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The multi-level process of trust and learning in university–industry innovation collaborations

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Abstract
Successful university–industry collaborations require high levels of trust among participants, yet achieving this goal is complex. In this study, we provide a fine-grained qualitative analysis of thirty interviews from four collaborative, government-funded case studies over a 2-year period to analyze how trust can facilitate and/or impede project outcomes. We identified two levels of trust (individual and organizational), at multiple stages of the collaboration. Scientists' reputation and shared values about information sharing helped build trust among individual scientists, while organizational-level trust centered on efficiency, including alignment with contract provisions and time commitment to the project. Our analysis shows that only one project had a positive outcome, demonstrating that the interaction of trust across levels and over time helps explain collaborative success or lack thereof. Such a holistic perspective can widen understanding of the outcomes of university–industry collaborative efforts.

Keywords University–Industry technology transfer · Innovation · Collaboration · Characteristic-based trust · Process-based trust · Shared knowledge · Individual and organizational level trust

JEL Classification O

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1 Introduction

University–industry innovation collaboration processes are based on interactions between university and industry scientists who are working to translate academic science with commercial potential toward market applications. Such market applications can include new drugs, software, biotechnology products or new technologies. Despite the potential importance of such collaborations (Geuna and Muscio 2009; Oliver 2009; Logar et al. 2014; Perkmann and Walsh 2008; Perkmann et al. 2013), the process of translation is highly complex: It requires substantial levels of shared knowledge and compatibility and can generate many tensions with regard to sharing and protecting knowledge (Bogers 2011; Philbin 2008; de Zubielqui et al. 2018). Inevitably, several constraints may need to be overcome, including differences in research culture between university and industry (Link 2003; McAdam et al. 2017; Meyer and Mizushima 1989; Siegel et al. 2003), individual incentives and behaviors (Filippetti and Savona 2017), and intellectual property (IP) secrecy, especially when a commercialization prospect is expected (Perkmann et al. 2013). Other management-related factors may include bureaucratic inflexibility, poorly designed reward systems, and ineffective management of technology transfer offices (Siegel et al. 2003). In order to overcome such barriers, it is especially important that such collaborations foster trustworthy behavior and trust between the partners, to facilitate effective joint learning, innovation, and collaboration (Ojasalo 2008).

This paper follows, over a period of 1 year, four case studies of such university–industry collaborations that were funded by a special governmental program. Our aim in the paper is identify the multiple ways in which trust can facilitate or impair such collaborations. We examine the development of trust building at both the individual and organizational level, as well as the possible causal mechanisms that drive transitions between the two levels over time, in order to more fully understand the outcomes of such collaborations.

We begin with a brief review of the literature on trust and trust development. Next, we describe the data and our qualitative analyses of four comparative cases.

2 Literature review

Substantial theoretical work developing the concept of trust has been offered by scholars in a range of disciplines, including sociology and organization studies (e.g., Cook 2001; Gambetta 1988; Mayer et al. 1995; Möllering 2006; Schoorman et al. 2007). Although definitions of trust are numerous, most contain common elements that pertain to risk taking and vulnerability, along with confident expectations of another's future behavior. A frequently adopted definition is that proposed by Mayer et al., which defines 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, irrespective of the ability to monitor or control that other party*. (Mayer et al. 1995, p. 712). As we clarify below, the term 'party' can be considered at both the individual level and the organizational level (Oliver 1997; Schilke and Cook 2013; Schoorman et al. 2007).

Of particular relevance is Zucker's early seminal paper on the production of trust (1986), in which she proposes three types of trust-building elements: characteristic-based trust, process-based trust, and institution-based trust. Zucker describes characteristic-based trust as that which is tied to the person and develops from the personal characteristics of

an individual; process-based trust derives from the nature of past and expected exchanges among partners; and institution-based trust is tied to formal social structures and mechanisms such as credentials and accreditation that can signal trustworthiness of an individual or an organization. Oliver and Liebeskind (1998) also found that initial trust can result from common values and interests (similar to Zucker's characteristic-based trust), as well as calculated and emerging social interactions (similar to Zucker's process-based trust). Others also have identified trust-building founded on personal characteristics of cultural similarity and shared values (Gillespie and Mann 2004; Jiang et al. 2011; Kerler and Killough 2009). More process-related drivers of trust have been identified as procedures that instill a sense of equity and fairness during interactions (Scheer et al. 2003), information sharing (Nguyen and Rose 2009), and communication quality (Stahl et al. 2011).

Zucker's work further suggests that drivers of trust operate simultaneously at multiple levels. Similarly, Oliver and Liebeskind (1998) argued that to adequately depict trust in complex relationships, it is essential to analyze multiple types of interactions. They suggested that network interactions involved in the exchange of intellectual capital between two organizations occur in three ways: (1) intra-organizational networks at the individual level within a single organization, (2) inter-organizational networks at the individual level working across two organizations, and (3) inter-organizational networks at the organizational level that depict the formal management level actions in the collaborations. Only by incorporating all three forms of interaction, can we understand the processes of knowledge exchanges and the associated trust development and/or erosion.

The multi-level, interactive aspect of trust building in inter-organizational relationships is nicely illustrated by Schilke and Cook (2013) who use a narrative approach to analyze trust building as a sequence of events over time that lead to change and, ideally, the development of trust. Through the process of collaborative interactions at both the individual and organizational levels, the collaborating parties learn about one another and gain information that becomes part of the trustworthy reputation of both individuals and firms. Fulmer and Gelfand (2012) propose a theoretical model to explain how trust in inter-organizational relationships is developed across various levels of analysis, and that, by integrating micro (individual-level) and macro (organizational-level) interactions, trust gradually becomes part of organizational action over time.

We follow Fulmer and Gelfand (2012) and Schilke and Cook (2013) in making the distinction with respect to trust building at three intersections: individual–individual, individual–organization, and organization–organization—at which there can be successive phases. Each of these intersections involves distinct activities, sometimes with different people leading to different outcomes in terms of trust building. As a result of these multiple interactions, it is possible that process-based trust building can take some unexpected turns, with a non-linear trajectory, whereby trust can erode and/or become an obstacle for a successful collaborative process. For example, in a study of collaborative alliances for start-ups, Marion et al. (2015) found that trust-based bonds can cloud an entrepreneur's judgment of a partner's abilities and lead to problems that threaten the venture's survival. In our analyses below, we will explore this possibility.

The importance of trust in university–industry collaboration for innovation is well documented in the literature (Meyer and Mizushima 1989; Daellenbach and Davenport 2004; Davis and Bryant 2010; Giaretta 2014; Hardwick et al. 2013). Previous research has shown that interpersonal trust (micro-level trust among individuals Liebeskind and Oliver (2000)) and inter-organizational trust (macro-level trust among leaders on behalf of their organizations) are related but distinct constructs, and play different roles in affecting negotiation processes and exchange performance between buyers and sellers (Zaheer et al. 1998).

The many challenges in such collaborations require structures such as formal contracts and informal agreements that will enhance successful collaborations (Mäkimattila et al. 2015). In addition, recent research on such collaborations found that the strength of ties (as based on friendship, trustworthiness, reciprocity of knowledge exchange and frequency of interaction) is associated with choosing how technology transfer interactions will take place; that is, whether the interactions will be more or less formalized and monitored. Thus, the nature of personal relations impacts the decision to commit time, knowledge and resources to university–industry innovation exchanges (Arza and Carattoli 2017).

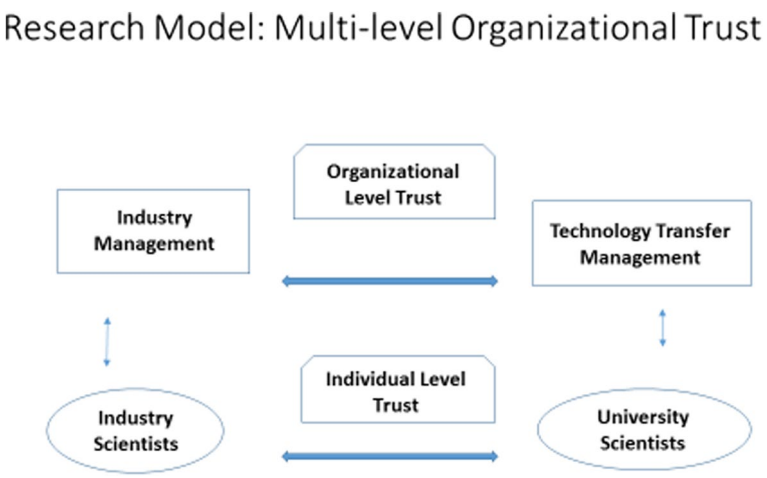
Organizational trust was found to be an important predictor of organizational innovation (Ellonen et al. 2008). Their study found that the various dimensions of trust in the organization explained 24.6% of the variance in product innovativeness and 35.6% of the variance in behavioral innovativeness. This finding further illustrates the importance of trust in innovative processes.

Finally, the literature provides evidence that managers and scientists do not necessarily share the same views with regard to openness in collaborations. In a case study of university–industry collaborations, the mangers were found to have different conceptions with regard to openness, as compared to the scientists involved in the studies (Moilanen et al. 2015).

3 Research aim

Our primary research question is: How can trust facilitate or impair the outcomes of university–industry innovation projects, on both the individual and organizational levels? We are guided by the literature reviewed here to explore possible causal mechanisms that drive transitions between the individual and the organizational levels over time, within the course of collaborative relations of university scientists with industry counterparts. The paper offers a qualitative process view of the integration of trust building (or erosion) and inter-organizational collaborations.

The general research model is presented here:



We explore these questions within the context of a national initiative to provide a supportive funding framework for university–industry collaborations in Israel (details below where the Israeli context and relevance is described). The initiative was designed to facilitate such collaborations toward the goal of commercializing university-based intellectual property (IP) generated in the university laboratory. The main advantage of the initiative is that State funding generated innovative opportunities for industry firms to seek university knowledge and technology compatibilities and to establish collaborations aiming to exploit the commercial potential of the academic knowledge. Further, as a regional innovation system, the initiative has the potential to enhance regional-level capacity for learning and interactive innovation. This is because knowledge, both tacit and explicit, can also be place-specific with a geographically immobile combination (Asheim and Isaksen 2002). In addition, it was claimed that one of the main weakness of metropolitan regions results from the low level of interactive learning especially in university–industry partnerships, yet these are of crucial importance (Etzkowitz and Leydesdorff 2000; Fritsch and Schwirten 1999; Looy et al. 2003). Thus, the current study offers a promising window into trust building within a particularly important set of metropolitan regional actors in strategic positions to foster innovation capabilities.

4 Method

4.1 Context

Israel provides a particularly interesting setting for examining the processes of university–industry technology transfer for knowledge intensive industries and trust (Frenkel et al. 2001, 2003), as the country is considered to be a highly entrepreneurial environment and a hotbed of technological innovation, comparable to Silicon Valley (Senor and Singer 2009; Engel and del-Palacio 2011; Trajtenberg 2001).[1]

For Israel, effective technology transfer projects are more crucial than many other countries. While Israel is among the world leaders in the productivity and intensity of its basic research in science and technology, its ability to transfer the fruits of this knowledge-creation engine to commercial applications has been regarded as inadequate (Meseri and Maital 2001).

With regard to university–industry technology transfer, the networks among scientists and practitioners in technological industries are tight, owing to two main factors: (1) the small number of research universities (seven main research institutions), and (2) the fact that many Israelis who enter the technology sector previously engaged in (mandatory) military service in the same units, where they acquired their strong technological skills (Chorev and Anderson 2006; Avnimelech and Teubal 2006). These characteristics facilitate close

[1] Israel is ranked 20th on the 2018 Global Competitive Report and first in its region. According to the GCR (2018) report, "The country has grown to become one of the world's innovation hubs, thanks to a very strong innovation ecosystem (10th best in the world)." The R&D expenditure is very high (4.3% of GDP). This can explain the rank of first worldwide on the index of growth on innovative companies (2018: 298). In addition, this report shows that Israel is the country where entrepreneurial failure is an accepted attitude, perhaps because entrepreneurial risks are so high. In addition, the financial market is well developed. The availability of venture capital is ranked second in the world, allowing strong support for the innovative private sector. Israel has also a strong innovation ecosystem and is ranked fifth on business dynamism and 16th on innovation capabilities worldwide.

and informal networks among technology experts, scientists and entrepreneurs (Honig et al. 2006; Oliver 2009).

4.2 Case sample and data collection

As this is a qualitative study, the multiple-case study approach recommended by Yin (2017) and Eisenhardt and Graebner (2007) was adopted using interviews with key stakeholders (Pirson and Malhotra 2011) representing four collaborative ventures. The key assumption was that different stakeholders have a different take on the collaborative process. The sample is drawn from a national experimental project of the Israeli Economic Ministry designed to facilitate innovation science projects through funding collaborations between university and industry. Each of the 2-year projects provided funding for dyadic collaborations between one university laboratory and one industry. The projects were titled MAGNETON, based on the symbolic meaning of establishing small 'magnet' forces for collaborations between universities and industry.

We sampled, out of the ten university–industry projects funded on the same year, four projects that had similar organizational characteristics, being collaborations between established universities and early-stage start-up firms. The cases differed in terms of research areas and technologies and the actual universities and firms involved. Project A is a biotechnology-related collaboration between a diagnostic biotechnology start-up and a university lab; Project B is a collaboration between a water purifying chemical firm and an electro-chemical scientist; Project C is a collaboration between a software start-up and a computer-science university professor; and Project D is a collaboration between a computerized-biotechnology start-up and a pharmacology professor.

Data for the four case studies were collected through semi-structured in-depth interviews with the main actors in the collaborations (e.g., the university or industry scientists and the technology transfer executives in the university and the related firm). Thirty interviews were conducted in total, of which 16 were conducted during the first year of the collaborative project (T1) and 12 were conducted after 1 year (T2).[2] We conducted two additional interviews with the government executive who was in charge of managing and following this policy initiative. To assure confidentiality and comply with research ethics, fictitious names are used for the involved scientists and managers.

4.3 Data analysis

The data analysis follows others' (Schutz 1967, 1973; Gioia et al. 2013; Tracy 2010) approach for rigorous qualitative analysis. Schutz identified first- and second-order constructs that need to be grounded in the subjective meaning of the actions of humans. Thus, the model must be recognizable and understood by the actors within everyday life (Schutz 1973). In our data collection and analysis, we followed the expectations for markers of quality in qualitative research (Gioia et al. 2013; Tracy 2010). We offered sincere, rich and rigorous data collection, on a worthy and important topic, where we aimed for credibility, coherence and a significant contribution. Then, we reviewed the transcripts and categorized the responses on the dimensions of trust and the perceptions of the scientists and

[2] Some people left the project, the firm or the university, and some were unavailable to be interviewed at T2.

the managers involved in each process. Further we documented the perceived changes that took place between the two stages of interviews with regard to the process and the levels of experienced trust/mistrust.

Our analysis was based on a two-stage process (Gehman et al. 2013; Gioia et al. 2013; Fereday and Muir-Cochrane 2006): The initial stage was inductive, moving from a thick description of the case studies based on the transcribed interviews in an effort to clarify a general model. The second phase was deductive, moving from the general model back to the narratives in the four cases, with the aim of analyzing the specific characteristics of each case and process and the distinct meaning it offers for understanding multi-level, multi-agent inter-organizational trust building or eroding process in university–industry scientific collaborations.

5 Findings

5.1 Trust in the process of university–industry collaboration and innovation

In our four cases, inter-organizational learning takes place between collaborators from different institutions (university and industry) who are involved in a reciprocal process of knowledge transfer that leads to the development of innovative applied knowledge with the aim for commercialization. Trust is a key ingredient in the process, because such reciprocal interactions are based on an initial stage of trust-building between the two primary collaborating actors. As Zucker (1986) argued, a certain degree of initial trust is essential and it is characteristic-based, resulting from similarities between two actors, such as a shared knowledge base, educational background, or professional norms and reputation. A second stage of inter-organizational learning develops from the mutual transfer of different types of knowledge and a collaborative integration of this combined knowledge. In the scientific context, this requires that scientists be committed to sharing reliable knowledge and to the joint search for truth. Following Zucker's model, this would develop as process-based trust.

The interaction of characteristic-based trust and process-based trust is illustrated by the following two quotes from an industry scientist (Stephany):

> Today I gave a lecture to the research team, and I was expecting some harsh responses. Maybe I was too blunt when I opened my talk with the quote: 'There is one thing even more vital to science than intelligent methods, and that is the sincere desire to find out the truth, whatever it may be (Charles Sanders Pierce).' This is, I believe, most important between us scientists.

This quote emphasizes that scientific collaborations require the open transfer of ideas and knowledge (process-based trust, according to Zucker), which can only take place when the collaborating partners share the goal of a scientific search for truth and have confidence in the scientific work of the other side (characteristic-based trust, according to Zucker). Stephany shows the interaction of these two bases of trust in her description of Sara, the collaborating university scientist:

> Sara is first of all professional and has strong technical abilities. She not only teaches and develops new theories, but also engages in her own chemistry lab work. This is the source for collaboration and knowledge, this is science. Working with her on science is very nice since she is very cooperative and a great person to work with and learn from. And we learn from each other.

Thus, we can extend the argument about the relationship between trust and inter-organizational learning. We argue that high levels of trust, in the form of characteristic-based trust among scientists (who respect one another's competencies and motivations), along with process-based trust (developed from past and ongoing encounters), can lead to a high level of inter-organizational learning, in the form of learning through innovation. That is, with trust as a precondition for inter-organizational collaboration and learning, a successful process of collaboration will further enhance trust between the collaborating actors, in a spiral of success. In contrast, when characteristic-based trust and/or process-based trust become weakened, the collaborative process suffers.

5.2 Process stories: the development of trust and collaborative innovation in the four cases

In this section, we provide a closer analysis of the four cases. Despite the similarity in resources available to the scientists and the industrial firms in the four case studies, the processes of the establishment (and erosion) of trust relations and of the collaborations that evolved were very different.

5.2.1 Project A: biotechnology diagnostics

This project involved a collaboration between a diagnostic biotechnology start-up firm and a university professor (Ann), who was also the entrepreneur and chief scientist in the start-up firm. Also involved were a team of scientists from the hospital who conduct animal testing of the diagnostic product. Ann was a physician, and thus had an understanding of both the medical and scientific aspects of the project. There was a high level of characteristic-based trust among the actors, as all the scientists (from both academia and industry) were already involved in the collaboration, and the hospital scientists had high reputations as scientists.

As a result, process-based trust developed over the first year, deriving from joint interests and a shared belief in the potential of the project. Ann described the process:

> I think we established an excellent system of trust here. This was something that really made me happy in this collaboration. This is really special since I was involved at both the university and the firm side. Thus, there was full trust and sharing of information. But the trust with the hospital research team was also very good. This is again because there was a personal-level relation with the professor in the hospital and the research scientists who did the coordination between the hospital and the firm and was always on top of things. I believe that this is what made each side feel that they knew what was agreed on and the reports were with all the needed details. This is what the specific trust system here was all about.

On the organizational level, process-based trust was formed over the contractual arrangements that started the collaboration. As the start-up CEO reported:

> The platform for collaborating with the university was established prior to this project. This was reflected in the way to agree on the contract, where everything was clear…and all initial suspicions were avoided… and because we had such good relations, I could call the TT manager and… within a few minutes we could reach agreement.

Through Ann's dual involvement, the joint platform of interest was already established before the formal contract was drawn; thus, the contractual stage was smooth and trustworthy.

Biotechnology as the main technology of the project also contributed to the success of the collaborative process. It was perceived as an innovative technology that could be best exploited when knowledge is shared and the learning process is based on synergetic reciprocity. Ann reported that every participant honored the important value of the other participants and the technology and knowledge of the other side.

The regular meetings between the teams were characterized as a fruitful process of sharing information, discussion, and mutual feedback, as illustrated in the comment from the CEO of the start-up:

> We have meetings every six weeks, and every experiment takes about six weeks so we actually have a meeting before and after every experiment. We jointly analyze the previous experiment and evaluate how this affects the next steps. We all discuss jointly the outcomes of the experiments aiming together for optimal outcomes….I really feel that the division of labor and efforts are real, meaning that every side gave the best of his side. Even our contract is based on equal contribution.

The CEO reported that the collaboration with the hospital was also very good:

> Because of the atmosphere we created, special ties emerged. When you come to a meeting where everyone shares their ideas and contributes to the discussion, it feels right and this is a real development process—when there is a ping-pong of ideas and real brain storming exchanges. This is the right way to work with physicians, and they were involved since they also expected to get publications out of this project.

It was clear that all participants felt that the process generated learning and innovation as a joint creation, where the two sides had equal contributions to the collaborative process.

5.2.2 Project B: chemical water purifier

The second project involved a collaboration between a water-purifying chemical start-up and an electro-chemical university scientist. The collaboration arose from a longtime professional acquaintance between the university scientist (Stone) and the CEO of the start-up (Julia), who was a former graduate student under Stone's supervision. Chemistry technology is not an easy area for collaboration. The development of the technology requires a long time and is hard to translate into industrial applied knowledge. This is why a shared research culture and understanding between the two sides is so essential.

Stone had been involved with the research in the start-up since its founding; thus, there was an expectation for a high level of process-based trust between the two parties, deriving from the initial characteristic-based trust. However, this turned out not to be the case. Trust at the individual level was thwarted when the start-up firm was acquired by another firm, and Julia was replaced by a new CEO who did not know Stone and who declared that he had no interest in the research collaboration. Although Julia knew the university professor well and understood the research culture of the university, the new CEO did not have such a background. As Stone recounted:

> I came to the new management without knowing them, yet willing to continue the process. Then gradually I felt that I was losing trust in them. When you work with an industry that does not see the applied potential of the project, you understand that it

> is not going to work… The previous CEO [Julia] was a real scientist and understood well what research is all about…

Stone described his feelings following the change in the start-up ownership, saying that it felt like an 'ugly divorce' and the research project was 'one of the children who lost its parents who did not care about him anymore.'

The buy-out led to an erosion of trust at the organization level as well, when the firm stopped adhering to the contract expectations, leading to procedural chaos. As the university TT manager reported:

> Once the CEO [Julia] left the firm…we immediately lost four important months and we did not know where we were going. They stopped transferring the funds and the project stopped. Even today, we do not know where exactly we are standing and they do not seem to understand us. It feels as if they are saying that this project is not important to them. This is very sad as it has become clear that the university and the firm don't share interests anymore and the firm is not interested in the project.

The new CEO was also displeased with the research collaboration with Stone and complained that the company had signed a bad agreement with the university. Those from the university side felt that the industry did not assign the needed priority and time resources to the project. Both Stone and the university TT manager felt that they had collaborated with the start-up firm in a trustworthy manner and had fulfilled their side of the process, but that the firm was no longer willing to fulfill their part. Since the contract did not provide a detailed account of what to do if the project dissolved, the struggle over IP rights was not settled, as Stone lamented, 'This is an absurd situation, as the industry does not wish to continue the project, yet, they still hold everything with them. It is a situation that does not allow swallowing nor vomiting'.

According to the university TT manager:

> Now, every side wants to minimize its losses. They want to get out of the contract yet have no losses…. The firm has our knowledge and they are not willing to give it back, they feel that they may use it in the future or sell it…. It is hard to deal with them now…

The new CEO felt that with a clear procedure of regular meetings, the collaborative process could be re-established. This, however, did not happen, and the project eventually terminated. Thus, the breach of trust led to the hold-up of the collaborative learning project.

5.2.3 Project C: software

This involved a collaboration between a software start-up and a computer-science university professor (Davis). At the individual level, initial trust was high between the teams of scientists at the university and the firm. The project began with mutual respect for the scientists' capabilities (characteristic-based trust). Process-based trust was reinforced because there were clear expectations for the tasks expected of each side, with the R&D process based on sequential additive tasks in one laboratory at a time, rather than joint R&D work.

The contract specified that only the university research team would initially develop the project, and then it would be transferred to the firm's technological scientists. Thus, the transfer of knowledge was relatively simple with very little overlap. When the two teams acted as expected, process-based trust remained strong, as expressed in the words of the university scientist (Davis):

> The trust between the people, this trust kept growing. I mean the trust in the professional capabilities. Every side understood what the capabilities of the other side were and how they matched. The trust between the university team and the firm programmers kept growing. This was simply because people understood that with the joint capabilities, we could collaborate to achieve our goal, and this would exist in both sides. No hidden agenda.

As the project moved on, however, Davis realized that unmet expectations had the potential to harm the individual-level process-based trust between the teams:

> The industry research team were doing their best, although we realized that the university team was taking a larger than expected role in the project. This meant that we had to invest more time and effort than I anticipated. In such collaborations, one needs to understand well their expectations of the other side. It took me time to realize that, because they are a small firm that was not capable of doing everything needed by the project including providing the needed data. Here, our expectations had to be modified.

Meanwhile, on the organizational level, the collaboration started with a high level of cooperation between the firm and the head of the university TT office (Frank), both of whom were eager to sign a creative contract that expressed substantial willingness to be flexible by both sides (process-based trust). This arose in part from their confidence in Davis's academic prestige and in part because the two managers found a strong personal chemistry and mutual interest (characteristic-based trust). In the words of Frank:

> We had great chemistry – the CEO of the firm and I. We would exchange e-mails at 3 a.m. and… you understand, suddenly, that there was something beyond regular work relations or a negotiation. Despite the fact that we had a few clashes, we became friends…. So the contract was written in a clear transparency toward them since they were people that we felt at ease contacting and talking with.

In a reciprocal way, the firm CEO expressed his appreciation of Frank and described a harmonious state of relations:

> He [Frank] is an amazing manager. I learned much from him. You can really learn from the other side of the process. He is excellent and I think he likes me. My feeling is that he was looking at us not as a small company, but as a company with whom you have long-term collaborations. Not something that you want to appropriate tomorrow morning.

However, despite the positive start, there was an erosion of process-based trust at the organization level during the first year, with complaints raised by both managers. The university TT office blamed the start-up firm for not transferring the needed funds on time, while the firm believed the university TT office were making exaggerated estimations of hours that they claimed were spent on the project.

In addition, the sequential order of the collaboration that, at first, contributed to the build-up of trust, was later perceived by the firm CEO as a problem, who reported in an interview a year after the project started:

> We have to remember that during the first year of the project, most of the work was on the university side. They used all kinds of algorithms that we neither understood, nor were interested in. This was for us a 'black box'—something we wanted to see that worked and that the needed expressions resulted from it. [Davis] worked in her

> lab with her team and we did not see her. We were not in her mind-set, but it was their responsibility. Although I am the boss and I am paying for the expenses, it was all far away from me. As our mothers used to say, distance makes it far from the heart. Now I understand that we did not manage the project properly and did not follow our development policy…. I feel that we are also responsible for the problem that emerged. I was supposed to visit the university lab, meet the team, and be coordinated with the project in the short term as well as in the long term.

This collaborative project started with high trusting relations on both sides and on the level of the scientists and the managers. Probably due to this high degree of trust, the firm scientists and management did not try to intervene during the first stage of the process, nor understand what was going on in the lab. This resulted in a lack of joint learning and a low level of involvement in what it took on the university side to generate the expected product. When it came to the integration stage, the expenses requested by the university were higher than the initial estimation. The CEO felt that the university had mismanaged the project, and the professor (Davis) realized that the firm was unable to match her new expectations for the further development of the product.

5.2.4 Project D—medical biotechnology

This project involved a collaboration between a computerized-biotechnology 5-year-old start-up and a pharmacology professor (Smart). It was a more complex project than the previous cases because the formal collaboration was between the start-up firm, the professor (Smart), and an independent scientist (Green), who had worked with Smart but was not an employee of the university. Green also had some experience with the industry scientist (Monroe), established through a few meetings at international conferences.

On the individual level, Smart possessed substantial professional prestige, as a high-impact scientist, contributing to strong characteristic-based trust. In addition, Smart and Monroe had been working together on other projects for several years, and had established strong process-based trust with collaborative efficiency. Smart thus began the project with high confidence, reporting:

> I can explain why this is a special collaboration. This is because I have worked with the firm scientist [Monroe] for 12 years now, and we have a wonderful chemistry between us. And we are the research managers on both sides. Therefore, we have a great network, and thus I anticipate no problems. Of course, there could be problems between people on lower levels; I cannot say there will not be. However, if we are aware of these potential problems we will be able to solve them.

Monroe felt the same way about Smart:

> Smart is first of all a professional. In fact, to tell the truth, every time I have a new research project, I go to consult with her and I feel her support. We always learn from each other, we work together and it is a real collaboration…

However, trust in the independent scientist (Green) was not as forthcoming, as Monroe reported:

> I have a high level of trust in the university professor [Smart] but less in the independent scientist [Green]. This is matter of differences between people. I am sure Smart will do good scientific work and will report all the findings. Whatever will

> work out – will work out, and if not – not. We will listen to her [Smart] and trust in her.

For her part, Green was more guarded in her feelings of trust toward the other scientists. She was confident in her own ability to contribute; however, her self-confidence did not translate into trust in the other scientists. This became evident after a few months when Green decided to quit working with Smart, arguing that the professor's methods were not applicable to the design of her project. In return, although Smart had initially trust in Green, who came with an important idea and a good suggested project, as well as a proven ability based on her publication record, Smart began to distrust Green's motives and reports, which indicated that Green's methods were inefficient and that her commitment to the collaboration was weak:

> Everything was ready and I was waiting for the results because I had built a working hypothesis and prepared some libraries. I did not get any feedback. Worked on the preparation of the experiment and no feedback. It felt like the scientist [Green] did not really want this collaboration.

Monroe also found Green's approach to the collaboration to be unsatisfactory:

> There are people who don't want anyone to be better than they are…maybe she [Green] wants to prove that anything done by others without her methods is not good… she did the bio assay and I don't believe in bio assay. I really want to tell her, send me my molecules back today and I will send it to a third party for examination.

On the organizational level, there were expressions of an initial level of trust that allowed actors to agree on the details of the collaboration and on the contract quite quickly. In fact, this was the first contract that was signed out of the four projects that started at the same time. But, as the project evolved, it turned out that many details in the contract had been underspecified or unspecified. Smart believed that the firm's CEO failed to check Green's reputation with regard to how well Green collaborated with others. In addition, Smart believed that the CEO should not have started the project without having a more detailed contract that specified how to handle contingencies:

> It is a matter of expectations, of how 'hungry' the person is, and not really a matter of trust. She [Green] has a high level of self-esteem and she believes that she deserved much more than the other side is willing to pay for. We started with a fair and legitimate negotiation but over time, her appetite increased and she kept asking for more…. There were written agreements and there were requests for more. We should have understood early on that this would go nowhere.

The collaboration ended after a few months, with loss of funds to the industry and time for Smart. However, Monroe felt at the end that, despite the failure, it helped her in re-framing her research decision-making process and that in the future she would avoid expressing a high level of initial trust with the collaborating scientists and would be more particular with the details of the contract.

Table 1 summarizes the main components of the individual-level and the organizational-level for each of the four projects. We characterize the trust at three stages of the projects: the initiation stage, the process, and the outcome of the projects and show the distinction between the individual and the organizational level. Out of the four technology transfer projects, only one was successful, while the other three suffered from erosion both on the individual and the organizational levels, however due to different reasons.

Table 1 Individual and organizational trust at initiation, process and outcome in the four cases of inter-organizational collaborative R&D relations

Project	Initiation	Process	Outcome
Project A Biotechnology diagnostics Individual level	Strong: Existing characteristic-based and process-based trust between all scientists who had collaborated in the past and had high reputations	Positive: University and industry scientists worked together in the research team of the university professor	Success: High level of learning, shared commitment to the collaborative process and shared and equal contribution and rights to the IP
Project A Biotechnology diagnostics Organizational level	Good: Process-based trust derived from the initial contracting relations between the university and the firm	Positive: Frequent meetings aligned with the experiments' time table and clear division of labor, where academic scientists focused on the what and how questions, and the company focused on the clinical trials	Success: High level of learning and project success
Project B Chemical water purifying Individual level	Strong: Existing research relationship between the university scientist and the firm CEO (the scientist's former Ph.D. student) generated characteristic-based trust	Eroded: Process-based trust did not benefit from the individual level following change in firm CEO, reflecting importance of a shared culture and interests	Project termination: University scientist wanted to continue the collaboration despite the IP disagreements with the new firm
Project B Chemical water purifying Organizational level	Good: Process-based trust derived from the initial contracting relations between the university and the firm	Eroded: Process-based trust did not survive at organization level, following suspicion by the TT manager that new CEO was not honoring contract commitments	IP and financial losses: Continuous legal disagreement with regard to the IP and the market potential of the project; both industry and TT managers wanted to cut losses
Project C Software Individual level	Strong: Initial characteristic-based trust derived from mutual respect for knowledge and research capabilities of university and firm scientists	Eroded: University scientists began to lower their process-based trust after realizing their expectations could not be met by firm scientists and the project was not being well managed by firm	Disappointment: the start-up was not able to provide the needed data for the project and therefore the joint learning was not taking place as initially hoped
Project C Software Organizational level	Strong: Process-based trust derived from the initial contracting relations between the university and the firm, augmented by characteristic-based mutual appreciation between TT and firm managers	Eroded: Initial positive interactions on organization level began to erode trust. The distant assignment of tasks, non-collaborative division of labor between the university and the firm, and contractual expectations were not honored	Mutual disappointment: The start-up was too small to assign enough time to provide the needed data and the CEO did not manage the project. Both sides believe that project had been mismanaged

Table 1 (continued)

Project	Initiation	Process	Outcome
Project D Medical biotechnology Individual level	Strong between university scientist and firm scientist: Existing characteristic-based trust deriving from university scientist's reputation, and process-based trust between university and firm scientist, who had a long collaboration history Equivocal trust regarding independent scientist, who had strong reputation and appealing idea, but was not well known to firm scientist; independent scientist was wary of others involved	Eroded: Collaboration revealed differences in expectations among scientists in terms of ability and commitment to the project, impairing process-based trust; the independent scientist did not follow the normative expectation for open sharing and collaboration and destroyed the research project	Frustration: Collaboration ended because the independent scientists did not deliver the expected technology. Project ended as a failure, with loss of funds to firm and time for university scientist
Project D Medical biotechnology Organizational level	Strong: Process-based trust derived from the initial contracting relations between the university and the firm, leading to rapid approval of contract, even without specifying contract details	Eroded: Failure to specify how to deal with contingencies at contract signing stage; failure to investigate independent scientist's collaboration practices in advance impaired process-based trust	Re-evaluation of decision making process and understanding that future collaboration needs better contractual arrangements with tasks clearly specified, especially for the role of independent scientists

6 Discussion

In this concluding section, we begin by reviewing our findings from the four case studies and relating them to previous literature. We then follow with comments about the contributions of the research to theory and practice, and suggestions for extensions of the research.

6.1 Summary of findings

Our analysis reveals several important insights about how trust contributes to and impairs collaborative innovation. The multi-level, multi-stage process model (Burke et al. 2007; Schilke and Cook 2013) allowed us to distinguish between individual-level trust within the learning collaboration involving the scientists, and organizational-level trust between the university TT manager and the firm CEO. Using this approach, we show how the elements contributing to trust at the two levels and at the initial and ongoing stages in the trust process are distinct and different.

First, on the individual scientists' level, we see the importance of initial trust based on scientists' characteristics, such as professional reputation and shared background. Most scientists had known each other in the past, either as a mentor and a doctoral student or as colleagues. They shared a deep interest in research and started with a commitment to utilize this funding opportunity to conduct joint research. Once the collaborations were underway, the trust that evolved surrounded the research process and the roles each of the scientists had to fulfill in the collaborative process. The processes included the knowledge compatibility between the scientists, the commitment of the scientists toward the project and its success, the expectations of the scientists with regard to the scientific work of the collaborators, and the scientists' openness and flexibility toward unanticipated changes in time and funding needed.

At the organizational level, initial trust typically reflected confidence in the scientists' reputations at the outset, along with the contract specification process. The processes of contracting for the projects were particularly important and included the specification and clarity about the details with regard to the expected contributions of each collaborator, the processes for transfer of funds and delivery of products/technology, the degree of monitoring and managing the collaborative process, the IP rights expected of each side, and the centrality and importance of the project to the involved firms.

Because of the complexity of the processes at both the individual and organizational level and because of the lack of experience of most firms in such collaborations, it is no surprise that huge challenges arose in building and maintaining trust at both levels. As a result, many of the desired outcomes were not achieved.

Our analysis shows that only one of the four collaborative projects could be considered successful (Project A). We attribute this success to the strong initial characteristic-based trust between the scientists, which derived from mutual respect for the qualifications of the collaborating individuals and a shared commitment to the project. The success was bolstered throughout the project, as process-based trust was established during a routine of regular collaborative meetings. Organizational-level trust complemented the individual-level trust, as the managers of the collaborating units shared in the commitment to the project and facilitated smooth communication and compliance with contract terms.

The other three projects suffered, especially at the process stage of trust-building, and at the individual and organizational levels. For example, in Project B a change in firm

ownership and the resulting erosion of trust highlights the critical importance of a shared research culture among collaborators, which existed at the outset between the university scientist and the firm CEO (a former student of the scientist). This was lost when a new CEO, who was unknown to the university scientist, did not share the research culture and gave a lower priority to the project. In Project C, an inability to adequately adjust to emerging contingencies in the research process and to manage changing expectations among collaborators eroded what had begun as high levels of trust at both the individual and organizational levels. In Project D, the project was undertaken and contract signed before it became evident that there was a lack of compatibility among collaborators in terms of commitment to the project and to shared knowledge production. Trust was eroded when scientists and managers looked for whom to blame for the failed collaboration.

6.2 Research contributions

Our findings endorse the argument by Filippetti and Savona (2017) that the individual characteristics that affect the degree of collaboration of academic scientists with those in other organizations have been overlooked in the literature. They maintain that "The notion of academic engagement should be enlarged to aspects that go beyond the commercialization or patenting of innovation, but embrace social and economic impact more at large. From the perspective of the firm, barriers to innovation might exert an effect on the likelihood to cooperate with universities and public research institutes, most especially to cope with lack of finance or access to frontier knowledge'' (2017: 719). We show that social issues related to the formation and maintenance of trust in university–industry collaborations greatly matter and that they are more complex than captured by the extant literature.

Our findings also are consistent with the classic literature on trust relations, as well as the multi-level classification of trust offered by Fulmer and Fulmer and Gelfand (2012) and the insights of Zaheer et al. (1998). At the individual level, we found evidence of both characteristic-based and process-based trust, which developed from cultural similarity between the scientists, trustees' reputations, past relations and shared values, and information sharing. When any of these factors were lessened, trust suffered. At the organizational level, we found evidence for trust as emerging or eroding around commitment and relational practices, equity and fairness, communication quality, and adherence to contract provisions.

To extend the existing research, we used a fine-grained case study of processes involved in four university–industry innovation collaborations over time. Through this approach, we were able to depict the complexities associated with achieving results in such collaborations. In particular, trust is built at two levels and on different foundations. One level refers to the involved scientists, and the other level refers to the involved institutions—the university and the industrial firm. At the individual level, the relations typically operate around the research project itself. The norms of doing science and sharing knowledge, and the similarities between the university and industry scientists, are strong lubricants for the collaborative research process (Bellini et al. 2018). Generally, formal contractual details are less important to the scientists, who recognize that research trajectories can be unpredictable. However, a scientist's inability to provide needed research expertise or a withdrawal from the commitment to share knowledge can lead to a breach of trust, thus impairing outcomes.

At the organizational level, the trust relations are influenced by alignment with organizational protocols and expectations of efficiency and effectiveness, rather than activities and norms of doing science and producing knowledge. That is, the involved managers in

both the university and industry are responsible for the protocols involved in the collaborative project and its success, based on the formal governing guidelines of the contract, including the transfer of funds, the commitment to the contracted timetable, and specified milestones for the success of the project. Should these items not be faithfully followed, trust is at risk, and along with it, the project itself.

Also theoretically important is the need for attention to the intra-organizational processes between the two levels and over time. As seen in our study, an enthusiastic scientist (Project B) with long-term trust relations between the individual actors convinced the university TT manager to agree to a general contract that did not include all the needed contingencies, assuming that the long-term relations between the actors provided assurance for trustworthy relations. Once the top management in the start-up firm changed, the trustworthy relations between the scientists were no longer sufficient for the project to continue. Similarly, frequent feedback loops, where each side learned about the actions between the two levels and the two collaborative sides also contribute to process-based trust (Oliver and Montgomery 2001). In the case where the scientific collaboration was built sequentially (Project C), the university manager felt that the firm should have checked the progress more frequently during the process, rather than assuming a smooth and trustful operation. Thus, it is not efficient, from an organizational perspective, to assume that the individual-level scientific collaboration (which may be successful from the scientists' perspective) matches the expectations of the organization from the management's perspective.

With regard to the literature on regional innovation systems (Tödtling and Trippl 2005) and the importance of the value of the institutionalized learning processes and the productive culture of innovation (Cooke et al. 1997), our findings highlight the need for particular attention to the ready availability of reputational information about participating scientists in a geographically immobile population. We have seen that reputational data are critical to forging initial trust, and such data can have a ripple effect throughout the region as collaborative relationships become both stronger and become strained. For these reasons, it may be especially important in regional innovation systems where collaborative contractual arrangements build on previous successes of university–industry relations. In addition to building on previous successful collaborations, regional innovation efforts should include outreach policies that provide industry and TT managers with higher sensitivity for the complexities in collaborative scientific processes. This last effort may help to neutralize the negative reputational effects of previous less-than-successful collaborations in the region.

The Israeli context may also contribute to our findings. The fact that the culture is highly entrepreneurial and R&D funding is available simplifies the formation of university–industry collaborations. In addition, because R&D failure is normatively accepted, with no harmful outcomes to the firms or the university, decisions to fail in university–industry collaborations may come more easily. Finally, the tight networks between scientists and technology experts may facilitate the formation of trust on the individual level between scientists; whereas similar networks and their positive effects on trust are less likely on the management level.

6.3 Limitations and extensions

Although the study contains rich longitudinal and multi-source data, we analyzed only four collaborative, research and technology-based case studies. Further research could focus on additional types of collaborations, (e.g., service-oriented collaborations), as well as examine the role taken by different kinds of organizations (e.g., government or socially oriented

non-profit organizations). Through studying collaborative processes between different types of organizations and different types of roles, we can gain a wider understanding of multi-level inter-organizational trust processes.

Another intriguing avenue for future research was suggested by our findings in the analysis of Project B, with regard to professional autonomy. In this case, trust became eroded at the organization level, leading to the dissolution of the collaboration, despite the willingness of the university scientist to continue the project. It is possible that small start-up firms are more like large bureaucratic firms than expected, when it comes to exerting control over the conditions of work by professionals (e.g., funding, timetables, deliverables, and even continuation of the project), (Leahey and Montgomery 2011; Montgomery 1992; Freidson 1973). Additional studies of other small, start-up firms where professionals collaborate may shed further light on this question.

As noted earlier, many studies have examined trust at the individual level, both in terms of antecedents and outcomes, and at the organizational level, such as strategic alliances (e.g. Das and Teng 2001) or technology transfer (Giaretta 2014). Far less common are studies that bring a synergistic perspective, simultaneously examining the individual and the organizational levels, and how they interact to affect collaboration outcomes. We maintain that a multi-level process approach has the potential to provide a holistic perspective on the production (and potential erosion) of inter-organizational trust.

Most important, such a perspective helps to understand why successful collaborative efforts are so difficult to achieve. If scholars focus on one level in a collaborative project (e.g., that of individual scientists interacting) to the exclusion of another level (e.g., that of the organizational level of TT managers interacting), they may fail to gain a thorough understanding of why certain outcomes arose. As a result of this incomplete picture, future projects may be doomed to repeat the same mistakes, with the same disappointing outcomes. Given that collaborative projects are the wave of innovation, it is essential that such dynamics are anticipated and handled before they become dysfunctional.

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