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The Knowledge Protection Paradox:

Imitation and Innovation through Knowledge Sharing

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ABSTRACT

Western multinational corporations (MNCs) that want market access in China have to share knowledge with Chinese partners. This may expose them to imitation, so MNCs prefer to protect knowledge resulting in a strategic paradox: MNCs have to both share and protect knowledge. To analyze this paradox we developed a theoretical conceptual model capturing the tensions and feedback cycles of this paradox. Next, based on data from the shipbuilding industry, a system dynamics model was developed to simulate the long-term effects of sharing and protecting strategies. The results indicate that protection is detrimental to long-term success, because it undercuts the trust of the Chinese supplier and irreparably reduces innovation rates. Knowledge protection thus *reduces* instead of increases the ability to share (new) knowledge in the future. A sharing strategy increases imitation, but also trust and knowledge sharing by the Chinese partner, such that it enhances the MNC's innovation rate and long-term performance.

KEYWORDS: knowledge protection, knowledge sharing, strategic paradox, innovation, imitation, system dynamics

INTRODUCTION

China is an attractive destination for business investment and expansion, primarily due to its consistently high growth rates, relatively good infrastructure, political stability, and liberalized trade and investment regime following its entry into the World Trade Organization in 2001 (Puck et al., 2009). The liberalization of government regulations has also produced new options for ownership by foreign multinational corporations (MNC's) investing in China; since 1997, it has been possible for wholly foreign-owned enterprises to operate in China (Puck et al., 2009; Yan and Warner, 2002). Prior to 2001, quid pro quo was explicit policy, which required MNC's to transfer technology (knowledge) in return for market access. Since the accession to the WTO, it is widely believed that China imposes quid pro quo as an implicit policy (Holmes et al., 2015; Nakumara and Nakumara, 2004).

When MNC's share knowledge with a Chinese partner, they do so primarily to access markets in China. However, we also know that these MNC's are concerned with protecting or hiding their knowledge (Bennett et al., 2001; Connelly et al., 2010; Hernandez et al., 2015), to prevent (potential) Chinese competitors from imitating new products or processes. Therefore, managers of these MNC's need to address competing strategic demands simultaneously: they have to share *and* protect knowledge. Long-term performance depends on engaging both alternatives, rather than choosing between them (Smith, 2014; Smith et al., 2010). These competing strategic demands can be characterized as paradoxes that denote tensions coexisting and persisting over time, posing competing demands that require ongoing responses rather than one-time resolutions (Lewis, 2000). Engaging in one domain typically triggers demands in the other and fuels cycles over time (Andriopoulos and Lewis, 2009; Smith, 2014).

As such, a dynamic approach is required to examine how managers deal with what we have called the knowledge protection paradox when collaborating with Chinese partners (Golan and Bamberger, 2015; Smith, 2014). As Van Burg et al. (2014) note, most research on interorganizational knowledge transfer is cross-sectional and these studies have not explained decisions to initiate, intensify, reduce, or terminate knowledge transfer. Therefore, we developed a conceptual dynamic model of the knowledge protection paradox that incorporates its competing demands and cycles (feedback loops). Then, by using data gathered from a Western MNC in the shipbuilding industry that currently operates in the Chinese market, we developed the conceptual model into a system dynamics model. The model allows us to examine different knowledge sharing and protection strategies over time, to identify which is most beneficial in the long term.

Our analyses reveal counterintuitive results. When the MNC protects its knowledge, imitation by the Chinese partners is reduced, but so is the inspiration the MNC receives in return. . Because knowledge transfer is a two-way street, knowledge protection by the MNC leads to reduced feedback from the Chinese partner about what the market really wants, in terms of new technologies or products. Knowledge protection thus hinders the innovation rate of the MNC, which ultimately reduces its ability to share new knowledge in the future and makes the company less attractive to Chinese customers and other partners. In contrast, in the knowledge sharing scenario, both imitation by the Chinese *and* innovation by the MNC increase, which has long-term benefits for the MNC.

Our findings contribute to current theory in a number of ways. First, we contribute to the theory on strategic paradoxes and show how these paradoxes can be tackled: first by unraveling its tensions and feedback cycles, and then by simulating the long-term effects of different strategies. In doing so, "either/or" thinking about the paradox is prevented and new, sometimes counterintuitive ("both/and") solutions can be discovered. As such, our method responds to the call for more dynamic decision making models to deal with paradoxes (Smith, 2014). Second, we advance previous research that distinguishes reciprocity in knowledge sharing (Černe et al., 2014; Grodal, et al., 2015; Halbesleben and Wheeler, 2015; Lai et al., 2016). Our findings show that reciprocity does not happen once ('you give me something and then I give you something'), but is continuous. It is characterized by a continuous in-and outflow of knowledge, thereby cultivating innovation. This innovation then boosts the potential for sharing new and interesting knowledge in the future, thereby feeding this continuous reciprocity phenomenon. This finding further supports the need for a dynamic approach in analyzing knowledge sharing and protection (Golan and Bamberger, 2015; Van Burg et al., 2014).

In the next section, we review the literature and develop a conceptual model consisting of feedback loops, followed by a description of an example from the shipbuilding industry and a presentation of a system dynamics model. We then analyze the different knowledge sharing and protection strategies, finally concluding with a discussion and implications.

LITERATURE REVIEW AND CONCEPTUAL MODEL

In a global supply chain, business success depends largely on a company's ability to access, share, transfer, and exploit its knowledge across borders. Before China's accession to the WTO, Western multinational corporations (MNCs) were forced to transfer knowledge in return for market access (Nakamura and Nakamura, 2004). This policy continues today as implicit policy (Holmes et al., 2015). As such, technology or knowledge shapes, sustains, and advances the competitive advantages enjoyed by MNCs in a global setting (Liu et al., 2006).

Interorganizational knowledge transfer is a process that involves organizational actors as sources and recipients, influenced by their relationships and the characteristics of the knowledge (Argote et al., 2003; Easterby-Smith et al., 2008; Van Burg et al., 2014). Knowledge transfer is often reciprocal and an organization can act as both a source and recipient of knowledge (Černe, et al., 2014; Grodal, et al., 2015; Halbesleben and Wheeler, 2015; Lai et al., 2016). As such, a MNC trying to gain market access in China will initiate the knowledge transfer process by first acting as a source of knowledge in order to engage the Chinese partner (Grodal et al., 2015). From the perspective of the MNC, this is also referred to as the knowledge outflow (Lai et al., 2016). Trust is perceived as integral to reciprocity in the social exchange (Colquitt et al., 2007;

Černe, et al., 2014; Halbesleben and Wheeler, 2015). It is known that the willingness to share knowledge with others tends to be higher in relationships characterized by trust and commitment (Dyer and Nobeoka, 2000; Inkpen and Tsang, 2005). Therefore, building trust is important before a Chinese counterpart reciprocates with knowledge inflow to a MNC (Chua et al., 2012).

Knowledge inflow from the Chinese partner to the MNC involves knowledge that can help the MNC understand how the Chinese market operates, such as the identity of decision makers in the market, its hidden rules, or what customers really want. This knowledge should increase the sales effectiveness of the MNC and enable it to attract Chinese customers. In essence, by sharing knowledge with the Chinese partner, the MNC gains trust and this is expected to lead to a reversed knowledge flow from the Chinese partner, which will help the MNC to gain access to the Chinese market. This is depicted in Figure 1 as the knowledge transfer loop. This loop is a balancing (B) feedback loop that describes goal-seeking behavior of the MNC (Sterman, 2000). The goal of the MNC is to access the Chinese market and thus it initiates the knowledge transfer process. . When the MNC approaches its goal, the need to keep sharing knowledge with the Chinese is reduced. Note that interorganizational knowledge transfer processes involve long delays, while cross-border knowledge transfers can take even more time, because dissimilar cultural contexts are far more intricate and difficult than those between companies or units located in similar cultures (Bhagat et al., 2002; Chua, 2012). These delays are depicted in Figure 1 as two lines perpendicular to the causal link.

Insert Figure 1 about here

The reason why the MNC will be tempted to reduce knowledge sharing with the Chinese once its goal is reached is the fear of imitation by the Chinese. The MNC will try to defend its share of the market by preventing knowledge leakage to potential rivals (Hernandez et al., 2015). As noted by Van Burg et al. (2014), when organizations frame future developments as threats (such as imitation by the Chinese), it will motivate them to disengage in interorganizational knowledge transfer. Accordingly, organizations will become more protective of their knowledge (Bennett et al., 2001; González-Álvarez and Muñoz-Doyague, 2006; Hernandez et al., 2015). By protecting knowledge, the MNC tries to prevent imitation, which is depicted by the imitation loop in Figure 1. This loop describes the risks associated with sharing knowledge with Chinese partners (McGaughey et al., 2000) who can use knowledge about the MNC's innovative products, and imitate the MNC's offerings (Butler and Grahovac, 2012). Imitation can result in new Chinese competitors for the MNC and this may have a negative impact on the MNC's sales effectiveness and its market share. This imitation loop is reinforcing (R); the more knowledge shared, the higher the level of imitation, which further reduces the MNC's sales effectiveness and market share causing a drift away from the MNC's goal. In turn, the MNC needs to collaborate even more with its Chinese partner to win back lost customers or acquire new ones, reinforcing the imitation process, and so on.

Gaining trust and increasing the risk of imitation are the direct (first-order) effects of transferring knowledge to the Chinese partner. But as the literature shows, there are also three indirect effects (second-order) to consider that also influence the long-term performance of the MNC. First, there is the indirect effect of word-of-mouth (Bass, 1969; Sterman, 2000). After collaboration with Chinese partners has been established and the first Chinese customers are acquired, more customers are likely to follow, thanks to the strengthened reputation or footprint of the MNC (Chua, 2012), as indicated by the reinforcing (R) *word-of-mouth* loop in Figure 1. This loop assumes an infinite number of customers and that the number of acquired customers will continue to increase over time, *ceteris paribus*.

Second, the *inspiration* loop in Figure 1 describes a positive indirect effect of knowledge sharing. The knowledge inflow from the Chinese partners to the MNC could inspire the MNC to innovate appropriate products for the Chinese market. Cultural diversity in the workplace (Giambatista and Bhappu, 2010) and exposure to foreign cultures (Maddux and Galinsky, 2009) have a positive effect on creativity which could lead to new innovations. According to Lai et al. (2016) more innovation is possible when both knowledge outflows and inflows are high. The inspiration loop is balancing, because ultimately, a higher innovation rate of the MNC stimulates sales and market share, which in turn reduces the need to keep sharing knowledge with the Chinese. Then, an opposite process can begin. Reducing knowledge sharing (protecting knowledge) will decrease trust and diminish knowledge sharing from the Chinese back to the MNC, which reduces its inspiration and innovation rate (Černe et al., 2014; Chua, 2013; Nielsen and Nielsen, 2009). As such, this loop is balancing. Knowledge protection and its negative effect on innovation and organizational performance have also been described by Hurmelinna-Laukkanen (2009) and Evans et al. (2015). Furthermore, causal ambiguity between manufacturer and supplier, as a way to protect knowledge is known to have a negative effect on performance (González-Álvarez and Muñoz-Doyague, 2006, Lippman and Rumelt, 1982; Potter and Lawson, 2013). That is, keeping the supplier in the dark about causal connections in a design should protect the manufacturer from imitation, but the causal ambiguity actually limits product development and managerial processes, which eventually limits the manufacturer's performance too.

The third and last indirect effect of transferring knowledge to the Chinese is the *continuous reciprocity* loop, according to which knowledge sharing by the MNC only succeeds if the MNC actually has some new knowledge to share with its Chinese partner. It depends on the perceived knowledge characteristics of the MNC, including the strategic importance of that knowledge

(Pérez-Nordtvedt et al., 2008; Tsang, 2002; Van Burg et al., 2014). If the partner already knows all there is to know or has already imitated all the new designs available, the MNC becomes a less attractive collaboration partner. Sharing knowledge that Chinese partners already have will not enhance trust any further and the knowledge transfer process could stagnate (Golan and Bamberger, 2015). However, if the MNC keeps renewing and innovating, it remains an interesting partner, because it creates new knowledge for its partner to learn. We have called this loop continuous reciprocity, because it does not describe a single knowledge outflow from the MNC to the Chinese with a knowledge inflow in return; it describes a continuous process of reciprocal behavior in which the MNC keeps innovating and as such, remains able to share new knowledge with the Chinese. Although this development will set off the imitation loop, it also creates a possibility for the MNC to share more and newer knowledge about future innovations, prompting an increase of trust in the Chinese partner, a greater innovation rate, and an even higher possibility for knowledge sharing. Therefore, this loop is reinforcing.

Our conceptual model with its five feedback loops captures the dynamic complexity of a so-called knowledge protection paradox faced by the MNC. As such, this paradox defies rational, linear logic and consequently, it creates uncertainty and ambiguity (Lewis, 2000). According to Smith (2014) individuals often respond by making an either/or choice between knowledge sharing (stimulating imitation) and protection (preventing imitation). But both options nourish vicious cycles over time which is detrimental for long-term performance. Thus, we ask, is it better to share or protect knowledge to ensure long-term survival in China? In the next section, we turn our qualitative conceptual model into a quantitative simulation model that will be used to analyze this research question.

METHOD

Setting

The past decade has seen rapid growth in China's shipbuilding sector. In 2010, China replaced South Korea as the world's top shipbuilder, and the volume of completed shipbuilding orders accounted for 43% of the global total (Siyu and Ran, 2011). In turn, the Chinese shipbuilding industry attracts ship technology and equipment suppliers and manufacturers, including several MNCs that have established China-based subsidiaries. The setting for our study is an MNC with a world-leading range of capabilities in the marine market, encompassing the design, supply, and support of power and propulsion systems. The headquarters of this MNC are located in Western Europe. The MNC is a leader in the integration of technologically complex, mission critical systems for offshore oil and gas, merchant, and naval vessels. To increase its customer base, the MNC expressed its desire to enter the Chinese market from the beginning of this century. As a result, in seeking long-term market access, it initiated a joint venture with a Chinese engineering company, in which a team of specialist engineers from both companies worked together. The engineers in the joint venture shared knowledge about ship designs, systems, and equipment, in an attempt to build specialized ships for Chinese ship owners, such as vessels for river transportation. Through this joint venture, the MNC could sell its high-tech equipment as well as attempting to acquire sufficient knowledge about the Chinese market to gain market access. Preparations for this joint venture started in 2000, resulting in the first Chinese order in 2005.

System Dynamics Model

To analyze the long-term effects of knowledge sharing and/or protection, we developed a system dynamics model. As a perspective and set of conceptual tools, system dynamics reveals the structure and behavior of complex systems; as a rigorous modeling method, it enables us to build computer simulations of complex systems, and then use those simulations to design more effective policies and organizations (Sterman, 2000). With the computer simulations, we test different "what-if" scenarios to explore the long-term effects of various decisions. System dynamics models can also approximate continuous time processes, rather than discrete time periods, and thereby explore the effects of time delays in decision making, as well as the results of the decisions (Garcia et al., 2003). Similar modeling has been used in studies to evaluate supply chain performance in terms of oscillation and amplification (e.g., Akkermans and Vos, 2003; Croson and Donohue, 2006), collaboration and trust between two partners in a chain (e.g., Smets et al., 2013; Van Burg and Van Oorschot, 2013), joint ventures (Gary, 2005; Tang and Lee, 2002), and innovative knowledge and organizational capabilities (Garcia et al., 2003; Repenning and Sterman, 2002). Simulation is especially useful for theory development when the focal phenomena involve multiple and interacting processes, time delays, or other nonlinear effects such as feedback loops and thresholds; when the theoretical focus is longitudinal, nonlinear, or processual and when empirical data are challenging to obtain (Davis et al., 2007). Because our research question suggests a tension between knowledge sharing and protection, the empirical data are difficult to obtain (long-term results of joint ventures between MNC's and Chinese partners are not yet available yet), and we have identified many delays and nonlinear relationships among the variables (i.e., loops in Figure 1), system dynamics is an appropriate method to analyze our research question.

The system dynamics model we develop is based on the conceptual model in Figure 1 and data we gathered through in-depth interviews with key participants, using a semi-structured approach. We interviewed 15 people (some several times) using one-on-one qualitative interviews (Patton, 2002). The list of interviewees is presented in Table 1. All interviewees had experience with knowledge transfer processes between the MNC and China. Eight of the interviewees had a Western European perspective (working for the MNC), while he other seven had a Chinese perspective (either working for the Chinese partner, or working closely with the Chinese partner). The duration of each interview was between one and three hours. The same researchers conducted all the interviews, to ensure consistency. When necessary, we exchanged follow-up e-mails after the face-to-face interviews to discuss any unclear data. Each interview was documented directly after it took place, and the documented interview was returned to each interviewee for approval. After we developed the model, we scheduled a workshop with two interviewees to consider the model validity and discuss the results. Validation is very important in this case, because we lack actual data against which we can compare the simulation results (i.e., data about market share and actual customers for the next decade are not yet available) and thus cannot use statistical measures of fit between actual and simulated values. Instead, during this workshop, we checked the values of the parameters (i.e., do stakeholders agree these values are correct?), reviewed the most important relationships and equations in the simulation (do the interviewees affirm these relationships and recognize their operationalization in mathematical equations?), and discussed the results. Subsequently, we made some minor adjustments to the model. As a final validation, we presented our model and findings in a workshop organized for the maritime industry in Norway. No changes needed to be made to the model after this final workshop.

The full simulation model with the five loops (knowledge transfer, word-of-mouth, imitation, inspiration, and continuous reciprocity) is presented in Figure 2. The model, built in *Vensim*, is also available from the authors on request. A full overview of model equations, list of variables and their abbreviations, values of constants, and the sources for these values is provided in Appendix 1 (following the guidelines for simulation-based research by Rahmandad and Sterman (2012)).

Insert Figure 2 about here

MODEL RESULTS

In this section, we will analyze two different knowledge strategies that were mentioned in the interviews. The first is the base case, which reflects the current strategy of the MNC. This strategy is called the *protection strategy*. The second strategy, the *sharing strategy*, is the strategy that the MNC did not select because of the perceived risk of imitation. We conclude this section with a number of sensitivity analyses to test the robustness of our findings.

The Protection Strategy

In the protection strategy, the MNC only shares the amount of knowledge that it believes is necessary to close the gap between its desired (20%) and actual (0% in the year 2005) market share. Such goal-seeking behavior implies that the smaller the gap becomes between the desired and actual market share, the less knowledge the MNC will share and the more it will protect. After reaching the goal, the MNC will stop sharing knowledge and focus on protection. Figure 3, Panel A, displays the behavior over time of actual market share for the MNC. From 2005 to 2014, its strategy pays off: actual market share increases gradually to a little over 20% during this period. However, its market growth stagnates around 2014, after which it gradually falls to 4% in 2025, even though desired market share continues to be 20%. Apparently, the MNC is unable to gain back lost market share. To explain this result, we also consider the behavior of the other variables in the model over time, as depicted in Panels B–D.

Insert Figure 3A-3D about here

Shortly after 2005, actual market share is close to 0%; the MNC needs to learn a lot about the Chinese market, so its desired knowledge equals 1 (Figure 3, Panel B). The MNC is also able to share a lot of knowledge in this period, because all its technological designs are still unknown to the Chinese partner (Panel B). Therefore, the MNC is both willing to share knowledge, because it needs to get to know the Chinese market, and able to share knowledge, because it has a lot of new technological knowledge to share. Panel C displays the amount of knowledge the MNC has shared with its Chinese partners; from 2005 to 2009, the level is very high. Our interview results revealed that it takes on average five years to build trust with the Chinese partners, so trust is increasing in this period too, though not as much or as fast as shared knowledge. Finally, trust prompts feedback from the Chinese partner, increasing the MNC's knowledge about China, though this process also takes time (Panel C). The MNC's knowledge of China is one of three factors that determine its sales effectiveness (Panel D), along with its footprint and technological advantage. In 2005, the joint venture is operational and the MNC received its first Chinese orders. Therefore, the MNC's footprint starts to grow after 2005. Together with this collaboration, imitation begins and the MNC's technological advantage starts decreasing (Panel C).

Between 2009 and 2012, the MNC slowly but steadily builds its market share (Figure 3, Panel A). As it approaches its goal of 20% market share, desired knowledge about the Chinese market decreases (Panel B), as does shared knowledge with the Chinese partner (Panel C). With the knowledge shared over the previous years, the Chinese partner has started to imitate some technological designs, which reduces the technological advantage of the MNC somewhat (Panel D). Because its footprint and knowledge of China continue to increase, the combined effect of the three sales effectiveness factors is still positive for the MNC, increasing its market share.

Next, between 2012 and 2017, the MNC reaches its goal: 20% market share (Figure 3, Panel A). In turn, it stops sharing knowledge with the Chinese partner, which has become a potential competitor. In response, trust decreases rapidly, which reduces the amount of knowledge the Chinese partner shares with the MNC (Panel C). Even as it becomes more difficult for the Chinese partner to imitate the MNC (due to reduced knowledge sharing), stabilizing the technological advantage of the MNC, the reduced knowledge about China that the MNC receives (Panel D) reduces its sales effectiveness somewhat (Panel A). The MNC's market share starts to fall; because the Chinese partner shares less knowledge, the MNC's innovation rate also diminishes, which increases the average age of its designs (Panel B). This trend becomes problematic in the next period, 2017-2021.

In this period, market share continues to decrease (Figure 3, Panel A), leading the MNC to start sharing knowledge with its Chinese partner again (Panels B and C). Even though the MNC wants to share knowledge, its ability to do so has greatly decreased (Panel B), because of its low innovation rate in the previous period. The Chinese partners are no longer interested in the knowledge the MNC possesses, because they have already imitated the designs that interest them, and the remaining designs are almost obsolete (i.e., increased average age of the hidden designs; Panel B). The Chinese partners therefore reduce their knowledge-sharing activities, reducing the sales effectiveness of the MNC, which causes a further decline of its market share (Panel A).

Finally, in the period 2021–2025, market share seems to stabilize, at an undesirable level for the MNC (4%). The low market share pushes the MNC to collaborate more with its Chinese partners and share more knowledge, but as Figure 3, Panel B, shows, despite the MNC's willingness to share a substantial amount of knowledge, it can no longer do so, because the Chinese partners know too much. The technological advantage of the MNC remains stable (Panel B), implying that the Chinese partner's imitation rate is approximately equivalent to the MNC's innovation rate, but its hidden designs have become obsolete (old-fashioned technology). The sales effectiveness of the MNC thus remains relatively low, whereas the sales effectiveness of the Chinese partner is relatively high (Panel A). Therefore, the market share of the MNC cannot bounce back in this period.

In summary, this protection strategy of the MNC (i.e., sharing knowledge only when its market share is lower than desired, protecting knowledge when the market share is close to its target) pays off in the short term but backfires in the long term. The long delays associated with gaining trust from the Chinese partner, followed by a lack of innovative inspiration when trust is low, mean that a strategy of protecting knowledge with high market shares is actually detrimental. Lost trust causes the feedback received from the Chinese partner to diminish, which decreases the innovative inspiration gained (lower innovation rate by the MNC) and reduces the MNC's ability to share knowledge in the future. Thus, the MNC gets stuck with low market share.

The Sharing Strategy

The results of the protection strategy suggest that sharing knowledge only if the market share falls below the target and protecting it otherwise is not a successful long-term strategy. What can the MNC do to remain successful (i.e., achieve target market share) over time? What might happen if the MNC stops protecting its knowledge and shares as much as possible, all the time, regardless of its market share success? To simulate this strategy, we needed to make a minor change to one of the variables in the model. In the protection strategy, the MNC needed to be both willing and able to share knowledge, whereas in the sharing strategy, the MNC only needs to be able to share knowledge because it is always willing to do so (equations are given in the Model Documentation in Appendix 1). The resulting behavior over time of this sharing strategy is depicted in Figure 4, Panels A–D.

Insert Figure 4A-4D about here

Compared with the protection strategy, the market share in the sharing strategy increases less quickly, but when it reaches the target of 20% (around 2014, compared with 2012 in the protection strategy), the subsequent behavior is more stable. Market share decreases somewhat after 2021, but this decline is not as steep, and in 2025, market share remains at 22%, compared with 4% in the protection strategy (Figure 4, Panel B). Shared knowledge by the MNC is high throughout the entire simulation period (Panel C). As a result, the imitation rate by the Chinese partners increases, as does the Chinese partners' sales effectiveness (Panel A), whereas the technological advantage of the MNC decreases (Panel D). However, because the trust of the Chinese partners also remains high (Panel C), the reverse knowledge-sharing process (from the Chinese partners to the MNC) continues without disruptions (Panel C), so that the inspiration loop persists, leading to an increased innovation rate for the MNC compared with the protection strategy. This higher innovation rate means the imitation rate also remains high, reducing the average age of the designs (Panel B). This means that the MNC keeps inventing and renewing its designs, making it a very interesting partner for the Chinese companies. We show the MNC's innovation rate and the Chinese company's imitation rate in both the protection and sharing strategies in Figure 5.

Insert Figure 5 about here

The imitation rate declines more in the protection strategy than in the sharing strategy, but as a side effect, this decline also reduces the innovation rate more. In the long term, the innovation rate nearly equals the imitation rate in both scenarios; the level of hidden designs remains stable. However, the higher imitation rate in the sharing strategy reduces the average age of the designs (Figure 4, Panel B), keeping knowledge new and state-of-the-art, which increases the MNC's ability to share knowledge. Although the Chinese partners imitate the MNC, the MNC keeps renewing its designs, thereby staying one step ahead of its competition. The combined effect of a stable and large footprint, substantial knowledge about the Chinese market, and a stable technological advantage enables the MNC to achieve sales effectiveness that is twice as high as in the protection strategy, leading to the high market share in the sharing strategy (Figure 4, Panel A).

Sensitivity Analyses

To test the robustness of our finding that the sharing strategy outperforms the protection strategy, we have performed extra simulations of strategies that are in-between sharing and protection (to check whether a balanced approach may result in better performance) and we have executed sensitivity analyses on four exogenous variables (constants). Firstly, beginning with the Protection Strategy (our base case) in which knowledge is protected as much as possible, we ran nine extra scenarios in which more and more knowledge is shared (with steps of 10%). The performance, with respect to a stable and high market share in the long-term, becomes gradually better when more knowledge is shared, with the Sharing Strategy as the best performing strategy. Figure 6 also shows more clearly that sharing less (i.e. protecting more) is good for short-term performance. The Protection Strategy (sharing as little knowledge as possible) reaches the target market share about two years before the Sharing Strategy, and it reaches a higher maximum market share than all other scenarios. However, the Protection Strategy reaches a point of no return in the long term, after which market share continues to decrease without the possibility of turning this around. These results strengthen our finding that the Sharing Strategy (with as much knowledge sharing as possible) is better than the strategies in which knowledge is protected to some degree.

Insert Figure 6 about here

Secondly, we performed sensitivity analyses on four exogenous variables (constants), see Table 2. These four variables were chosen, because our interviewees revealed that they were not really sure about the values they estimated for these variables. As such, it is important to examine what happens to the two strategies when we vary the values of these variables. To compare different sensitivity runs, we looked at the market share at the end of the simulation (long-term result) in the year 2025. In addition, to verify that a particular scenario is not only successful in the year 2025 but also in the years before, we calculated the number of years the market share was on or above target (the higher this number, the better). The results of these analyses are given in Appendix 2, and summarized below.

Insert Table 2 about here

Copying time of the Chinese: Interview results revealed that it takes the MNC about three years to develop new technological equipment (innovation time, *it* = 3) and it takes the Chinese about three years to copy these designs (copying time, *ct* = 3). We tested what would happen if it took the Chinese less or more time to copy designs. The sensitivity analysis revealed that the balance between innovation time and copying time (meaning that they are about equal) is really important. Although the sharing strategy is always better (for copying times that are both shorter and longer than innovation times), when copying time is only about 8.3% shorter than the innovation time (2.75 years compared to three years), it will be extremely difficult for the MNC to reach the target market share.

Technological advantage of the Chinese: Our model assumes that the technological advantage of the Chinese competition primarily comes from their imitating behavior. There is however, some original innovation by the Chinese. This minimum Chinese technological advantage (*minCta*) is set to 0.10. So, the Chinese technological advantage will never be lower than 0.10, but can be higher when they start copying designs. We simulated different values of this minimum level. The results indicate that even when the Chinese are better able to innovate on their own (higher *minCta*), the sharing strategy still outperforms the protection strategy. Only for values higher than or equal to 0.40, the MNC will not be able to compete with the Chinese, but these values are not realistic.

Imbalance factor: Interviewees described an imbalance between knowledge sharing by the MNC, trust, and knowledge sharing by the Chinese. Trust has to be really high before the Chinese start sharing knowledge. We have operationalized this with an imbalance factor (*if*) of 0.5, meaning that for every trust unit, only 0.5 knowledge unit is received. Different values of *if* are simulated to test its impact on our results. We find that when the imbalance factor is lower than 0.5, results deteriorate fast (regardless of the knowledge strategy). For very low values (0.375 and 0.25) there is no difference between the protection strategy and sharing strategy. However, these values do not seem realistic. The chosen value of 0.5 is already a conservative assumption. For values above 0.5, the sharing strategy only becomes more interesting and rewarding.

Weight of leakage through customer and partner: Knowledge about core technology can leak away through Chinese partners (suppliers), but also through Chinese customers that first buy new equipment and then try to imitate the designs. However, it is more likely that Chinese partners become future competitors than Chinese customers. To model this, we have used different weights where, initially, the weight of leakage through customers (*wlc*) is 1, while the weight of leakage through partners (*wlp*) is 2. We have tested different values to analyze what would happen if, for example, customers become competitors. The sensitivity analyses reveal that the sharing strategy still outperforms the protection strategy even when it is more likely that Chinese customers are imitating technological designs than the Chinese partners/suppliers.

Overall, the sensitivity analyses reveal that our finding is robust even with changes in the four model variables: the sharing strategy in which the MNC is always willing to share knowledge outperforms the protection strategy in which the MNC prefers to protect knowledge whenever this is possible. As such, these analyses uphold confidence in the model and support its results.

DISCUSSION

We have examined the strategic paradox that innovative Western companies (MNC) face when trying to enter China's market. To gain market access, Western MNCs must invest in the Chinese market by initiating collaborative relationships with Chinese partners. However, the stronger these collaborative ties, the more knowledge may be shared, and the greater the risk that these Chinese partners learn too much and start to imitate best business practices or, even more dangerously, innovative designs. When this happens, the MNC's long-term success in China's market may be endangered. However, if the MNC protects its knowledge as much as possible, the market entry process becomes far more difficult and may never succeed. This strategic paradox led to the following research question: Is it better to share or to protect knowledge if the goal is long-term survival in the Chinese market? Because this research question involves dynamic, nonlinear behavior (i.e., variables influencing one another over time, delays between actions and outcomes, feedback loops), we decided to analyze it using a system dynamics model, based on an example from the shipbuilding industry.

Interviews revealed that the chosen strategy was a defensive one: the MNC preferred protecting its knowledge, and only decided to share knowledge to get access to the market. As soon as market share hit the target, the MNC stopped sharing and started protecting its intellectual property and technological advantage. This defensive approach is typical of managers facing a strategic paradox (Smith, 2014; Vince and Broussine, 1996). Perri and Andersson (2014) observed this behavior in the semiconductor industry, where one partner tolerates the leakage of knowledge in order to build up the trust needed to facilitate knowledge inflows. But as soon as the knowledge level increases to a certain desired level, the outflow diminishes again. Similar behavior has also been found in the aerospace industry. When the future is framed as an opportunity (e.g. gaining market share), knowledge sharing is initiated. But when the future is framed as a threat (e.g. increased imitation and the loss of market share), knowledge sharing is blocked (Van Burg et al., 2014). According to Grant (2013), people who exhibit such behavior are "takers" who try to maximize what they can get from a relationship. The simulation results of this protection strategy revealed that this "taking approach" is beneficial in the short term, but in the long term, the benefits decline to a level that is so low, the MNC cannot recover. The protecting strategy eliminates trust in the relationship, which results in a disruption of the feedback and knowledge-sharing process from the Chinese partner back to the MNC (Chua, 2012). This disruption reduces not only the innovation rate of the MNC but also its sales effectiveness. In the meantime, its Chinese competitors have grown so powerful that the MNC can hardly compete. Anderson and Lewis (2014) find that in most cases, disruptions of the knowledge-sharing process reduce performance temporarily, but sometimes, they permanently hinder performance. In our conceptual model this was described by the continuous reciprocity feedback loop: Protecting knowledge reduces the company's future innovation rate, and as such reduces its ability to share new knowledge in the future, which makes it a less interesting partner to work with for the Chinese.

The sharing strategy instead shows what could happen if the MNC were to pursue a giving strategy (Grant, 2013) and always share knowledge, regardless of its market share. This strategy offers more sustainable results in the long term. Although the MNC's market share rises more slowly than it would in the protection strategy, the market share remains stable and on target over time. The feedback mechanisms in the system lead the Chinese partner to match the giving approach with high trust and knowledge sharing in return. This effect also increases the Chinese partner's imitation rate, but it boosts the MNC's innovation rate simultaneously (through inspiration and continuous reciprocity from the Chinese partner). The sharing strategy allows the MNC to keep one step ahead of its imitating competitors, so it enjoys an advantage in the Chinese market that translates into a stable, high market share.

As such, the strategic paradox companies appear to be facing is caused by thinking in terms of "either/or": either we share knowledge or we protect knowledge. To find a way out of this strategic paradox, managers should be thinking in terms of causal feedback loops, like those presented in Figure 1, to analyze the consequences of both strategic options. In this situation, a knowledge protection strategy leads to reduced imitation, but also limited innovation in the long term. On the other hand, a knowledge sharing strategy increases imitation, but also boosts innovation in the long term. As such, by considering the consequences of each strategy, the paradox of “either sharing/or protecting”, turns into “both imitation/and innovation” (Smith, 2014). By focusing on the long-term consequences (imitation and innovation) of strategic choices a solution to the paradox can be found. By continuously sharing knowledge, the imitation rate by the Chinese will increase, but what is more important is that the innovation rate by the MNC will also increase. Our simulation results reveal that in the long-term this innovation rate drives performance (in terms of market share) much more than the level of knowledge that is kept hidden: providing that the time needed to innovate is no longer than the time needed to imitate, the MNC will remain one step ahead of competition and enjoy first-mover advantages in the market.

CONTRIBUTIONS AND LIMITATIONS

Our findings have important implications for both theory and practice. First, we contribute to the theory on strategic paradoxes and show how these paradoxes can be tackled. Our approach starts with unraveling the ingredients (variables) and feedback mechanisms of the paradox, followed by exploring the long-term effects of different strategies through simulation. In doing so, defensive thinking about the paradox is prevented and new, sometimes counterintuitive solutions can be discovered. As such, our method responds to the call for more dynamic decision making models to deal with paradoxes (Smith, 2014). Second, we advance previous research that distinguishes reciprocity in knowledge sharing (Černe et al., 2014; Grodal, et al., 2015; Halbesleben and Wheeler, 2015; Lai et al., 2016). Our analysis builds on previous findings by Černe et al. (2014) who stress the importance of trust for knowledge sharing and hiding. Although these authors note an individual-level distrust loop that limits creativity, they do not analyze the loop in a dynamic way, i.e., in the long-term. We have developed a loop in which trust leads to knowledge sharing from the Chinese partner to the MNC, which boosts the innovation rate of the MNC, enhancing not only the MNC's sales effectiveness but also its future potential to continue collaborating with the Chinese partner (continuous reciprocity). The higher the MNC's innovation rate, the more interesting it is to Chinese partners, and the more willing they are to continue the collaboration. At this point, the continuous reciprocity loop becomes more important than the imitation loop in driving the MNC's performance. Innovation boosts the potential to keep sharing new and interesting knowledge in the future, thereby feeding this continuous reciprocity phenomenon. This phenomenon is characterized by a continuous and high in- and outflow of knowledge, which supports the findings of Lai et al. (2016). Finally, our study builds on previous research that demonstrates that knowledge sharing among organizations can have both desired and undesired side effects, including leaked intellectual property. Through a simulation, we achieve a long-term perspective, from which we can compare two strategies with different outcomes over time. Our research therefore responds to the need for a dynamic perspective in analyzing knowledge sharing and protection (Golan and Bamberger, 2015; Van Burg, et al. 2014).

These results in turn have important managerial implications. Our simulation shows that giving is a better strategy than taking, which appears counterintuitive, especially in the context of the competitive Chinese market, with its reputation for active imitation. Implementing this finding requires specific management training, because Western managers generally do not intuitively behave in a giving fashion in the market. Instead, they must be motivated to share their knowledge with others (Connelly et al., 2010). Furthermore, our results show that it is extremely important for managers, when faced with a strategic paradox, to recognize the feedback loops that are operating in this paradox, as well as the delays between actions and outcomes. Understanding the feedback mechanisms will prevent defensive or paralyzing "either/or" framing of the paradox and open up for new ways of thinking, such as “both/and”.

The model we have presented also has some limitations. By definition, models are limited, simplified representations of the real world, and therefore, all models are wrong (Sterman, 2000). The most important simplifications of our model deal with the focus on only one relationship between two organizations. Because the MNC is a global player, it is likely that the experiences the MNC gains by working with the Chinese partner will impact its other collaborations in other parts of the world as well. Likewise, the Chinese partner may also start selling products globally. These side-effects are not included in our model and present an avenue for future research. Furthermore, we treat “China” as a homogeneous entity. In reality locations across China will differ in terms of local business systems and the way Chinese organizations in each location respond to different knowledge sharing strategies by the MNC (Williams and Du, 2014). Once the MNC starts expanding in China and begins to collaborate with multiple Chinese partners in different locations, the values of the exogenous variables in our model should be changed and new simulations executed. Finally, because our model uses data from this one particular relationship, it is difficult to make generalized statements about our findings. However, even though our simulation results are case-specific, the relationships in the model and its feedback loop are not. Only the values of the exogenous variables (the constants) are specific for the relationship between the MNC and its Chinese partner (for a list of these variables, please see Table C in Appendix 1). These values are likely to be different for different relationships, with partners from different countries, so, although our findings hold for the relationship that we studied, the model can be re-used for other companies, or relationships between the MNC and other partners. The values of the exogenous variables will have to be re-estimated for each new case that is modeled.

The goal of our research was not to develop a model that precisely mimics reality but rather to clarify and understand the feedback loops that exist in the knowledge protection paradox, as well as the ways in which the loops influence behavior both immediately and over time. Our conceptual model consisting of five feedback loops is based on an extensive review of the literature. By using actual data from a setting in the shipbuilding industry, we were able to explore which loops can become dominant over time and drive behavior. Although more actual (and longitudinal) data is necessary to increase confidence in our model, our results can still be considered useful and insightful (Homer, 2014) and help managers make better decisions when confronted with the knowledge protection paradox. Finally, our model provides a basis for further research into the long-term (dynamic) effects of knowledge sharing and protection.

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Table 1: Overview of interviews

Interviewees	Date	Duration & form	Topics
Head of section Marine Systems, MNC	May 23, 2011	1 h, open-ended	History and background of the China enterprise
President Merchant Ship Technology and Systems, MNC	Aug 30, 2011 Nov 30, 2011 Nov 26, 2012	2 h, semi-structured 1 h, open-ended 2 h, open-ended	History and background of the China enterprise, motivation for sourcing from China, the development of the China enterprise, knowledge sharing in shipbuilding projects, validation of simulation model
Former Senior Vice President, MNC	Aug 30, 2011	2 ½ h, open-ended	History and background of the China enterprise
Managing Director Marine China, MNC	Sep 14, 2011 Nov 30, 2011 Nov 26, 2012	2 h, semi-structured 1 h, open-ended 1 ½ h, open-ended	Knowledge sharing in shipbuilding projects, the development of the China enterprise, validation of simulation model
Technical Director Merchant, MNC	Nov 30, 2011	1 h, open-ended	Knowledge sharing in shipbuilding projects
Site Director & Vice President Operations, MNC	Nov 30, 2011	1 h, semi-structured	Knowledge sharing in ship technology assembly and manufacturing
Vice President Merchant Ship Technology and Systems, MNC	Jun 18, 2012	1 ½ h, semi-structured	Project management across borders and organizations, knowledge sharing in shipbuilding projects
Contract Manager, MNC	Sep 14, 2012	2 h, semi-structured	Project management across borders and organizations, knowledge sharing in projects
Project Manager, Ship Design, MNC	Dec 5, 2012	1 h semi-structured	Knowledge sharing between Chinese partner and the MNC
Technical director, MNC	Sep 17, 2012	1 h, semi-structured	Project management across borders and organizations, knowledge sharing between Chinese partner and the MNC
Executive Director, Chinese partner	Dec 5, 2012	1 h, semi-structured	Knowledge sharing between Chinese partner and the MNC
General Manager, Chinese partner	Dec 5, 2012	1 h, semi-structured	Knowledge sharing between Chinese partner and the MNC
Manager Engineering Department, Chinese partner	Dec 5, 2012	1 h, semi-structured	Knowledge sharing between Chinese partner and the MNC
President Merchant Ship Technology and Systems, MNC & Vice President Finance, Marine Operation Strategy, MNC	Mar 8, 2013	2 ½ h, workshop	Validation of simulation model, discussion of simulation results
About 30 participants from the Maritime Industry in Norway	Dec 15, 2014	4 h, workshop	Validation of simulation model, discussion of simulation results

Table 2: Settings of sensitivity analyses

Variable	Symbol	Value	Sensitivity Range	# Extra Simulations
Copying time of Chinese	*ct*	3	2 – 4	10
Technological advantage of Chinese	*minCta*	0.1	0.05 – 0.40	10
Imbalance factor	*if*	0.5	0.25 – 1.00	10
Weight of leakage	*wlc & wlp*	1, 2	1 – 2	4

Figure 1: Conceptual model of the knowledge protection paradox

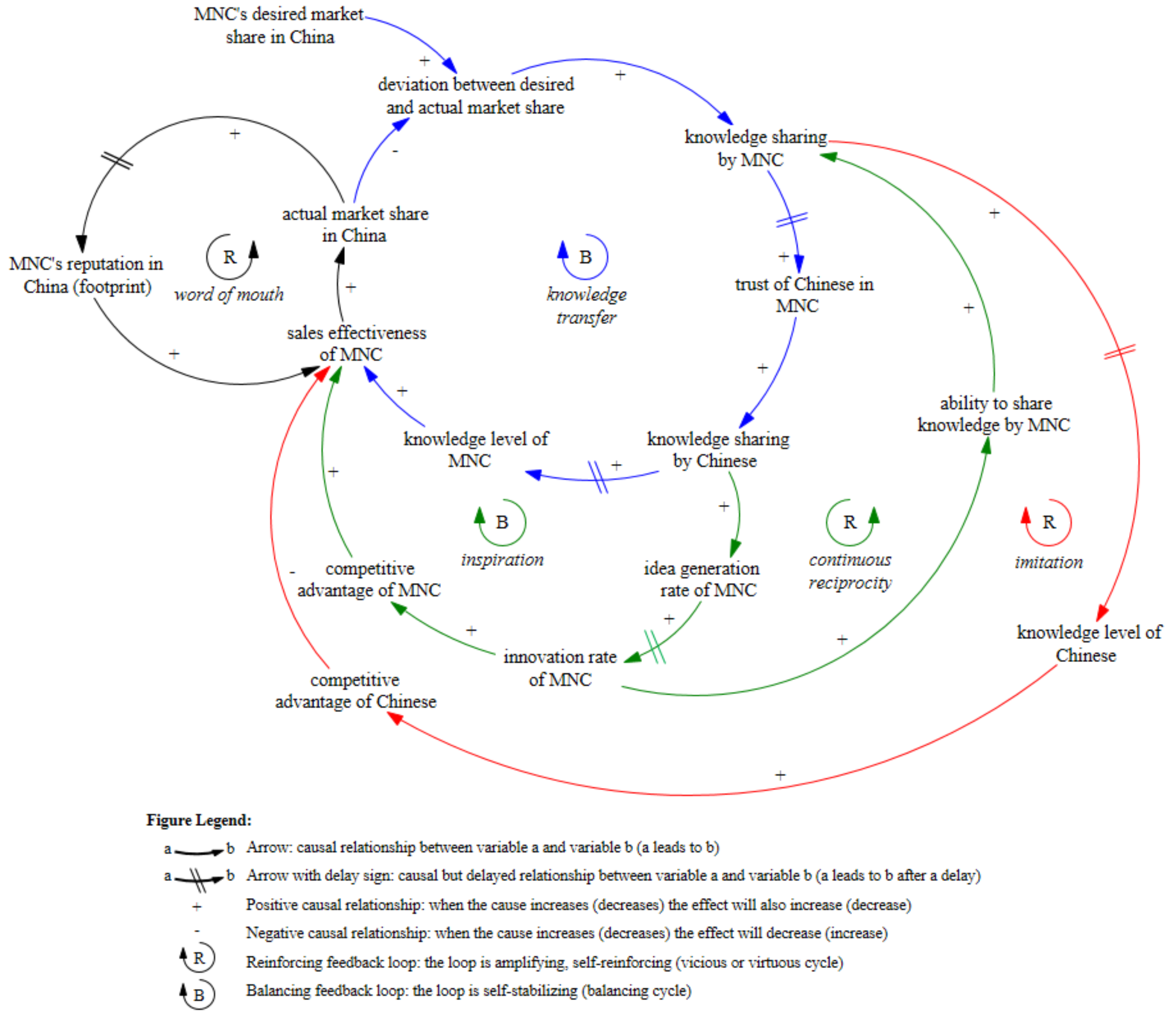


Figure 2: System dynamics model of the knowledge protection paradox

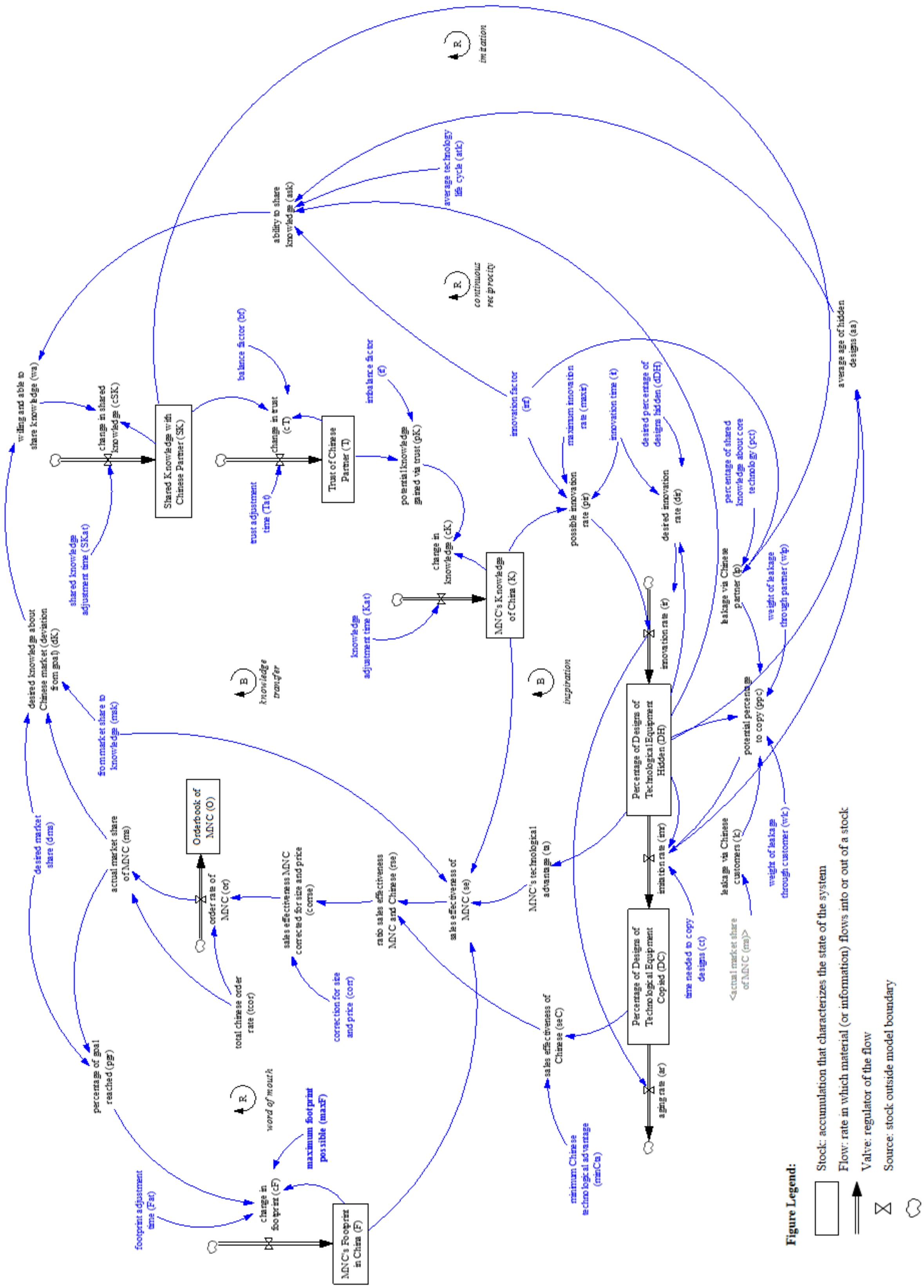


Figure 3: Behavior over time of the Protection Strategy

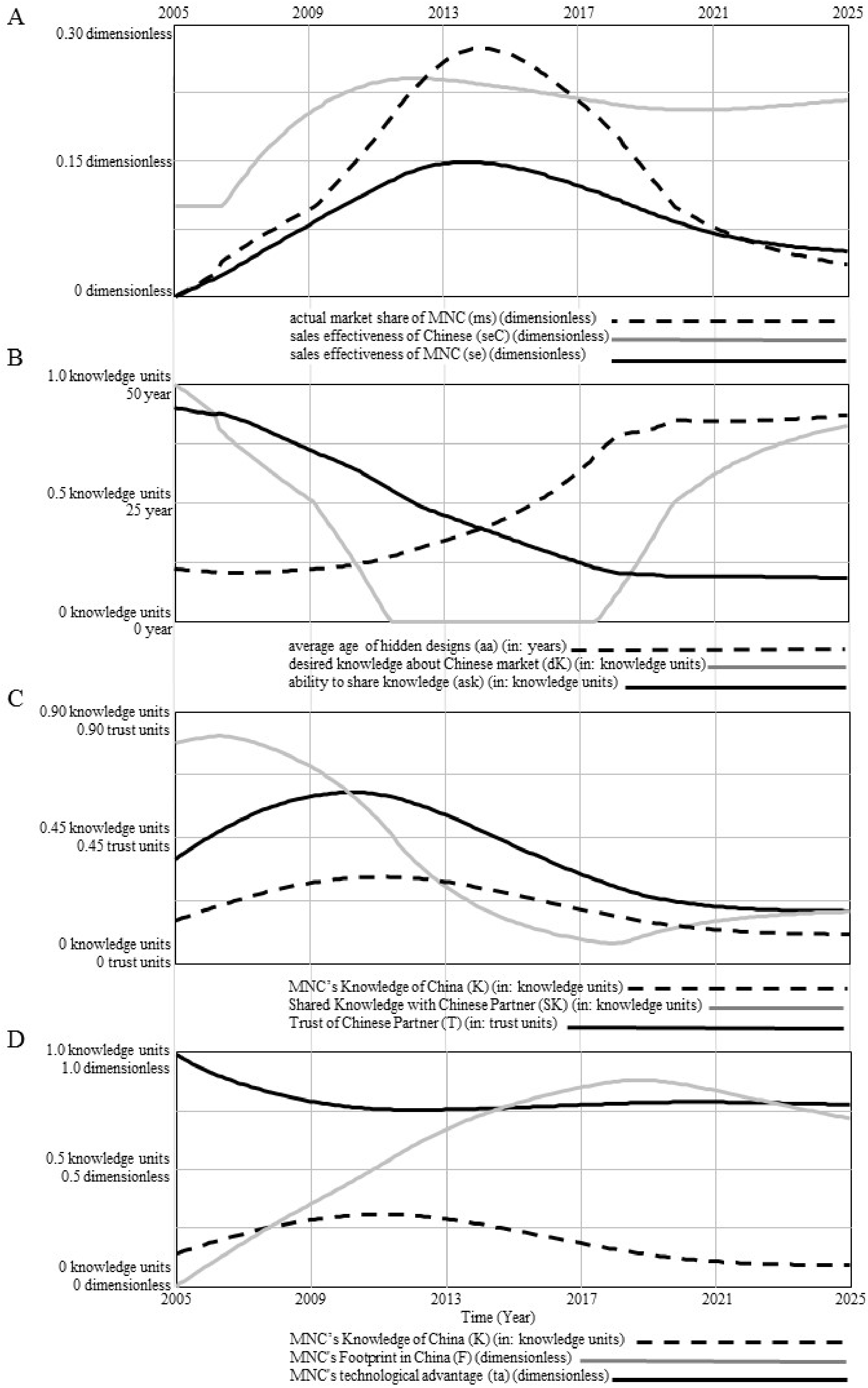


Figure 4: Behavior over time of the Sharing Strategy

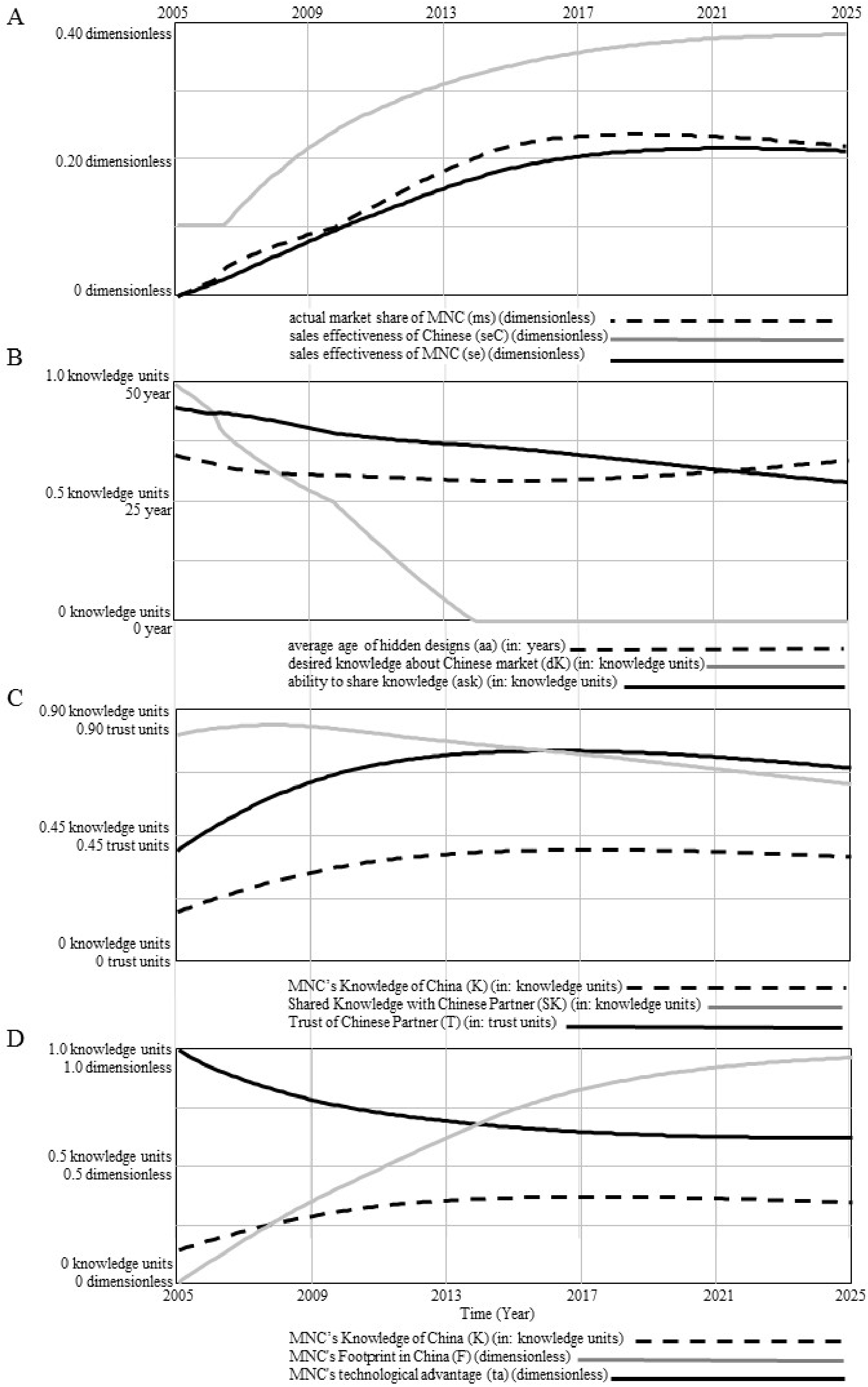


Figure 5: Innovation and imitation rates

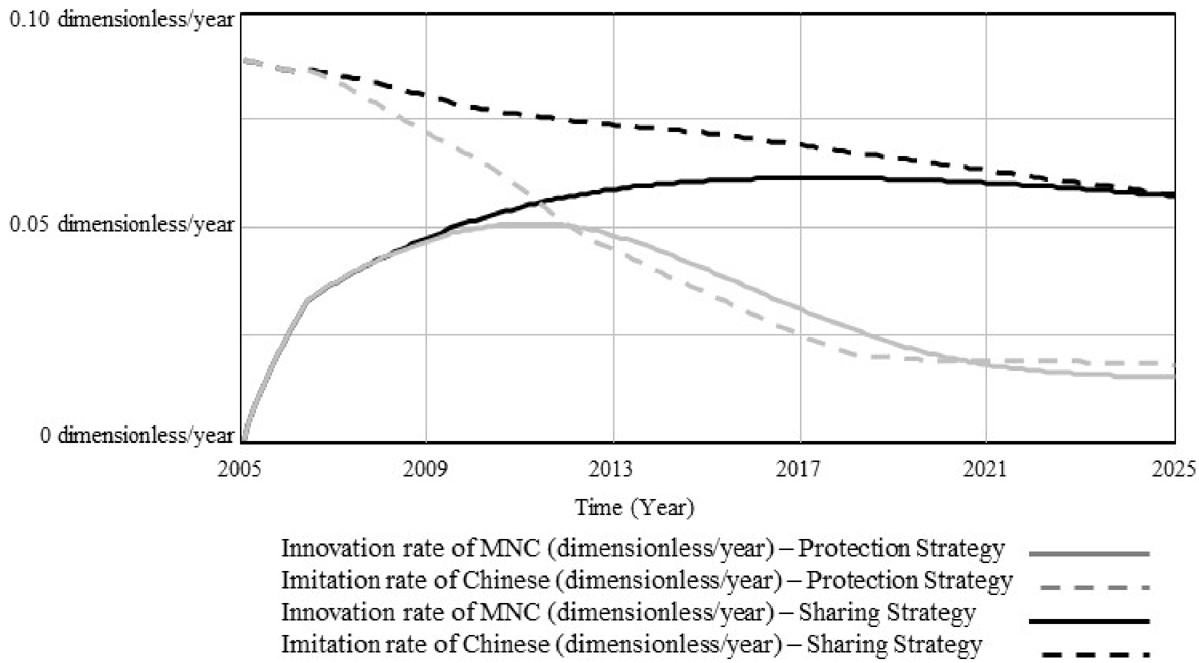
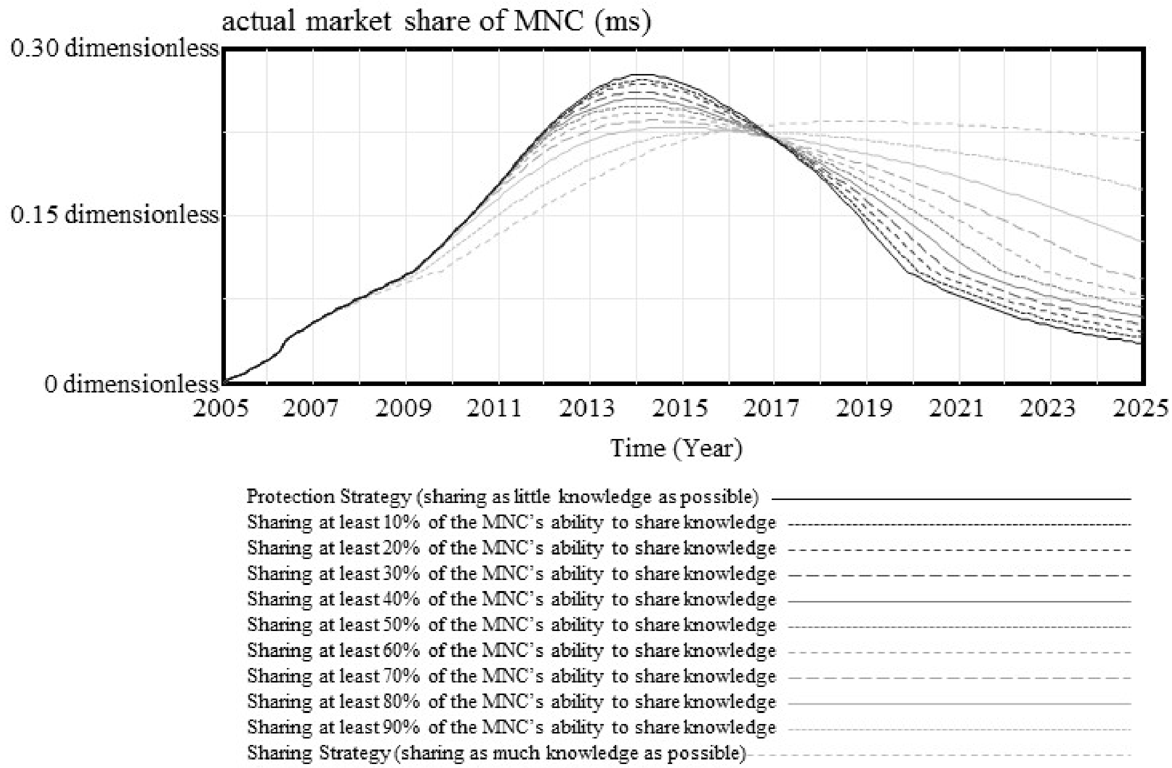


Figure 6: Impact of sharing gradually more knowledge on market share



Appendix 1: Model Documentation

This model documentation gives a full description of equations used in the system dynamics model with its five main feedback loops (Table A: Formulation and Comments). Next, we give a list of symbols used and explain what these stand for (Table B: Alphabetical List of Model Variables). Finally, we present a table with the values used for all exogenous variables (constants in the model), and we motivate the choices for these values and provide the reader with references where required (Table C: Values of Exogenous Variables).

Table A. Formulation and Comments

Formulations and comments: Generic simulation and scenario parameters	**Units**
Initial time = 2005 The initial time for the simulation.	Years
Final time = 2025 The final time for the simulation.	Years
Time step = 0.125 The time step for the simulation	Years
Vensim® software version 6.3 using Euler integration	

Formulations and comments: Knowledge transfer loop — **Units**

$$dK(t) = \max\left(0, \left(\frac{dms - ms(t)}{dms}\right) / msk\right)$$ Knowledge units

$$ms(t) = \frac{or(t)}{tcor}$$ (orders per year / orders per year) Dimensionless

The desired knowledge about the Chinese market (*dK*) is determined by the difference between the desired (*dms*) and actual market share of the MNC (*ms*), where *ms* is the ratio of the order rate of the MNC in China (*or*) to the total Chinese order rate (*tcor*). To translate market share (expressed as percentage) into knowledge units, we use the constant *msk* (from market share to knowledge units).

$$wa(t) = \max\big(p \cdot ask(t), \min(dK(t), ask(t))\big)$$ Knowledge units

The MNC has to be both willing and able to share knowledge. The amount of knowledge that the MNC is willing and able to share is defined by *wa*. Willingness stems from *dK*; ability (*ask*) is determined by the technological knowledge that the MNC has and the Chinese partner wants. Furthermore, the knowledge sharing strategy of the MNC plays a role in its ability to share knowledge. In the protection strategy, the percentage of extra knowledge sharing (*p*) is 0, which means that *wa* is determined by the minimum of the MNC's willingness and ability to share knowledge. (Please note that the ability to share knowledge will be explained later.):

$$wa(t) = \min(dK(t), ask(t))$$ Knowledge units

In the sharing strategy ($p = 1$), the MNC is always willing, but still needs to be able to share knowledge. As such, in the sharing strategy, the following equation is used:

$$wa(t) = ask(t)$$ Knowledge units

$$SK(t) = SK(0) + \int_0^t cSK(s)ds; SK(0) = 0.81$$ Knowledge units

$$cSK(t) = \frac{wa(t) - SK(t)}{SKat}$$ Knowledge units/year

Because it takes time (three years on average, according to our interview results) before knowledge gets shared with and absorbed by the Chinese partner(s) (*SKat*), we model the amount of shared knowledge (*SK*) as an adaptive expectation that gradually adjusts to *wa* (Sterman, 2000) through changes in the shared knowledge (*cSK*). The initial value of *SK* (*SK(0)*) is not equal to 0, because the MNC already started sharing knowledge in year 2000 (5 years before the start of our simulation).

$$T(t) = T(0) + \int_0^t cT(s)ds; T(0) = 0.37$$ Trust units

$$cT(t) = \frac{(SK(t)/bf) - T(t)}{Tat}$$ Trust units/year

Shared knowledge then should prompt trust by the Chinese partner(s) to follow (*T*), through the variable change in trust (*cT*). Changing trust is a slow and gradual process. Based on interview results, we have assumed that the time it takes to adjust trust (*Tat*) is on average 5 years. To convert knowledge to trust, we use the variable *bf* (balance factor). Interview results reveal that sharing knowledge and trust behave in similar ways, although there is a delay between them. The initial value of trust is not 0, because the process of gaining trust already started in 2000, 5 years before the start of the simulation.

$$K(t) = K(0) + \int_0^t cK(s)ds; K(0) = 0.14$$ Knowledge units

$$cK(t) = \frac{pK(t) - K(t)}{Kat}$$ Knowledge units/year

$$pK(t) = T(t) \cdot if$$ Knowledge units

The level of trust the Chinese partner has in the MNC determines the amount of knowledge the partner shares with the MNC. However, there is an imbalance in this relationship; if trust is, for example, .3 on a scale of 0 to 1, it does not imply that the Chinese partner shares 30% of its knowledge. Rather, our interviews indicate that the level of trust must be very high before Chinese partners feel confident enough to share ideas or knowledge with the MNC. We introduce an imbalance factor (*if*) to model this behavior. The knowledge the MNC has of China (*K*) is again modeled as an adaptive expectation that gradually adjusts over time (*Kat*) to the potential knowledge that can be gained through trust (*pK*).

$$se(t) = K(t) \cdot msk \cdot F(t) \cdot ta(t)$$ Dimensionless

Using the level of knowledge the MNC has about China, we can address the sales effectiveness of the MNC (*se*). In addition to knowledge, *se* depends on the footprint or reputation of the MNC in China (*F*) and the technological advantage (*ta*) the MNC has over its Chinese rivals. Our interviews revealed that these three factors must be multiplied to determine the *se*; in other words, all three factors are required if the MNC wants to increase its market share in China. If one or two factors is low or null, sales effectiveness also is low or null. We explain *F* and *ta* later. (Note that the multiplication with *msk* is required to convert the knowledge units into units that are similar to those of *F* and *ta*.)

$$rse(t) = \frac{se(t)}{seC(t)}$$ Dimensionless

$$corrse(t) = corr(rse(t))$$ Dimensionless

$$corr(t) \geq 0, corr'(t) > 0, corr''(t) > 0, corr(0) = 0, corr(0.2) = 0.03, corr(0.6) = 0.25, corr(1) = 0.6,$$
$$corr(2) = 0.75, corr(2) = 0.92, corr(3) = 0.99, corr(4) = 0.995, corr(5) = 1$$ Dimensionless

Next, the sales effectiveness of the MNC needs to be compared with the sales effectiveness of the Chinese rivals (*seC*, explained later), by calculating the ratio of the sales effectiveness of the MNC and the Chinese rival (*rse*). This comparison is necessary, because even if the sales effectiveness of the MNC is equal to that of its Chinese rivals, potential Chinese customers likely choose a local Chinese partner, which should have a cost advantage over the

MNC. Furthermore, as the interviews revealed, when the MNC's market share grows too large, potential customers might not choose the MNC, because they do not want the foreign MNC to become too powerful in their national market. Therefore, to calculate the *real* sales effectiveness of the MNC, we correct for both size and price (*corrse*), modeled as a non-linear, increasing function (S-curve) of *rse* that starts at 0 and increases to a maximum of 0.75.

$$O(t) = O(0) + \int_0^t or(s)ds; O(0) = 0$$ Orders

$$or(t) = corrse(t) \cdot tcor$$ Orders/year

Thus, *corrse* equals the percentage of Chinese customers placing orders with the MNC. Then the order rate of the MNC (*or*) is equal to the product of the total Chinese order rate (*tcor*) and *corrse*. All orders eventually accumulate in the stock Orderbook of MNC (*O*).

Formulations and comments: Word-of-mouth loop	**Units**

$$pgr(t) = 1 - \frac{dms - ms(t)}{dms}$$ Dimensionless

The second loop we define is the word-of-mouth loop, which describes what happens when the MNC starts to build a customer base in China. The more customers the MNC has, the better its footprint (*F*) or image, which attracts even more customers (or more returning customers) in the future. To define all variables in this reinforcing loop, we start again at the top: the actual market share of the MNC (*ms*), which we compare with the desired market share (*dms*) to calculate the percentage of the MNC's goal reached (*pgr*).

$$F(t) = F(0) + \int_0^t cF(s)ds; F(0) = 0$$ Dimensionless

$$cF(t) = \frac{\frac{1}{2} \cdot (maxF + pgr(t)) - F(t)}{Fat}$$ Dimensionless/year

The footprint depends on two factors: the collaborations the MNC has with Chinese partners and the market share, or number of customers, the MNC already has. The first factor influencing *F* depends on Chinese suppliers, and the second reflects customers. Collaborations with Chinese partners involves joint ventures. In our case, the MNC started preparing for a joint venture in China in 2000, and as of 2005, this joint venture was fully operational. That is, from 2005 onward, the maximum footprint possible through collaborations (*maxF*) is 1. A higher market share has a more positive effect on *F*. We assume both factors have equal influences on *F* and thereby model *F* as an adaptive expectation that slowly and gradually adjusts to changes over time (*Fat*).

Formulations and comments: Imitation loop	**Units**

$$DH(t) = DH(0) + \int_0^t (ir(s) - imr(s))\,(s)ds;\; DH(0) = 1$$ Dimensionless

$$DC(t) = DC(0) + \int_0^t (imr(s) - ar(s))\,(s)ds;\; DC(0) = 0$$ Dimensionless

$$ar(t) = ir(t)$$ Dimensionless/year

$$DH(t) = ta(t)$$ Dimensionless

To model imitation by the Chinese, we distinguish between the percentage of all designs that remain hidden from or unknown to Chinese companies (*DH*) and the percentage of all designs that have been copied (*DC*). The innovation rate (*ir*) of the MNC increases *DH*; the imitation rate of the Chinese (*imr*) lowers *DH* but increases the *DC*. Every time the MNC innovates, we assume the innovation can replace an old version that has been imitated already. Therefore, the *ir* determines the aging rate (*ar*), which decreases the *DC*. The Chinese company could continue to use an old design, but doing so does not enhance the sales effectiveness of the Chinese company when the MNC introduces a new design to the market. (Because *DH* and *DC* are modeled as percentages of all available designs, and any design is either hidden or copied, we assume *DH* + *DC* = 1.) The percentage of designs that are hidden (*DH*) determines the technological advantage of the MNC (*ta*).

$$ir(t) = MIN(dir(t), pir(t))$$ Dimensionless/year

$dir(t) = (dDH - DH(t))/it$ Dimensionless/year

$pir(t) = K(t) \cdot inf \cdot maxir/it$ Dimensionless/year

The innovation rate (*ir*) of the MNC is defined by two variables. Similar to knowledge sharing, the MNC must be both willing and able to innovate. Willingness to innovate is determined by the desired innovation rate (*dir*), which equals the difference between the desired (*dDH*) and actual percentage of designs hidden, adjusted for the time it takes to innovate (*it*). The ability to innovate, or potential innovation rate (*pir*), depends on the knowledge of the MNC about Chinese customers and their requirements (*K*) and the maximum innovation rate (*maxir*). No matter how much knowledge the MNC has, it can never innovate more than this maximum. The innovation factor (*inf*) is used to convert the knowledge units of K into innovation percentages (dimensionless).

$imr(t) = MIN(DH(t), ppc(t))/ct$ Dimensionless/year

The imitation rate of the Chinese companies (*imr*) depends on the number of designs still hidden (*DH*); the percentage of designs the Chinese companies potentially could copy, due to leakage through partners or customers (*ppc*); and the time needed to copy designs (*ct*).

$ppc(t) = DH(t) \cdot \left(\frac{wlp \cdot lp(t) + wlc \cdot lc(t)}{wlp + wlc}\right)$ Dimensionless

The *ppc* reflects the percentage of designs that leaks away through Chinese partners (*lp*) or customers (*lc*). Because it is more likely that a Chinese partner tries to copy designs, compared with a customer, we assign leakage through partners greater weight (*wlp*) than leakage through customers (*wlc*).

$lp(t) = SK(t) \cdot pct \cdot inf$ Dimensionless

Leakage through Chinese partners is determined by the level of knowledge shared by the MNC (*SK*). Because not all knowledge shared by the MNC is technological (e.g., the MNC shares knowledge about managerial and production processes), we multiply *SK* by the percentage of shared knowledge about the core technology (*pct*).

$lc(t) = ms(t)$ Dimensionless

Leakage by customers is similar to the actual market share (*ms*) of the MNC: higher market share means more customers of the MNC, and thus more knowledge leakage through these customers.

$seC(t) = MAX(minCta, DC(t))$ Dimensionless

As described in the previous section, sales effectiveness depends on three factors: knowledge about the Chinese market and customers, the footprint of the company that tries to sell products in China, and the technological advantage of this company and its products. For Chinese companies, we assume both knowledge and footprint are at the highest possible levels (1). Therefore, the only variable that determines the sales effectiveness of the Chinese partners (*seC*) is the technological advantage of the Chinese companies, which equals the percentage of designs that they have managed to copy (*DC*), taking into account that even when *DC* is null, they still have some minimum technological advantage to offer customers (*minCta*).

Formulations and comments: Inspiration and Continuous reciprocity loops **Units**

$ask(t) = \left(DH(t)/\left({aa(t)}/{atlc}\right)\right)/inf$ Knowledge units

$aa(t) = DH(t)/imr(t)$ Years

The ability to share knowledge (*ask*) is determined by the level of *DH* but also the average age of the hidden designs (*aa*). This reflects the phenomenon that newer designs are probably more attractive to the Chinese market than relatively old or obsolete designs. Whether age is considered high or low depends on an industry average, that is, the average technology lifecycle (*atlc*). The higher the *DH* and the lower the *aa*, the higher the ability of the MNC to share knowledge (*SK*).

Table B: Alphabetical List of Model Variables

Symbol	Variable
aa	average age of hidden designs
ar	aging rate
ask	ability to share knowledge
atlc	average technology life cycle
bf	balance factor
cF	change in footprint
cK	change in knowledge
corr	correction for size and price
corrse	sales effectiveness MNC corrected for size and price
cSK	change in shared knowledge
ct	time needed to copy designs
cT	change in trust
DC	percentage of designs of technological equipment copied
dDH	desired percentage of designs hidden
DH	percentage of designs of technological equipment hidden
dir	desired innovation rate
dms	desired market share
F	MNC's footprint in China
Fat	footprint adjustment time
if	imbalance factor
imr	imitation rate
inf	innovation factor
ir	innovation rate
it	innovation time
K	MNC's Knowledge of China
Kat	knowledge adjustment time
lc	leakage via Chinese customer
lp	leakage via Chinese partner
maxF	maximum footprint possible
maxir	maximum innovation rate
minCta	minimum Chinese technological advantage
ms	actual market share of MNC
msk	from market share to knowledge units
O	orderbook of MNC
or	order rate of MNC
p	percentage of extra knowledge sharing
pct	percentage of shared knowledge about core technology
pgr	percentage of goal reached
pir	possible innovation rate
pK	potential knowledge gained via trust
ppc	potential percentage to copy
rse	ratio sales effectiveness MNC and Chinese
se	sales effectiveness of MNC
seC	sales effectiveness of Chinese
SK	shared knowledge with Chinese partner
SKat	shared knowledge adjustment time
T	trust of Chinese partner
ta	MNC's technological advantage
Tat	trust adjustment time
tcor	total Chinese order rate
wa	willing and able to share knowledge
wlc	weight of leakage through customer
wlp	weight of leakage through partner

Table C: Values of Exogenous Variables (constants)

Symbol	Source	Value	Units
atlc	(c)	10	years
bf	(a)	1	knowledge units/trust units
ct	(c)	3	years
DC(0)	(a)	0	dimensionless
dDH	(a)	1	dimensionless
DH(0)	(a)	1	dimensionless
dms	(a)	0.2	dimensionless
if	(a)	0.5	knowledge units/trust units
inf	(b)	1	dimensionless/knowledge units
it	(a)	3	years
F(0)	(a)	0	dimensionless
Fat	(a)	5	years
K(0)	(a,f)	0.14	knowledge units
Kat	(a)	1	years
maxF	(a)	1	dimensionless
maxir	(a)	0.5	dimensionless/year
minCta	(a)	0.1	dimensionless
msk	(a)	1	dimensionless/knowledge units
O(0)	(a)	0	orders
p	(g)	any number between 0 and 1	dimensionless
pct	(a)	0.5	dimensionless
SK(0)	(a,e)	0.81	knowledge units
SKat	(a)	3	years
T(0)	(a,f)	0.37	trust units
Tat	(a)	5	years
tcor	(d)	2000	orders/year
wlc	(a)	1	dimensionless
wlp	(a)	2	dimensionless

(a) Interview results
(b) Common modeling definition
(c) Common industry value, see also Bennett et al. (2001)
(d) The *tcor* value is based on real data from the Chinese shipbuilding industry from 2000–2012 (Community of European Shipyards Associations, 2011-2012). In these years these order rates show a steep increase (boom) until 2007, followed by a decrease (bust) in 2009. To make sure our modeling results are influenced only by the parameters that reflect policy choices and not these external boom and bust cycles, we have modeled *tcor* as a constant number over the entire simulation period. This number reflects the average of the order rates from 2000 until 2012.
(e) Shared knowledge is modeled as goal seeking behavior. As such, we can write:
$SK(t) = wa(t) - \left(wa(t) - SK(0)\right)e^{-t/_{SKat}}$
Before our simulation starts (from year 2000 until year 2005), we can assume that *wa* is constant, with a value of 1. In year 2000, the actual value of shared knowledge is 0. Because our simulation starts in 2005, we can use this equation to calculate what the value of *SK* should be in 2005, assuming the knowledge sharing process started in 2000:
$SK(5) = 1 - (1 - 0)e^{-5/_3} = 1 - e^{-5/_3} = 0.8111$
(f) Trust (*T*) and the MNC's knowledge of China (*K*) are also modeled as goal seeking behavior, although the goals are not a constant but the goals are respectively, *SK* and *T*. To calculate the initial values of *T* and *K*, we have developed a small model with only these three stocks (*SK*, *T*, and *K*) and their netflows, and simulated this model to find the values of *T* and *K* after 5 years, assuming all stocks start with the value 0. As such, we find: T(0) = 0.3653, and K(0) = 0.1372.
(g) Scenario choice: 0 means the MNC wants to share as little as possible (Protection Strategy), 1 means the MNC wants to share as much as possible (Sharing Strategy).

Appendix 2: Sensitivity Analyses

description of sensitivity analysis (scenarios in bold are used in main text)		actual market share, end of simulation t = 2025	number of years on or above target t >= 2005	number of years on or above target, first 10 years t <2015	number of years on or above target, second 10 years t >=2015
1 *Copying time, ct*					
ct = 2.00 years	base case	0.032	0.000	0.000	0.000
ct = 2.00 years	improved case	0.036	0.000	0.000	0.000
ct = 2.50 years	base case	0.076	0.000	0.000	0.000
ct = 2.50 years	improved case	0.095	0.000	0.000	0.000
ct = 2.75 years	base case	0.060	0.000	0.000	0.000
ct = 2.75 years	improved case	0.169	0.000	0.000	0.000
ct = 3.00 years	**base case**	**0.035**	**6.125**	**3.500**	**2.625**
ct = 3.00 years	**improved case**	**0.216**	**11.000**	**1.000**	**10.000**
ct = 3.50 years	base case	0.031	8.125	6.375	1.750
ct = 3.50 years	improved case	0.277	16.000	6.000	10.000
ct = 4.00 years	base case	0.031	9.125	7.250	1.875
ct = 4.00 years	improved case	0.334	17.130	7.130	10.000
2 *Minimum Chinese technological advantage, minCta*					
minCta = 0.05 dimensionless	base case	0.035	6.125	3.625	2.500
minCta = 0.05 dimensionless	improved case	0.216	11.000	1.000	10.000
minCta = 0.10 dimensionless	**base case**	**0.035**	**6.125**	**3.500**	**2.625**
minCta = 0.10 dimensionless	**improved case**	**0.216**	**11.000**	**1.000**	**10.000**
minCta = 0.20 dimensionless	base case	0.039	6.250	3.000	3.250
minCta = 0.20 dimensionless	improved case	0.216	11.000	1.000	10.000
minCta = 0.30 dimensionless	base case	0.048	2.875	0.000	2.875
minCta = 0.30 dimensionless	improved case	0.214	10.130	0.130	10.000
minCta = 0.35 dimensionless	base case	0.085	0.000	0.000	0.000
minCta = 0.35 dimensionless	improved case	0.219	3.750	0.000	3.750
minCta = 0.40 dimensionless	base case	0.091	0.000	0.000	0.000
minCta = 0.40 dimensionless	improved case	0.094	0.000	0.000	0.000
3 *Imbalance factor, if*					
if = 0.250 knowledge units/trust units	base case	0.008	0.000	0.000	0.000
if = 0.250 knowledge units/trust units	improved case	0.008	0.000	0.000	0.000
if = 0.375 knowledge units/trust units	base case	0.026	0.000	0.000	0.000
if = 0.375 knowledge units/trust units	improved case	0.026	0.000	0.000	0.000
if = 0.450 knowledge units/trust units	base case	0.073	0.000	0.000	0.000
if = 0.450 knowledge units/trust units	improved case	0.094	0.000	0.000	0.000
if = 0.475 knowledge units/trust units	base case	0.042	4.125	1.125	3.000
if = 0.475 knowledge units/trust units	improved case	0.159	0.000	0.000	0.000
if = 0.500 knowledge units/trust units	**base case**	**0.035**	**6.125**	**3.500**	**2.625**
if = 0.500 knowledge units/trust units	**improved case**	**0.216**	**11.000**	**1.000**	**10.000**
if = 1.000 knowledge units/trust units	base case	0.072	12.250	8.375	3.875
if = 1.000 knowledge units/trust units	improved case	0.750	18.250	8.250	10.000
4 *Weight of leakage through customer and partner, wlc & wlp*					
wlc = 1, wlp = 2	**base case**	**0.035**	**6.125**	**3.500**	**2.625**
wlc = 1, wlp = 2	**improved case**	**0.216**	**11.000**	**1.000**	**10.000**
wlc = 1, wlp = 1	base case	0.031	5.750	5.750	0.000
wlc = 1, wlp = 1	improved case	0.231	16.500	6.500	10.000
wlc = 2, wlp = 1	base case	0.038	4.875	4.875	0.000
wlc = 2, wlp = 1	improved case	0.234	17.380	7.380	10.000