02	.68	(.92)			
I/UCRC performance	3.77	.83	.63	.59	(.89)		
Satisfaction with I/UCRC	4.21	.56	.53	.65	.86	(.94)	
Commitment to I/UCRC	4.05	.61	.52	.38	.63	.63	(.91)

$N = 51$ . All correlations significant at  $p < .05$ . Coefficient alphas are in diagonal. All scale scores range from 1 to 5 except for Trust, which ranges from 1 to 7

procedure to analyze mediation effects recommended by Baron and Kenny (1986) and colleagues (Kenny et al. 1998). Although lower in power than structural equation modeling procedures, the Baron and Kenny procedure yields conservative estimates and is most commonly used to assess mediation in social science research (Fritz and MacKinnon 2007).

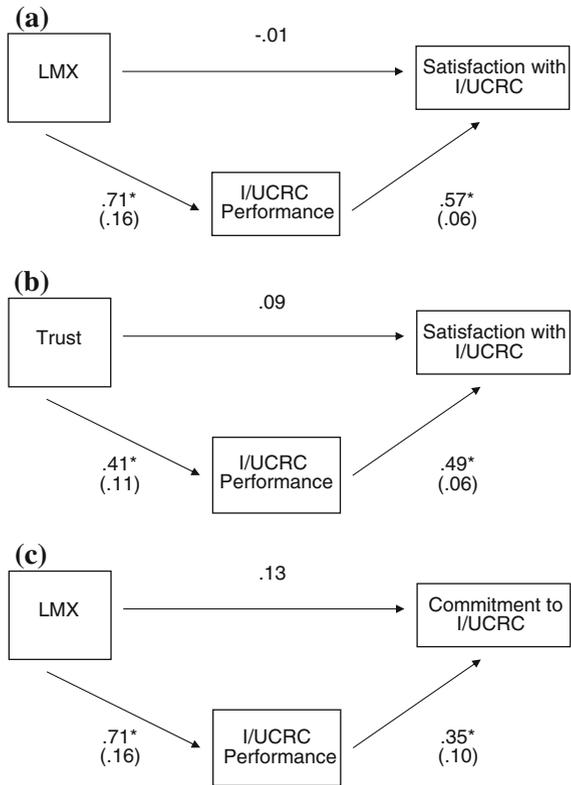
The Baron and Kenny procedure requires four steps to provide evidence for mediation. First, the predictor must be significantly related to the outcome. Second, the predictor must be significantly related to the mediator. Third, the mediator must be related to the outcome. Fourth, to show that the mediator completely mediates the relationship between the predictor and outcome, the coefficient representing the relationship between the predictor and outcome should become zero when controlling for the mediator. Additionally, Baron and Kenny recommend using a statistic developed by Sobel (1982) to test the significance of the mediation effect. The Sobel test calculates a Z statistic that follows the standard normal distribution. We also calculated a variation of the Sobel test using an alternative method for calculating standard errors developed by Aroian (1944) as recommended by MacKinnon et al. (2002). We used an interactive calculator provided by Preacher and Leonardelli (2009) to calculate the Sobel test and its Aroian variation. We first report results treating center performance as a mediator of the relationship between LMX and trust and university administrator satisfaction and commitment to the I/UCRC. We then report results from analyzing LMX and trust as mediators of the relationship between center performance and satisfaction and commitment to the I/UCRC.

As expected, LMX significantly predicted university administrator satisfaction with the I/UCRC,  $F(1, 49) = 7.23, p < .01, B = .31$ . The regression equation including LMX and I/UCRC performance was also significant,  $F(2, 48) = 49.28, p < .0001$ . The regression coefficient between LMX and satisfaction with I/UCRC approached zero and was no longer significant with inclusion of I/UCRC performance in the equation, whereas the regression coefficient between I/UCRC performance and satisfaction with I/UCRC and between LMX and I/UCRC performance were significant thus providing evidence for mediation (Fig. 1a). Tests for the mediation effect were also significant: Sobel = 3.99,  $p < .001$ ; Aroian = 3.97,  $p < .001$ . These results demonstrate that I/UCRC performance fully mediated the relationship between LMX and satisfaction with I/UCRC.

As expected, trust significantly predicted university administrator satisfaction with I/UCRC,  $F(1, 49) = 17.14, p < .0001, B = .28$ . The regression equation including trust and I/UCRC performance was also significant,  $F(2, 48) = 51.82, p < .0001$ . The regression coefficient between trust and satisfaction with I/UCRC approached zero and was no longer significant with addition of I/UCRC performance to the equation, whereas the paths between trust and I/UCRC performance and between I/UCRC performance and satisfaction with I/UCRC were significant (Fig. 1b). Tests for the mediation effect were significant as well: Sobel = 3.46,  $p < .001$ ; Aroian = 3.44,  $p < .001$ . These results show that I/UCRC performance fully mediated the relationship between trust and satisfaction with I/UCRC.

As expected, LMX significantly predicted university administrator commitment to the I/UCRC,  $F(1, 49) = 8.77, p < .005, B = .38$ . The regression coefficient for LMX approached zero when I/UCRC performance was entered into the equation. The regression equation including LMX and I/UCRC performance was significant,  $F(2, 48) = 10.77, p < .0001$ . The paths between LMX and I/UCRC performance and I/UCRC performance and commitment to the I/UCRC were significant (Fig. 1c) as were the significance tests for the mediation effect: Sobel = 2.67,  $p < .01$ ; Aroian = 2.62,  $p < .01$ . These results demonstrate that I/UCRC performance fully mediated the relationship between LMX and university administrator commitment to the I/UCRC.

**Fig. 1** Regression analysis of LMX and trust with satisfaction and commitment to I/UCRC mediated by I/UCRC performance.  $N = 51$ . \*  $p < .01$ . Unstandardized regression coefficients are on paths. Standard errors are in parentheses



Contrary to expectations, trust did not predict commitment to the I/UCRC,  $F(1, 49) = 2.03$ , n.s. Because this relationship was not significant, mediation was impossible and was not tested.

We also analyzed the reverse order of the mediation effect, that is, LMX and trust as mediators of the relationship between I/UCRC performance and university administrator satisfaction with and commitment to the I/UCRC. I/UCRC performance was significantly related to satisfaction and commitment to the I/UCRC, duplicating the effects reported above, but LMX and trust were not significant as mediators. Because none of the mediation effects was significant, the regression results are not reported.

### 7 Discussion

Most award-winning innovations in the United States result from collaboration (Block and Miller 2008), and the success of collaborative innovation requires trust and effective leadership relationships (Santoro and Saporito 2003). We examined an important form of collaborative relationship that has received little attention in the literature devoted to management of research centers—the leadership relationship between directors of NSF I/UCRCs and the university administrators to whom they report. This is important because research on leadership in R&D organizations has not included study of cooperative research centers such as I/UCRCs (Elkins and Keller 2003). Consistent with previous

research and theory, our results document the importance of the leadership relationship—specifically trust and LMX quality—in shaping attitudes of university administrators toward the I/UCRC that reports to them. Moreover, our results show that I/UCRC performance fully mediated the influence of the leadership relationship on university administrator attitudes toward the I/UCRC. The leadership relationship with the I/UCRC director influences the extent to which university administrators are satisfied with and committed to the I/UCRC, but these effects are transmitted through the achievement of center success.

Models of the leadership relationship emphasize that trust and LMX quality, while related conceptually and empirically, are independent constructs that vary in the breadth of their focus and their connection with outcomes. Our results support this view. The original formulation of LMX treats it as a narrower construct that emphasizes the role making and exchange aspects of the leader-member dyad, which are chiefly cognitive in nature (Dansereau et al. 1975; Graen and Cashman 1975). Recent reformulations have broadened the LMX construct, but most researchers continue to focus more narrowly on its role making and exchange aspects (Liden and Maslyn 1998). Brower et al. (2000) explain the relative contribution of LMX quality and trust to the leadership relationship. Trust is a broader construct that includes the reciprocity associated with leader-member exchange but also includes perceptions of trustworthiness, benevolence, openness, receptiveness, and the emotions associated with trusting (Brower et al. 2000; Butler 1991; McAllister 1995). Moreover, trust inherently requires risk taking (Mayer et al. 1995). Despite differences in breadth, LMX and trust have common features (Brower et al. 2000). They both develop over time through reciprocal, mutually reinforcing influence between members of the leader-member dyad. Leader and member perceptions of both may disagree, yet it is their individual perceptions that influence their attitudes and behaviors. Both constructs share similar antecedents such as ability and performance. LMX quality and trust are correlated yet explain unique variance in important outcomes such as satisfaction and commitment. Trust may serve as an antecedent of LMX quality although there is little empirical evidence to support this expectation (Brower et al. 2000). LMX quality may improve as trust strengthens and both parties demonstrate willingness to be vulnerable to each other and discover that such vulnerability is rewarded and not betrayed (Mayer et al. 1995). In our results, LMX quality was related to the extent to which university administrators were satisfied with and committed to the I/UCRC that reported to them, whereas trust was related only to satisfaction with I/UCRC. Although both aspects of leadership are related, these results suggest that the exchange aspects of the leadership relationship may exert greater influence than more affective aspects such as trust in shaping attitudes that senior university leaders have toward the I/UCRC that reports to them.

To enhance the exchange quality of the leadership relationship with university administrators, center directors should first determine the phase of their relationship (Graen and Scandura 1987; Graen and Uhl-bien 1991). During the first and most important phase of the relationship, its beginning when both members of the dyad meet, center directors should establish clear roles and expectations. They should determine the deliverables most important to university administrators and then deliver them. They should keep commitments, demonstrate loyalty and reliability, and extend upward offers of help and support. Consistent performance will enhance trust and encourage deepening of the relationship. As time goes on, the relationship should focus on refinement of exchange and deepening of trust. Once the relationship is thoroughly established, center directors should encourage administrator commitment to the mission and objectives of the center and, by extension, its director. Attempts to influence university administrators should employ tactics that

strengthen exchange and are more successful in gaining desired resources (consultation, collaboration, inspirational appeal, rational persuasion, friendliness, bargaining, and ingratiation) and avoid upward influence tactics that are likely to alienate university administrators and weaken the exchange relationship (appealing to higher authority, organizing antagonistic coalitions, and excessive assertiveness; Deluga and Perry 1991; Yukl and Chavez 2002; Yukl and Michel 2006). Ingratiation—efforts to make the university administrator like the director—coupled with rationality—using data and facts to complement ingratiation and support requests—may be particularly effective as upward influence tactics (Deluga and Perry 1994; Higgins et al. 2003). Examples of effective ingratiation behaviors that may be directed toward university administrators include providing praise, agreeing with opinions, showing appreciation, and demonstrating respect and deference (Yukl 2010, p. 187).

The emphasis on exchange is supported further by the importance of I/UCRC performance in shaping university administrator attitudes. Our results show that I/UCRC performance fully mediated the relationship involving LMX and trust when they were significantly related to I/UCRC satisfaction and commitment. The importance of performance is consistent with previous research and theory concerning trust and LMX quality (Brower et al. 2000; Dirks and Ferrin 2002; Erdogan and Liden 2002; Gerstner and Day 1997). The strong relationship with performance is likely due to the length of time that university administrators and center directors have worked together (more than 3 years, on average) and the resulting stability of the relationship. LMX quality tends to emerge during the early formation of the leader-member relationship and remains relatively stable over time (Liden et al. 1993). Trust is more dynamic and tends to be renegotiated on a situation-by-situation basis, but it may remain high when performance is consistently strong over time (Brower et al. 2000).

### 7.1 Limitations and future research

Our conceptualization of LMX quality and use of the LMX-7 to measure it was consistent with most research concerning this construct (Erdogan and Liden 2002; Gerstner and Day 1997; Graen and Uhl-Bien 1995), but it may ignore other important aspects of leader-member exchange (Schriesheim et al. 1999). LMX quality may also include elements of affect, loyalty, contribution, and professional respect in addition to exchange and role making, (Liden and Maslyn 1998). Future research should consider using broader measures of leader-member exchange that may capture the full range of the LMX construct. Moreover, other aspects of the leadership relationship beyond LMX quality and trust may be important. “High quality connections” that focus on creation of identity, growth and development, and learning in an effort to “enliven” people may also be important for technological innovation (Dutton and Heaphy 2003). Beyond the focus on leader relationship, future research should also examine transformational leadership style, team leadership, and leadership focused on boundary spanning as these are also important in managing innovation (Elkins and Keller 2003).

The models we tested were simple with only two aspects of the leadership relationship and a single mediator. Our sample was too small to evaluate large multivariate models that may more completely represent the complexity of leadership relationships in industry-university cooperative research centers such as I/UCRCs. Future research should examine leadership relationships in larger samples that would provide sufficient power to test complex multivariate models that more fully capture the diverse dynamics of leadership relationships. Our sample included all I/UCRCs in the United States and was as large as

possible. Researchers should examine the role of trust, LMX quality, and other aspects of leadership in different types of collaborative research centers that focus on technological innovation that are supported by NSF, such as engineering research centers (NSF 2009), as well as other types of collaborative research centers in which universities and industry participate.

Our data collection relied on use of self-report questionnaires. Although such methods are commonly used to study trust, LMX quality, and performance, reliance on single sources of data, particularly self-report ratings, may yield a form of measurement bias that can inflate observed correlations. Common method bias may be particularly problematic when measuring subjective attitudes such as satisfaction and commitment (Crompton and Wagner 1994), although the extent of such inflation may be less common than once thought (Spector 2006). Moreover, aspects of the leadership relationship such as LMX quality may be more highly correlated with subjective ratings of performance such as those we used (Duarte et al. 1993, 1994). We attempted to reduce the influence of common methods bias by presenting scales that assessed outcome variables first in the questionnaire followed by scales that assessed predictors to reduce carryover effects in rating (Bradburn et al. 2004), but our effort may not have controlled common method bias. To examine the generalizability of our findings and the possibility that our results may have been influenced by common method bias, future research should use multiple methods of data collection, for example, objective measures of center performance in addition to subjective ratings. Future research should also use longitudinal, experimental designs to examine more clearly the mediated causal relationships among LMX, trust, and performance and their impact on outcomes such as senior leader attitudes and support over the lifespan of the center.

Our findings have some implications for science policy. If the emphasis on “Big Science” and collaborative research continues to grow, greater attention will have to be paid to the leadership challenges that result from the organizational complexity of such efforts. Traditionally trained academic scientists and engineers, who are more experienced working independently with small groups of graduate students and post-doctoral researchers, may be less capable of leading and engaging in the teamwork required to manage the complexity of large, multidisciplinary, multiorganizational research enterprises such as I/UCRCs. Scientists and engineers who wish to lead such efforts will need to learn to collaborate effectively as participants in “team science” (Gray 2008). If they are not effective in this role, center performance is likely to suffer and, if our findings are accurate, so too will the support, commitment and influence they need from key university administrators. A downward spiral of weakening relationships and reduced support will diminish center success and ultimately produce failure.

Our research documents the importance of leadership relationships in I/UCRCs, a powerful and effective form of partnership involving industry and university researchers sponsored by the National Science Foundation. If I/UCRC directors are to achieve their ambitious research and development goals, they must cultivate high quality leadership relationships with fellow researchers, university administrators, and industry partners.

**Acknowledgments** We thank the National Science Foundation for their financial support (EEC-0437631). We also thank Alex Schwartzkopf, Denis Gray, Eric Sundstrom, Beth Coberly, Edward Haug, Richard Muller, and Bruce Thompson for their assistance in design and implementation of this study, and Mathew Loesch for his help with portions of the literature review. Terri Scandura provided useful comments on an earlier draft of this paper. We are extremely grateful for the participation of all NSF I/UCRC center directors, site directors, and their university administrators. A previous version of this paper was presented at the annual meeting of the Society for Industrial and Organizational Psychology, New Orleans, April 2009.

## References

- Amabile, T. M. (1988). A model of creativity and innovation in organizations. *Research in Organizational Behavior*, *10*, 123–167.
- Amabile, T. M., Schatzel, E. A., Moneta, G. B., & Kramer, S. J. (2004). Leader behaviors and the work environment for creativity: Perceived leader support. *Leadership Quarterly*, *15*, 5–22.
- Aroian, L. A. (1944). The probability function of the product of two normally distributed variables. *Annals of Mathematical Statistics*, *18*, 265–271.
- Arrow, K. (1974). *The limits of organization*. New York: Norton.
- Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*, 1173–1182.
- Betz, F. (1996). Industry-university partnerships. In G. H. Gaynor (Ed.), *Handbook of technology management* (pp. 8.1–8.13). New York: McGraw Hill.
- Block, F., & Miller, M. R. (2008, July 9). *Where do innovations come from? Transformations in the US national innovation system, 1970–2006*. Retrieved January 26, 2009 from [http://www.itif.org/index.php?s=policy\\_issues&c=Science-and-R38D-Policy](http://www.itif.org/index.php?s=policy_issues&c=Science-and-R38D-Policy).
- Bradburn, N. M., Sudman, S., & Wansink, B. (2004). *Asking questions*. San Francisco: Jossey-Bass.
- Brower, H. H., Schoorman, F. D., & Tan, H. H. (2000). A model of relational leadership: The integration of trust and leader-member exchange. *Leadership Quarterly*, *11*, 227–250.
- Butler, J. K. (1991). Toward understanding and measuring conditions of trust: Evolution of a conditions of trust inventory. *Journal of Management*, *17*, 643–663.
- Coberly, B. M. (2004). Faculty satisfaction and organizational commitment with industry-university research centers. *Dissertation Abstracts International*, *65*(06), 3221B. UMI No. 3137105.
- Costigan, R. D., Ilter, S. S., & Berman, J. J. (1998). A multi-dimensional study of trust in organizations. *Journal of Managerial Issues*, *10*, 303–348.
- Crampton, S. M., & Wagner, J. A., III (1994). Percept-percept inflation in microorganizational research: An investigation of prevalence and effect. *Journal of Applied Psychology*, *79*, 67–76.
- Cunningham, J. B., & MacGregor, J. (2000). Trust and the design of work: Complementary constructs in satisfaction and performance. *Human Relations*, *53*, 1575–1591.
- Dansereau, F., Graen, G. B., & Haga, W. J. A. (1975). A vertical-dyad linkage approach to leadership in formal organizations. *Organizational Behavior and Human Performance*, *13*, 46–78.
- Davis, D. D. (1995). Form, function, and strategy in boundaryless organizations. In A. Howard (Ed.), *The changing nature of work* (pp. 112–138). San Francisco, CA: Jossey-Bass.
- Deluga, R. J., & Perry, J. T. (1991). The relationship of subordinate upward influencing behavior, satisfaction and perceived superior effectiveness with leader-member exchanges. *Journal of Occupational Psychology*, *64*, 239–252.
- Deluga, R. J., & Perry, J. T. (1994). The role of subordinate performance and ingratiation in leader-member exchanges. *Group & Organization Management*, *19*, 67–86.
- Den Hartog, D. N., House, R. J., Hanges, P. J., Ruiz-Quintanilla, S. A., & Dorfman, P. W. (1999). Culture specific and cross-culturally generalizable implicit leadership theories: Are attributes of charismatic/transformational leadership universally endorsed? *Leadership Quarterly*, *10*, 219–256.
- Dirks, K. T. (1999). The effects of interpersonal trust on work group performance. *Journal of Applied Psychology*, *84*, 445–455.
- Dirks, K. T. (2000). Trust in leadership and team performance: Evidence from NCAA basketball. *Journal of Applied Psychology*, *85*, 1004–1012.
- Dirks, K. T., & Ferrin, D. L. (2002). Trust in leadership: Meta-analytic findings and implications for research and practice. *Journal of Applied Psychology*, *87*, 611–628.
- Duarte, N. T., Goodson, J. R., & Klich, N. R. (1993). How do I like thee? Let me appraise the ways. *Journal of Organizational Behavior*, *14*, 239–249.
- Duarte, N. T., Goodson, J. R., & Klich, N. R. (1994). Effects of dyadic quality and duration on performance appraisal. *Academy of Management Journal*, *37*, 499–521.
- Duchon, D., Green, S. G., & Taber, T. D. (1986). Vertical dyad linkage exchange: A longitudinal assessment of antecedents, measures, and consequences. *Journal of Applied Psychology*, *71*, 56–60.
- Dutton, J. E., & Heaphy, E. D. (2003). The power of high-quality connections. In K. S. Cameron, J. E. Dutton, & R. E. Quinn (Eds.), *Positive organizational scholarship: Foundations of a new discipline* (pp. 263–278). San Francisco: Jossey-Bass.
- Elkins, T., & Keller, R. T. (2003). Leadership in research and development organizations: A literature review and conceptual framework. *Leadership Quarterly*, *14*, 587–606.

- Erdogan, B., & Liden, R. C. (2002). Social exchanges in the workplace: A review of recent developments and future research directions in leader-member exchange theory. In L. L. Neider & C. A. Schreisheim (Eds.), *Leadership* (pp. 65–114). Greenwich, CT: Information Age Publishing.
- Fombrun, C. (1996). *Reputation: Realizing value from the corporate image*. Cambridge, MA: Harvard University Press.
- Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychological Science*, *18*, 233–239.
- Gerstner, C. R., & Day, D. V. (1997). Meta-analytic review of leader-member exchange theory: Correlates and constructs issues. *Journal of Applied Psychology*, *82*, 827–844.
- Graen, G. B. (1976). Role-making processes within complex organizations. In M. D. Dunnette (Ed.), *Handbook of industrial and organizational psychology* (pp. 1201–1245). Chicago: Rand McNally.
- Graen, G. B., & Cashman, J. A. (1975). A role making model of leadership in formal organizations: A developmental approach. In J. G. Hunt & L. L. Larson (Eds.), *Leadership frontiers* (pp. 143–165). Kent, OH: Kent State University press.
- Graen, G. B., Novak, M. A., & Sommerkamp, P. (1982). The effects of leader-member exchange and job design on productivity and job satisfaction: Testing a dual attachment model. *Organizational Behavior and Human Performance*, *30*, 109–131.
- Graen, G. B., & Scandura, T. A. (1987). Toward a psychology of dyadic organizing. In B. M. Staw & L. L. Cummings (Eds.), *Research in organizational behavior* (Vol. 9, pp. 175–208). Greenwich, CT: JAI Press.
- Graen, G. B., & Uhl-Bien, M. (1991). The transformation of work group professionals into self-managing and partially self-designing contributors: Toward a theory of leadership-making. *Journal of Management Systems*, *3*(3), 33–48.
- Graen, G. B., & Uhl-Bien, M. (1995). Relationship-based approach to leadership: Development of leader-member exchange (LMX) theory of leadership over 25 years: Applying a multi-level multi-domain perspective. *Leadership Quarterly*, *6*, 219–247.
- Gray, D. O. (2008, Summer). Making team science better: Applying improvement-oriented evaluation principles to evaluation of cooperative research centers. In C. L. S. Coryn & M. Scriven (Eds.), *Reforming the evaluation of research: New directions for evaluation*, *118*, 73–87.
- Gray, D. O. (2009). *Industry-university cooperative research centers (IUCRC) program evaluation project*. Retrieved January 30, 2009 from <http://www.ncsu.edu/iucrc/ProcessOut.htm>.
- Gray, D. O., & Walters, G. W. (Eds.). (1998). *Managing the industry/university cooperative research center: A guide for directors and other stakeholders*. Columbus, OH: Battelle Press.
- Higgins, C. A., Judge, T. A., & Ferris, G. R. (2003). Influence tactics and work outcomes: A meta-analysis. *Journal of Organizational Behavior*, *24*, 89–106.
- House, R. J., & Aditya, R. N. (1997). The social scientific study of leadership: Quo Vadis? *Journal of Management*, *23*, 409–473.
- Hoyle, R. H., & Kenny, D. A. (1999). Sample size, reliability, and tests of statistical mediation. In R. Hoyle (Ed.), *Statistical strategies for small sample research* (pp. 195–222). Thousand Oaks, CA: Sage Publications.
- Jones, T. M. (1995). Instrumental stakeholder theory: A synthesis of ethics and economics. *Academy of Management Review*, *20*, 404–437.
- Kahn, R. L., Wolfe, D. M., Quinn, R. P., Snoek, J. D., & Rosenthal, R. A. (1964). *Organizational stress: Studies in role conflict and ambiguity*. New York: Wiley.
- Kenny, D. A., Kashy, D. A., & Bolger, N. (1998). Data analysis in social psychology. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (4th ed., pp. 233–265). New York: Oxford University Press.
- Korsgaard, M., Schweiger, D., & Sapienza, H. (1995). Building commitment, attachment, and trust in strategic decision-making teams: The role of procedural justice. *Academy of Management Journal*, *38*, 60–84.
- Lewis, J., & Weigert, A. (1985). Trust as a social reality. *Social Forces*, *63*, 967–985.
- Liden, R. C., & Graen, G. B. (1980). Generalizability of the vertical dyad linkage model of leadership. *Academy of Management Journal*, *23*, 451–465.
- Liden, R. C., & Maslyn, J. M. (1998). Multidimensionality of leader-member exchange: An empirical assessment through scale development. *Journal of Management*, *24*, 43–72.
- Liden, R. C., Sparrowe, R. T., & Wayne, S. J. (1997). Leader-member exchange theory: The past and potential for the future. In G. R. Ferris & K. M. Rowland (Eds.), *Research in personnel and human resources management* (Vol. 15, pp. 47–119). Greenwich, CT: JAI Press.
- Liden, R. C., Wayne, S. J., & Stilwell, D. (1993). A longitudinal study of the early development of leader-member exchanges. *Journal of Applied Psychology*, *78*, 662–674.

- MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods, 7*, 83–104.
- Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review, 20*, 709–734.
- McAllister, D. J. (1995). Affect- and cognition-based trust as foundations for interpersonal cooperation in organizations. *Academy of Management Journal, 38*, 24–45.
- Meyer, J. P., Stanley, D. J., Herscovitch, L., & Topolnysky, L. (2002). Affective, continuance, and normative commitment to the organization: A meta-analysis of antecedents, correlates, and consequences. *Journal of Vocational Behavior, 61*, 20–52.
- Mowday, R. T., Steers, R. M., & Porter, L. W. (1979). The measurement of organizational commitment. *Journal of Vocational Behavior, 14*, 224–247.
- National Science Board. (1982). *University-industry research relationships: Myths, realities, and potentials*. Washington, DC: US Government Printing Office.
- National Science Board. (2006). *Science and engineering indicators 1996 (NSB-96-21)*. Arlington, VA: National Science Foundation.
- National Science Foundation. (2008). *Industry and university cooperative research program (I/UCRC)*. Retrieved June 23, 2008 from <http://www.nsf.gov/eng/iip/iucrcl/>.
- National Science Foundation. (2009). *Engineering research centers*. Retrieved January 30, 2009 from [http://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=5502&org=EEC](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5502&org=EEC).
- Porter, L. W., Steers, R. M., Mowday, R. T., & Boulian, P. V. (1974). Organizational commitment, job satisfaction, and turnover among psychiatric technicians. *Journal of Applied Psychology, 59*, 603–609.
- Preacher, K. J., & Leonardelli, G. J. (2009). Calculation of the Sobel test: An interactive calculation tool for mediation tests. Retrieved July 31, 2009 from <http://www.people.ku.edu/~preacher/sobel/sobel.htm>.
- Rousseau, D. M., Sitkin, S. B., Burt, R. S., & Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of Management Review, 23*, 393–404.
- Santoro, M. D., & Chakrabarti, A. K. (2001). Corporate strategic objectives for establishing relationships with university research centers. *IEEE Transactions on Engineering Management, 48*, 157–163.
- Santoro, M. D., & Saporito, P. A. (2003). The firm's trust in its university partner as a key mediator in advancing knowledge and new technologies. *IEEE Transactions on Engineering Management, 50*, 362–373.
- Scandura, T. A., & Schriesheim, C. A. (1994). Leader-member exchange and supervisor career mentoring as complementary constructs in leadership research. *Academy of Management Journal, 37*, 1588–1602.
- Schriesheim, C. A., Castro, S., & Cogliser, C. C. (1999). Leader-member exchange research: A comprehensive review of theory, measurement, and data-analytic procedures. *Leadership Quarterly, 10*, 63–113.
- Scott, S. G., & Bruce, R. A. (1994). Determinants of innovative behavior: A path model of individual innovation in the workplace. *Academy of Management Journal, 37*, 580–607.
- Scott, S. G., & Bruce, R. A. (1998). Following the leader in R&D: The joint effect of subordinate problem-solving style and leader-member relations on innovative behavior. *IEEE Transactions on Engineering Management, 45*, 3–10.
- Sobel, M. E. (1982). Asymptotic intervals for indirect effects in structural equations models. In S. Leinhardt (Ed.), *Sociological methodology 1982* (pp. 290–312). San Francisco: Jossey-Bass.
- Spector, P. E. (2006). Method variance in organizational research: Truth or urban legend? *Organizational Research Methods, 9*, 221–232.
- Tabachnik, B. G., & Fidell, L. S. (2001). *Using multivariate statistics* (4th ed.). Boston: Allyn and Bacon.
- Tierney, P., Farmer, S. M., & Graen, G. B. (1999). An examination of leadership and employee creativity: The relevance of traits and relationships. *Personnel Psychology, 52*, 591–619.
- Van de Ven, A. H. (1986). Central problems in the management of innovation. *Management Science, 32*, 590–607.
- Yukl, G. (2010). *Leadership in organizations* (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Yukl, G., & Chavez, C. (2002). Influence tactics and leader effectiveness. In L. L. Neider & C. A. Schriesheim (Eds.), *Leadership* (pp. 139–165). Greenwich, CT: Information Age Publishing.
- Yukl, G., & Michel, J. W. (2006). Proactive influence tactics and leader member exchange. In C. A. Schriesheim & L. L. Neider (Eds.), *Power and influence in organizations* (pp. 87–103). Greenwich, CT: Information Age Publishing.