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Effect of Non-Practicing Entities on Innovation Society and Policy: An agent based model and simulation

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Abstract

Non-practicing entities (NPE) have been controversial patent market players in terms of their effects on innovation society, owing to their having both positive and negative impacts on society-level innovation performance. However, measuring the net effect as well as finding ways to control the probable negative effects has been a challenging issue. In this paper, we propose an agent model of the patent market to address the issue. We conduct a simulation to test whether NPEs produce more harm than good. Further, a computational study evaluates the efficacy of possible legislative options to control NPEs' undesirable effects, which are being discussed by scholars and policy makers in the U.S. Our result concludes that the negative effects of NPEs are likely to outweigh their potential benefits. In addition, it provides a first look at the effectiveness of each policy in relieving the NPE effect. We provide a quantitative ground for policy makers to use in discussing policy options regarding the NPE issue and practical guideline for implementation of such policies.

Keywords:

Non-practicing Entity (NPE), Patent Assertion Entity (PAE), Patent troll, Patent policy, Innovation Policy

Highlights

- We model patent system and patent market into an agent-based computational model.
- We examine the net effect of NPEs on innovation performance at society level through simulation.
- We evaluate the effectiveness of the three legislative options in reducing the negative effect of NPEs: regulating the amount of damages NPEs can collect, reducing the injunction rate in NPE lawsuits, and exempting defendants from litigation costs in NPE lawsuits.
- Our result shows that the NPE strategy yields an overall negative effect on society-level innovation creation.
- Controlling the injunction rate in NPE lawsuits is the most effective policy.

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1. Introduction

A non-practicing entity (NPE[2]) has been identified as patent assertion entity (PAE) since it exerts patent rights to enforce practicing firms to agree on expensive licenses or patent right transfer contracts as a settlement in lieu of defending a risky patent infringement lawsuit (Golden, 2007; Shrestha, 2010; Reitzig, Henkel, & Schneider, 2010; Reitzig, Henkel, & Heath, 2007; Layne-Farrar & Schmidt, 2010). Narrowly defined, an NPE acquires currently or potentially infringed patents from inventors including individuals, universities, and private companies (Fisher & Henkel, 2012), but rarely develops and practices the patented innovations (Bessen, Meurer, & Ford , 2011; Yeh, 2012). Instead, they seek to earn money simply through lawsuits.

The effect of NPEs on innovation society has generated debate regarding whether NPEs have positive or negative effects on innovation society. In particular, their impact on society-level innovation performance has been a core question of the debate.

A number of previous researches (Bessen, Meurer, & Ford , 2011; Tucker, 2012; Turner, 2013; Meurer & Bessen, 2014) have come up with evidence as well as the theoretical conclusion that NPEs discourage innovation by generating excessive social costs through frivolous litigation.

Aligned with these prior studies, the U.S. Congress recently introduced a bill titled 'Saving High-Tech Innovators from Egregious Legal Dispute-SHIELD act H.R 845 as of 2013' to help practicing firms cope with threat of NPEs. Furthermore, the Federal Trade of Commission expressed concern that NPEs may exert a negative effect on innovation creation, stating that they currently do more harm than good in its official report.[3] Recently, President Obama stated that NPEs should be strongly regulated by the authorities of the American Innovation Society. Along with such a stance by U.S. policy makers, some legislative options are being discussed in U.S. Congress including the following three for reducing NPEs' leverage: (1) limiting damages that can be awarded to NPEs to a reasonable level, (2) reducing the injunction rate in NPE lawsuits, and (3) shifting litigation costs of defendants in NPE lawsuit onto NPEs (Yeh, 2012).

However, several studies counter this argument by suggesting that NPEs can provide benefits by their aggressive patent acquisition activities, such as the technology/patent market activation effect or innovation promotion effect for small and medium enterprises (SMEs)/individual inventors (Shrestha, 2010; Yeh, 2012; Hosie, 2008; McDonough, 2006).

Due to this controversy, policy makers have struggled to find clues that clarify the net effect of NPEs and develop proper legislative options to suppress their probable negative effects.

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[2] In this paper, NPE represents the PAE or patent shark.
[3] See FTC Report, *Supra* note4, at 67-68; Love, *Supra* note 34.

Unfortunately, previous studies were unable to address this question because (1) it is challenging to quantify the potential benefits and drawbacks together. The positive or negative effects of NPEs on society's innovation performance are potential effects that are unable to be observed and quantified directly; (2) measuring NPEs' net effect on the whole of innovation society, which is an aggregated outcome of various probable microscopic interactions between individual players and NPEs, is impossible to conduct with a conventional research approach.

Describing the effect of NPE from a microscopic perspective may be straightforward and obvious. For example, the effect of NPEs on technology-practicing firms would be negative because an NPE's business heavily extracts patent infringement lawsuit settlement fees from practicing firms. However, it may offer benefits to technology-intensive start-ups or SMEs that usually struggle in terms of R&D investment by the costs incurred in purchasing their patents. However, one unclarified but central issue is the aggregate effect on the whole of society, especially in term of the society-level innovation performance. To address this issue, it is necessary to adopt a different approach to study the society-level outcomes different from the revealed microscopic dynamics generated by NPEs.

The agent-based model (ABM) and computational simulations provide a proper approach to address this issue. A goal-directed software agent, which represents complex social system players, has microscopic internal (between players) and external (with the system) interactions within given action rules. These individual interactions generate system-level dynamics that correspond to virtualized society-level outcomes. Therefore, it is possible to observe macroscopic dynamics that emerge from microscopic interactions between economic entities. We are also able to evaluate a certain factor's influence on system-level outcomes by introducing it as a stylized simulation factor. For the present study, the ABM presents itself as a powerful research tool by providing such an alternative method to quantify the entangled effect that cannot be examined in the real world (Davis & Bingham, 2007).

The present research primarily focuses on seeking answer to the core question using both ABM and a simulation. We model the patent system and patent market into an ABM. Actors such as Enterprise, University, Bank, NPE, and Federal Court are modeled as independent virtual agents. Through this simulation, we measure the extent of system-level innovation performance, representing the society-level innovation performance that is affected by the NPE agent. In addition, the suggested three remedies to control negative effects of NPEs are modeled into individual sub-models. Subsequently, we estimate the extent to which system-level outcomes are changed by the introduction of each virtualized remedy.

This paper is structured as follows: Section 2 reviews previous studies on the NPE effect and computational studies on innovation dynamics using ABM. Section 3 mainly describes the designed ABM utilized in the present research. Section 4 presents simulation parameters, sub-models for policy analysis, and simulation results with statistical analysis on the NPE effect. In Section 5, we conduct a policy analysis on the suggested legislative options being discussed in U.S. Congress on the NPE issue. Based on the analysis, we further offer suggestions for policy makers to design more effective remedies for mitigating NPEs negative effects. Section 6 discusses directions for further research.

2. Literature review

2.1 Studies on NPEs

(1) Negative perspective on NPE

Bessen et al., (2011), Tucker (2012), and Turner (2013) indicated that NPEs may interrupt the innovation process of practicing firms. Practicing firms in NPE lawsuits are not willing to develop further innovations in order to avoid a situation that could be recognized as an advertent patent infringement by authorities. Furthermore, the underlying financial implications for settlements discourage practicing firms' from engaging in further R&D. Thus, NPE lawsuits make practicing firms hesitant to develop new innovations.

Some scholars state that the imbalanced bargaining power between the NPEs and practicing firms for patent infringement settlements overestimates the value of NPEs' patents (Lemley & Shapiro, 2007; Reitzig, Henkel, & Heath, 2007; Henkel & Reitzig, 2008; Turner, 2013). The NPE's negotiation power is systematically leveraged by the financial risk of practicing firms in patent infringement lawsuits by (1) paying damages, (2) losing expected sales revenue from infringing products and the substantial amount of resources invested to develop the product (service) following an injunction, and (3) paying expensive litigation costs. In line with previous studies, some policymakers blame NPEs for frivolous litigation. They insist that NPEs bring unnecessary lawsuits and abuse the litigation process, which generates social costs, simply to obtain stronger bargaining power against practicing firms. Tucker (2012) reported that product innovation can actually diminish during the course of an NPE lawsuit. Through empirical evidence, she observed decreases of sales revenue and new product development speeds of medical imaging software companies during the NPE lawsuits. Bessen et al., (2011) measured changes in stock value of defendants in NPE lawsuits before and after the lawsuit, and found out that these values significantly declined. The study argued that social cost generated by NPEs discourages further innovation by defendants with no significant financial investment available for patent acquisition, which can encourage a patent seller to engage in further innovation, by showing that less than 2% of a defendant's loss in an NPE lawsuit is reinvested in patent acquisition. A recent study conducted by Fisher and Henkel (2012) also takes a pessimistic perspective on the technology transfer promotion effect of NPEs' patent acquisition. They insist that technology transfer is not same with patent transactions for infringement settlements. The revenue source of an NPE business is not a commission fee from technology transfer meditation but a legal dispute settlement fee from a defendant, which means that an NPEs' patent acquisition activity is rarely related to technology transfers and mostly toward transactions associated with patents that are already being infringed (or might be infringed). Therefore, they argue that NPEs' patent acquisition does not contribute to activating the technology market.

(2) Other perspectives on NPEs

On the other hand, NPEs can contribute to encouraging innovation in several ways. First, NPEs can serve a secondary patent market (Hosie, 2008; Shrestha, 2010; Yeh, 2012) through patent acquisition. According to this argument, aggressively acquiring patents that could not have otherwise been monetized in a typical patent market can provide more opportunities for inventors to generate revenue from their patents. Particularly, NPEs' patent acquisition extends the financial state of individual inventors or SMEs by rewarding their innovations. If this reward is subsequently reinvested in further innovation, NPEs' patent acquisitions can play a role in stimulating innovation.

Besides this positive view on NPEs, another argument exists that they should not be discriminatively recognized from typical firms because their strategy is similar to the general patent strategy that is also taken by non-NPEs and does not generate a distinguishable problematic effect. For example, by showing that the royalty rate of license contracts offered by NPEs could not be distinguished from contracts offered by non-NPEs, Lu (2012) casts doubt on the common belief that NPEs are systematically overcompensated by the patent system. Shrestha (2010) concluded that the quality of NPE patents was high, contrary to the common belief that NPE patents are more likely to be of low quality (Lerner, 2006). Furthermore, he found no significant difference in the success rate of patent infringement lawsuit by NPEs compared with other litigants. Therefore, he argues that NPE litigations should not be considered as frivolous.

(3) Policy in consideration

Regarding this dispute, policymakers have discussed how to measure the total effect of NPEs on the innovation society as well as ways to relieve their probable negative effect (Reitzig, Henkel, & Heath, 2007; Reitzig, Henkel, & Schneider, 2010; Fisher & Henkel, 2012). Indeed, the U.S. Congress has been discussing several legislative options to deal with this issue. The current suggestions include reducing the injunction rate in NPE lawsuits, shifting more litigation cost onto NPEs, and placing controls when estimating the damages that can be awarded to NPEs to reduce the possibility of overcompensation (Yeh, 2012). Among them, shifting litigation cost onto NPEs is ready to be executed by the SHIELD act via the Anti-Patent-Troll Bill. Reducing the injunction rate in NPE lawsuits has been implicitly in effect following the 2006 eBay case.

2.2 Studies on innovation dynamics using ABM

Computational modeling and simulations have been adopted as new streams in research methodologies within various fields of study (Axelrod, 1997; Jianhua, Wenrong, & Xiaolong, 2008). Particularly, it is increasingly being used in social science (Wooldridge & Jennings, 1995) as well as developing theories focused on organizational strategy (Davis & Bingham, 2007). The ABM is one approach being recognized as a proper way to describe complex dynamics that emerge through interaction between social systems and humans (Wooldridge, 2009; Gilbert & Troitzsch, 2005; Gilbert, 2007). Several previous works have tried to study dynamics in innovation systems using the ABM, but none have modeled the patent system thus far. Herein, we only review computational studies on innovation system dynamics and the knowledge diffusion process that are close to present study's topic.

A milestone computational study on innovation dynamics through the ABM is the "Simulating Knowledge Dynamics in Innovation Network" (SKIN) project. Gilbert et al. (2001) introduced an ABM-based model for describing the knowledge sharing and innovation diffusion process. An R&D-intensive firm, a venture capitalist, and a university/research institute were modeled into virtual agents. A new firm is created from an agent who successfully developed new knowledge that fits into a given innovation hypothesis. Existing agents can establish or destroy partnership with other agents over the network. In this way, the entire network-structure is dynamically organized.

Ahrweiler el al. (2011) studied the effect of industry–university links on the innovation performance of individual firms. They quantitatively compared virtually generated R&D collaboration network structures and how much innovation was diffused over the network in both a university-less system and a university-inclusive system. The study showed that university–industry links enhance innovation diffusion and collaborative arrangements.

Jianhua et al. (2008) introduced an ABM describing a macro-level innovation system. The model is composed of an innovation market, society, enterprises, and government. Each agent is linked by information. This study showed that ABM methodology can be employed to describe innovation system dynamics.

Antonelli and Ferraris (2011) introduced a simulation model that represents the generation of new technological knowledge and the introduction of innovations by interaction between virtual agents. The model explores the effects of intellectual property right regimes and different architectural configurations of regional structure upon what types of knowledge interactions take place. According to the simulation, innovation is likely to emerge faster and to a greater extent in organized complex systems characterized by high levels of disseminations and accessibility to knowledge externalities.

Lopolito et al. (2013) studied the importance of innovation policy in innovation niche development processes using an ABM that captures three innovation niche creation mechanisms:

expectation, networking, and learning. The study analyzed the impact of two specific policies upon stimulating innovation niche emergence. Their research revealed that a policy consisting of an information campaign to increase innovation actors' expectations towards new technology would be more effective than a policy of subsidies. All those studies are summarized in Table1.

Table 1. Innovation studies using the agent-based model (ABM)

Study	Research Topic	Type of Agents	Key Findings
Gilbert, Pyka, & Ahrweiler, 2001	Innovation Process over innovation network	Firm Venture Capitalist Policy Maker University Innovation Oracle	Introduction of Simulating Knowledge Dynamics in Innovation Network project, and model description with two case studies for model validation.
Ahrweiler, Pyka, & Gilbert, 2011	Effect of industry–university links on innovation performance	Firm Venture Capitalist, University Innovation Oracle	Positive effect of industry–university links on innovation performance
Jianhua, Wenrong, & Xiaolong, 2008	Studying innovation generation process	Enterprise Government	Product market competition is a major driver of innovation generation. ABM is applicable for studying innovation systems
Antonelli & Ferraris, 2011	Generation of new technological knowledge	Worker Shareholder Researcher Consumer Enterprise	Innovation is likely to emerge faster and better in organized complex systems characterized by high levels of dissemination and accessibility to knowledge externalities
Lopoliro, Morone, & Taylor, 2013	Which policy would be appropriate to stimulate the emergence of innovation niche?	Producing Firm	Policy intervention is important in innovation niche creation. The study shows that the dominance of information spreading activities over subsidies. Such a policy is fundamentally helpful to promote efficient knowledge diffusion and the effective use of individual and network resources

In the present research, we construct a cellar automata (CA)-based ABM for the patent system. The model is described by "Overview, Design Concepts and Details" (ODD), which is a general documentation protocol for ABM suggested by Grimm, et al., (2006). Sub-model sections, which include detailed algorithms and analytical models, are separately provided in Appendices.

3. Model description

Dynamics in the virtualized patent system emerge by patent-strategic interactions between agents, with the following provisos: (1) included patent market players are technology-intensive firm (*ENT*), university (*UNIV*), bank (*BANK*), NPE, and federal court (*COURT*); (2) such agents are goal-directed: firms take the most profitable actions to maximize revenue, the university tries to engage in R&D as much as possible, and the federal court makes judgments on correctly-filed lawsuits; (3) the following patent strategies are allowed: licenses, cross-licenses, patent right-transfers, litigating against a patent infringer, and patent collateral for financing. Each agent makes investments to have new patented technology through internal R&D processes.

3.1 Objective

We build an ABM and conduct a simulation to study the effect of NPEs and navigate ways to counter their negative effects on system-level innovation performance. The system-level outcome corresponds to society-level outcomes as the present model virtualizes innovation society in terms of the patent-system.

For our simulation, we introduce a variation in the number of NPE agents into the system. By profiling the extent to which system-level outcomes responded to the variation, we can quantify the effects of NPEs.

Second, the technological complexity of a product, which is defined as the number of essential technological components required for product implementation, is introduced as a simulation parameter. By observing how much the NPE effect is aggravated or relieved by this factor, we find the degree to which a product's technological complexity affects the level of impact from NPEs on the entire system. From this simulation, we test a common belief that the NPEs' business model capitalizes on the technological complexity of product.

With each of the simulation factors, we also examine NPEs' potential positive effects such as an innovation promotion effect for patent sellers or the patent/technology market activation effect by comparing system-level outcomes in systems both with and without NPEs.

We test the extent to which three legislative options would relieve the negative effects of NPE. The three options, which have been suggested as ways to reduce the leverage of NPEs in settlement negotiation, are (1) limiting NPEs' potential damage awards to reasonable amounts, (2) controlling the injunction rate in NPE lawsuits, and (3) redeeming litigation costs for defendants in an NPE lawsuit (Yeh, 2012). For each of these remedies, we mainly quantify the extent by which system-level innovation performance and system-level litigation volume are changed by each option. Comparison with an NPE-less system allows measuring the effectiveness of the options in relieving NPEs' negative effects.

For testing the first remedy, we place a discounting factor on the damage that can be awarded to the NPE. The injunction rate in NPE lawsuits is controlled for testing the second remedy. The last remedy is modeled by exempting defendants' litigation costs in NPE lawsuits.

3.2 State variable and scales

The ABM for the present research virtualizes the high-tech product market, patent market, and patent system. In the model, product is defined by Utterback and Abernathy's (1975) definition, which states that product is implemented by combination of determined technological elements. We define a product's technological complexity (*TC*) by the total number of essential technological components for its implementation. From this definition, a patented technology's identity is recognized by the technological group it falls into as well as technological novelty (Fig. 1). A product's technological competitiveness is measured by the average value of "the highest technological novelty-patents" over all necessary technological components.

Each agent has a matrix that represents the so-called patent matrix (Fig. 1-a). This is depicted by the column corresponding to technological novelty and the row for technological group of an agent's existing patented technology. Thus, the size of the row shows the product's technological complexity. If an agent is capable of practicing a certain patented-technology, the corresponding cell is filled with 1, and otherwise 0. For instance, if an agent developed a technology in technological group "3" and has 2 novel technologies, the cell {2, 3} in the matrix is set to "1".

Agents except *COURT* have four patent strategies: patent rights transfer, license (including cross-license) contracts, litigating against a (suspected) patent right infringer, and borrowing money from *BANK* through patent collateral. The four options can be modeled into a simple patent matrix operation. For example, a license contract can be expressed as temporal copying of a licensor's focal patent into licensee's patent matrix for a certain period (Fig. 1-c). Two agents' sharing their patent matrices with each other for a certain period is the model of a cross-license contract (Fig. 1-d). Permanent patent rights transfer the focal patent of one party's patent matrix to that of another party, an act that becomes the model of patent rights transfer (Fig. 1-e). Litigation is modeled as requesting the judgment of the *COURT* on the patent infringement case (Fig. 1-f). Finally, transferring the patent matrix of a patent holder to a *BANK* during a loan period (*pLoan*) and borrowing money from the *BANK* becomes the model of patent collateral. If the borrower cannot repay the loan to the *BANK* upon expiry, the patent matrix becomes permanently owned by the *BANK* (Fig. 1-b).

[Figure 1]

Each agent can take any of the following five states: zero-state (*Z*), non-manufacturing state (*NM*), manufacturing state (*MN*), sales-banned state (*BAN*), and exit-state (*EXIT*). If an agent cannot practice any technology, the state is set to *Z*. If agent is not in state *Z* but cannot produce the product, its state turns to *NM*. The state of an agent who satisfies the conditions for product implementation can become *MN* by the agent's own decision. The *MN*-state is available only for *ENT* because of its willingness to be a practicing firm in the model. The state of an agent in *MN* who is then sued by another agent for patent infringement changes to *BAN* if the *COURT* issues an injunction. Once an agent's capital assets become negative, it is eliminated from the system as a bankrupted agent. The state change rule is summarized in Fig. 2.

[Figure 2]

ENT should meet two requirements in order to be a manufacturer: It should (1) be able to practice all required technologies for product implementation, (2) have a specific asset, that is, a factory. In order to have the factory, the *ENT* must spend a certain amount of money as an investment for building the factory (*Fi*). The manufacturer earns sales revenue, an amount which is determined by its calculated market share (*MS*) and a given total market demand (*M0*). The model requires manufacturers to pay factory maintenance costs (*Fm*) at every turn. By considering such costs and revenue, the manufacturer makes a decision whether to exit from or stay in the product's market. If the manufacturer exits from the product market, it liquidates the factory and recoups its salvage value (*Fsv*). All patent owning agents are required to pay a patent renewal fee (*Cr*) at every turn. Once an agent develops a new technology, the corresponding patent is valid for the patent's life (*Plife*) as long as *Cr* is paid by the agent. *Plife* is discounted by one at every turn and the patent expires if *Plife* becomes 0 or the agent fails to pay the *Cr*. The expired patent can then be freely utilized by every agent without a formal patent transaction. Agents engaged in patent infringement lawsuits pay litigation costs (*Lc*). Non-NPEs interact with four neighboring agents (Moore's neighborhood) but NPEs can interact with eight neighboring agents (Von-Neumann's neighborhood) around their location. This difference is intended to reflect NPEs relatively stronger capabilities in patent information analysis compared to non-NPEs.

3.3 Process overview and scheduling

1) Patent infringement trial process

COURT adjudicates whether a defendant in a lawsuit has infringed the plaintiff's patent. Once recognized as a patent infringer, the defendant is ordered to pay damages as calculated by the *COURT* to the plaintiff. The *COURT* also can issue an injunction, which changes the defendant's state from *MN* to *BAN*.

2) Cost and revenue calculation process

Each agent's capital assets have several costs deducted, namely operating cost (*OP*), *Cr*, and *Fm*, while sales revenues are added to assets.

3) Royalty cost and revenue calculation process

Licensees pay the contracted royalty to the licensor as long as the license contract is valid. If the licensee fails to pay the royalty to the licensor or the patent expires, the license contract is terminated.

4) R&D process

ENT and *UNIV* can engage in an R&D process as long as they have sufficient capital assets for such an R&D investment, as set by the system variable (*RnDInv*). The created new technology takes the same or one higher level of technological novelty than the system-level up-to-date technology that is randomly assigned to each technological group.

5) Patent transaction process

Each agent identifies a patent strategy to its neighborhoods and calculates the expected profit from pursuing each strategy. An agent interacts with its neighbors in pursuit of the most profitable option. If the neighbors also expect positive revenue from the suggestion, the option becomes an official agreement. Otherwise, the agent suggests the next profitable strategy until the two agents reach an agreement or no more profitable options remain. Table 2 summarizes the available patent strategy as depending on the agent's state.

Table 2. Available action set by state

State/Action set	Licensing Out	Patent selling	Cross Licensing	Litigation
Zero-state (*Z*)	N	N	N	N
Manufacturing (*MN*)	Y	Y	Y	Y
Non-manufacturing (*NM*)	Y	Y	N	Y
Exit (*EXIT*)	N	N	N	N
Banned (*BAN*)	Y	Y	N	Y

Y: available, N: Not available

6) Patent collateral clearance process

The process checks all collateral contracts. A loan borrower pays loan principal and interest (*iLoan*) to the *BANK* on expiry of the loan. If the loan borrower was able to pay back the loan principal and interest, the *BANK* returns the collateralized patents to the loan borrower. Otherwise, the *BANK* becomes the patents' permanent owner and the contract is terminated.

7) Patent expiration process

In the model, a patentee has exclusive ownership of a patent for a certain period of time. If the patent's lifespan expires, any attendant patent rights also expired so all agents can freely practice the patent.

8) State transition process

Each existing agent's state is updated according to the established state-transition rule (Fig. 2).

9) Migration process

Each agent finds a new location for interaction with new neighborhoods. If a proper position is found, It migrates to the new place after completing interactions with current neighbors at the currently occupied position. Otherwise, the agent stays at the current position.

3.4 Design concept

1) Adaptation and prediction

To measure the profitability of an available patent strategy set, an agent estimates the expected changes in market share within the product market to calculate expected changes in sales revenue and accompanied costs or revenue following execution of the corresponding action. For example, when an agent considers licensing out technology, he or she first calculates the expected rent dissipation effect brought about by product market share loss incurred by the licensor's market penetration using the licensed technology. Then, it measures the expected royalty revenue to be paid by the licensor. This refers to a theoretical model suggested by Motohashi (2008) and Arora et al. (2001; 2003). The manufacturer can change its state of its own accord based on calculated net revenue. Once the manufacturer expects negative revenue, it changes its state to the *NM* state and liquidates its factory.

2) Sensing

All agents are able to access given system parameters as well as internal variables such as capital assets, patent-matrix, and so on, with the exception of other agents' internal variables other than information about patents that are being practiced. In order to engage in litigation, agents find prior-arts, which are defined as patents that have same identity with were developed earlier than the currently-infringed patents. Typical agents have limited access in searching for prior arts, but *COURT* has full access.

3) Interactions

Agents except *COURT* interact with neighbors from the most-profitable option among the available strategies. *COURT* interacts with lawsuit-involved agents.

4) Stochasticity

The model employs a number of internal stochastic processes. First, the system's initialization process randomly distributes Novelty-1 technologies over all technological elements to each agent. Second, *COURT* makes decision whether or not the non-prevailing agent is actually a patent infringer by considering prior arts information in an internal stochastic process. Third, the agent invests a certain amount of capital assets to develop new technology in an R&D process. Success or failure of the R&D is decided by an internal stochastic process. Fourth, NPEs select the royalty or patent price randomly within the viable value range. For example, the royalty is set to a value between the benchmark royalty (*Rs*) and the maximum royalty that makes the license-in the less costly option than being involved in a lawsuit with the non-prevailing party. Fifth, in the migration process, the agent randomly selects the next available locations on the grid. Finally, *ENT*s copy other agents' patents without a formal patent transaction (patent infringement) within an internal stochastic process.

3.5 Experimental set-up for the simulation

The simulation is repeated 50 times for every condition, and takes the mean value of each target outcome. We introduced random seeds at each of simulation condition to eliminate probable path-dependency by sequence of processes or initially given condition, which are not related to the simulation factors. The parameters are explained in Tables 3. As a fixed condition for the initial number of agents, 160 *ENTs*, 10 *UNIVs*, 10 *BANKs*, and 1 *COURT* are introduced. Initial capital assets of *ENT*s are given differently, as the distribution in Table 4 illustrates. This is intended to capture the typical difference in financial capabilities between large firms and SMEs in initiating their businesses. The simulation's time-span is set to 100 because this was considered sufficient time to have stabilized system-level outcomes, namely the number of survived agents.

Table 3. Experimental parameters

Parameter	**Value**	**Description**
M0	1E09	Product market size at a turn
Plife	20	Default patent life to expiry
G	100*100 (10,000 cells)	Grid for agent location
Rs	4% of sales revenue	Benchmark royalty for license contract
Lp	15	Benchmark license contract period
pLoan	5	Benchmark loan contract period
iLoan	5% of loan	Benchmark loan interest (at every turn, compounded)
Cr	100	Patent renewal cost per a patent
OP	2.5% of retaining capital asset	Operating cost ratio
Lc	1E06	Default litigation cost
RND	5E04	Public R&D fund for *UNIV*
Fi	1E06	Required investment for building up a Factory
Fm	1E05	Factory maintenance cost
Fsv	1E05	Factory salvage value
RnDInv	5E04	Required R&D Investment
TH	0.9 for ENT 0.8 for UNIV	Threshold value for determining technological novelty of newly develop patent
ω	75%	Weigh Weight of marketing experience on Market power
TC	[5,10,20,30,40,50]	Technological Complexity of Product
M_ENT	3.3E05~1E07	Initial capital asset of ENT
M_UNIV	1E07	Initial capital asset of UNIV
M_BANK	1E07	Initial capital asset of BANK
M_NPE	1E06	Initial capital asset of NPE
N_NPE	[0,10,20,30,40,50,60,70]	Number of introduced NPE agents
Pinjunc	50%	Injunction rate

Table 4. Distribution of initial capital asset of *ENT*

Initial capital asset	1.0E+07	5.0E+06	2.0E+06	1.0E+06	6.7E+05	5.0E+05	3.3E+05
# of *ENT*s	10	20	30	40	30	20	10

For every simulation condition, the following system-level outcomes are observed.

- System-level innovation performance
  - Quantity of innovations: Total number of patents including expired patents at t = 100
  - Quality of innovations: Average technological novelty of system-level up-to-date technologies over the entire technological group at t = 100
  - Innovation volume: Multiplication of indices for quantity and quality of innovations
- System-level litigation volume
  - Accumulated number of litigations during the simulation observed at t = 100

4 Simulation (1): Net effect of NPEs

4.1 Effect of NPEs on system-level innovation performance

The simulation results in Figs. 3-a and 3-b show that the number of *NPE*s has a negative correlation with system-level innovation performance. Introducing more *NPE*s gives sharply declining quantity and quality of innovations. The main reason of the result can be found in the declining number of surviving *ENT*s. Fig. 3-c shows that *NPE*s have a fatal impact on the survival of *ENTs* who can engage in further rounds of R&D.

We also found that system-level innovation performance declines more sharply as a product's technological complexity increases. Figs. 3-a and 3-b show that higher technological complexity imparted a larger negative impact from *NPE*s on the entire system-level innovation performance. This occurred because (1) the royalty stacking problem (Lemley & Shapiro, 2007) was exacerbated by *NPE*s as the technological complexity increased, (2) attack by NPEs is concentrated on a smaller number of manufacturers via increased product-market entry barriers in the higher-technological-complexity product market. This is supported by the results shown in Fig. 3-d.

In the case of technologically complex products that require a substantial number of technological components, patents that cover the necessary components are more likely to be infringed due to increased patent thickets, which can be defined as dense webs of overlapping patent rights (Shapiro, 2001). Therefore, manufacturers producing technologically complex products are more likely to be exposed to the risk of a patent infringement lawsuit. For this reason, the market for products having higher technological complexity is a profitable field for NPE businesses (Reitzig, Henkel, & Heath, 2007). As a result, manufacturers in the market for products of higher technological complexity would be more vulnerable to NPEs and ultimately pay more rent to NPEs in total. In addition, the higher technological complexity of products having a higher number of patentable technological components generates higher product market entry requirements (Hall, Helmers, Graevenitz, & Rosazza‐Bondibene, 2013; Graevenitz, Wagner, & Harhoff, 2013; Graeventiz, Wagner, & Harhoff, 2011). Therefore, this product market is dominated by a smaller number of manufacturers than market for technologically less-complex products.

In the latter's case, the threat from NPEs would more be concentrated on manufacturers, a situation that can make NPEs more fatal for technology-practicing firms. Indeed, the simulation result is consistent with the findings of the theoretical study by Lemley and Shapiro (2007), which states that NPEs exacerbate the royalty stacking problem by capitalizing on patent thickets.

[Figure 3]

4.2 Patent market activation effect and technology transfer by NPEs

To examine whether NPEs activate the patent market, we profiled patent transaction propensity, which is defined as the ratio of the number of transacted patents among the total number of patents created. It represents the liquidity of patents and provides an estimate for the patent market activation effect.

Fig. 4 shows that the patent transaction propensity, which is defined as the ratio of liquidated patents among all patents generated in the system, is positively correlated with the number of NPEs. When more NPEs are introduced into the system, the relative value of patent transaction propensity on normalized patent transactions in an NPE-less system has a higher value. This finding supports the argument that NPEs can contribute to activating the patent market. To determine whether or not NPEs promote technology transfer as well, the patent transaction is broken into two groups by type of patent seller who liquidated the patents to non-NPE agents: (1) sold by NPEs, (2) sold by non-NPEs. Fig. 4-b shows that technology transfers by non-NPEs declined as more NPEs are introduced. This finding indicates that NPEs exert a negative impact on technology transfer propensity opposite to the patent market activation effect.

The two analyses show that even though overall patent-liquidity has been enhanced by NPEs, technology transactions between inventors and pure technology demanders have been negatively affected. This reflects the fact that NPEs' business model is based on patent infringement by manufacturers who already have implemented technology patented by NPEs into their product or services. An NPE's patent transaction is, therefore, rarely related to technology transfer, but mainly contributes to the patent transaction for settlement of the patent infringement case. Furthermore, due to the NPE acquiring patents from inventors for a legal-dispute-based business rather than mediating patented technology between inventor and technology demander, NPE's patent acquisition also takes the form of pure technology transfer between inventor and technology demander. Another interesting point is that technology transfer propensity drops as a product's technological complexity increases. As the above simulation result shows, the *ENT* survival rate displays a greater significantly decrease in the higher technological complexity product market. Thus, the size of pool of potential inventors and technology buyers also has been decreased by NPEs. This results in a significantly decreased volume of patent transactions between non-

NPEs. Accordingly, NPEs have aggravated the propensity for technology transfer in the higher technological complexity product market.

[Figure 4]

4.3 NPEs' innovation promotion effect

In the simulation, financially constraint agents, defined as agents who started business with initial capital less than 1E06, have either not been affected at all or have been negatively affected by NPEs in their innovation performance. We measured the mean value of the number of created innovations by each financially constraint agent before patent transactions with NPEs (*Nb*) and after patent transactions (*Na*). Subsequently, $Nb - Na$ is calculated. Therefore, a positive value means that the patent seller produced fewer innovations after than before patent transactions with NPEs. Fig. 5 shows that $Nb - Na$ has a positive value in all simulations, which supports the conclusion that NPE's innovation promotion effect is not in fact supported.

[Figure 5]

This finding contradicts the argument that NPE's patent acquisition activity can help financially constraint inventors engage in further rounds of innovation by rewarding their patented innovations and financially encouraging them to invest the reward into further R&D.

Due to the fact that the NPE business does not generate revenue through technology mediation but rather through excessive returns generated by acquiring patents at cheap prices and selling them at expensive prices, NPEs' patent acquisitions and resultant rewards are unlikely to be financially sufficient for enabling inventors who sold their patents to engage in any further R&D processes. Accordingly, patent acquisition by NPEs of financially constrained inventors' patents is not financially sufficient to bring about further innovations.

5 Policy Analysis - Analysis of the legislative options for relieving the NPE effect

We also test which of the legislative options would be effective in ameliorating the NPE effect by introducing a sub-model featuring each option. System-level innovation performance and system-level litigation volume according to the simulation conditions are monitored. In particular, if a remedy brings more system-level litigation volume, it should be considered as an unfavorable effect due to the fact that more litigation incurs higher social costs such as costs for litigation process, administrative costs, and so on. The virtualized legislative options are provided in the following table.

Table 5. Links between Legislative options and virtualized remedies

Legislative Option	Modeled remedy	Rationale
Changing royalty calculation rule	Discounting the amount of damage awardable to NPE	NPE leverage bargaining power by overcompensated damage using the royalty calculation rule
Reducing injunction rate in NPE lawsuit	Reducing Injunction rate in NPE lawsuit systematically	The leverage NPEs can exert by threatening an injunction from a federal court
Shifting more of the burdens and costs of litigation onto NPEs	Exemption cost in litigation-procedure of defendant agent in an NPE lawsuit	NPEs leverage their bargaining leverage over defendant's product companies.

We conducted further statistical analysis on the simulated data. Dependent variables are the indices representing system-level innovation performance and system-level litigation volume. Independent variables are: (1) product technological complexity (*tc*), (2) number of NPEs introduced into the system (*n_npe*), (3) discount rate on the calculated original amount of damages awarded to NPEs (*d_award*), (4) injunction rate in NPE lawsuits (*inc_prob*), (5) litigation cost exemption for defendants in NPE-launched lawsuits, which has 0 when "no exemption applied" and 1 otherwise (*exempt*). If the defendant agent is recognized as a patent infringer, *COURT* can issue an injunction. Otherwise, the lawsuit is cleared by a compulsory license contract on the standard royalty rate. We applied the TOBIT model to test innovation volume (*inv_vol*) and average technological novelty over the entire technology group (*inv_lvl*), as they have continuous positive values. The Poisson model is applied for remaining dependent variable that has an integer value. Fig. 6 summarizes the sub-models used for policy analysis.

[Figure 6]

Table 6. Stylized simulation parameter for policy analysis

Simulation factors	Value	Description
inc_prob	50%: default value 10% 5%	Injunction rate in NPE lawsuit
d_award	100%: Default rate 10% 5% 1%	Discount rate on damage calculated by *COURT*. Represents ratio of awardable amount of damage to NPE on calculated default damage
exempt	0: No exemption (Default) 1: Exempt	Litigation cost exemption for defendant in NPE litigation

Table 7−a. Regression on system-level innovation performance and litigation volume

	Innovation Performance				Indices for litigation volume			
	ent_surv	*inv_vol*	*inv_num*	*inv_lvl*	*tot_lit*	*univ_lit*	*ent_lit*	*npe_lit*
tc	−0.00249***	−654.0***	0.00686***	−0.539***	0.0105***	0.0254***	0.00669***	0.0291***
	(−114.50)	(−291.97)	−1001.68	(−343.57)	(−823.4)	(−509.21)	(−471.29)	(−748.95)
n_npe	−0.00114***	−15.17***	−0.000443***	−0.00789***	−0.0124***	−0.0398***	−0.0158***	0.0246***
	(−76.00)	(−9.74)	(−92.61)	(−7.24)	(−1355.01)	(−940.67)	(−1535.18)	(−859.53)
inc_prob	−0.325***	−2836.0***	−0.161***	−0.810***	−1.219***	−0.170***	−0.907***	−8.034***
	(−185.09)	(−16.01)	(−291.86)	(−6.53)	(−1073.86)	(−43.76)	(−744.64)	(−794.31)
d_award	−0.00765***	−36.55	−0.00175***	−0.0179	0.410***	−0.0129***	−−0.0573***	8.220***
	(−9.10)	(−0.42)	(−6.59)	(−0.30)	(−892.41)	(−6.84)	(−102.27)	(−466.51)
exempt	0.00166*	19.12	0.000742***	0.00537	0.0376***	0.00657***	0.00832***	0.259***
	(−2.4)	(−0.27)	(−3.39)	(−0.11)	(−91.86)	(−4.25)	(−18.32)	(−215.7)
_cons	5.157***	36295.3***	7.145***	27.67***	6.217***	3.675***	6.322***	−3.986***
	(−5175.35)	(−346.61)	(−21883.93)	(−377.55)	(−10453.56)	(−1603.1)	(−9902.18)	(−224.72)
sigma								
_cons		8559.3***		5.991***				
		−339.41		−339.41				
N	57600	57600	57600	57600	57600	57600	57600	57600

ent_surv: # of survived ENTs, inv_num: quantity of innovation, inv_lvl: average tech level of the latest techs over all tech group, inv_vol = inv_num × inv_lvl
tot_lit: Total number of litigation case, univ_lit: # of litigation launched by *UNIV*, ent_lit: # of litigation launched by *ENT*, npe_lit: # of litigation by NPE

Table 7-b. Regression on litigation propensity of NPE (*npe_litp*) and *ENT* (*ent_litp*), and The number of manufacturers (*manu*)

	npe_litp	*ent_litp*	*manu*
tc	0.00126***	0.00426***	−0.0190***
	(−38.07)	(−269.05)	(−543.76)
n_npe	0.00154***	−0.00272***	−0.00240***
	(−61.6)	(−246.82)	(−104.36)
inc_prob	−0.218***	−0.0284***	−0.809***
	(−77.67)	(−22.67)	(−289.34)
d_award	0.278***	0.00189**	−0.0180***
	(−183.78)	(−3.08)	(−13.99)
exempt	0.0164***	0.000612	0.00335**
	(−15.56)	(−1.21)	(−3.18)
_cons	−0.232***	0.128***	−0.0190***
	(−102.37)	(−173.23)	(−543.76)
sigma	0.0753***	0.0605***	−0.00240***
_cons	(−162.07)	(−339.41)	(−104.36)
N	57600	57600	57600
	** p < 0.01	*** p < 0.001	* p < 0.05

5.1 Discounting amount of awardable damage to NPE

The *d_award* in Table 6 represents the ratio of the amount of damages that can be awarded to NPEs based on the calculated fair value of damages (by the reasonable royalty method). Therefore, a lower value for *d_award* means a relatively smaller amount of damage would be given to the NPE (stronger limitations). Accordingly, a positive coefficient for each independent variable should be interpreted to mean a more parsimonious damage award for NPE yields lower system-level outcomes. In Table 7-a, the coefficient between *d_award* and *inv_num* is negative with high significance but no relationship with *inv_vol* and *inv_lvl*. Furthermore, *d_award* is negatively correlated with *ENT* survival rate (*ent_surv*). This implies that the remedy may reduce the fatal effect of NPEs upon the survival rate of inventors, but it is not sufficient to reclaim the entire system-level performance in terms of innovations. The effect on system-level litigation volume displays an interesting result. A positive coefficient between *d_award* and *tot_lit* shows that a lower amount of damages awardable to NPEs generates a smaller volume of litigation at system-level, which means it is effective in suppressing litigation.

Damages are calculated by summation of the stream of a reasonable expected royalty to be paid by the infringer during any patent infringement period. Therefore, it becomes a certain ratio corresponding to the *ex-post* royalty rate on the total sales volume that the infringer earned during the infringement period from the infringing product or service. Given that the royalty rate is generally around 4% across industry (Razgaitis, 2009; Goldscheider, Jaroz, & Mulhern, 2002), which is also the benchmark royalty rate in the present model, damages would not be a significant financial risk to the manufacturer. For this reason, the remedy was not sufficient to strike a balance in negotiation power between NPE and manufacturer; therefore, it was not effective in overcoming the negative effect of NPEs on system-level innovation performance. However, the fatal effect that induces other *ENT*s to exit could be reduced to some extent because the first remedy systematically reduces total amount that infringers must pay to *NPE*s. Reducing the amount of damages payable to *NPE*s decreases NPEs profitability from litigation because they recognize such damages as probable revenue that can be awarded following a successful lawsuit. According to this logic, the first remedy reduced the amount of revenue that NPEs can expect by pursuing the litigation option. Accordingly, NPEs become less likely to select litigation as profitable strategy, which in turn reduces litigation volume. The positive coefficient between *d_award* and *npe_litp* shown in Table 7-b, which means a lower amount of damages for NPEs brings about a reduced litigation propensity by NPEs, supports this.

5.2 Reducing the injunction rate in NPE lawsuit

The second remedy involves reducing the injunction rate in NPE lawsuits. According to the result shown in Table 7-a, *inc_prob* is negatively correlated with *ent_surv*. This means that a lower injunction rate in NPE lawsuits results in a higher survival rate for *ENT*s. This implies that the remedy was effective in ameliorating the fatal effect of NPEs upon *ENT*s. In addition, all system-level innovation performance indices have negative coefficients with *inc_prob.* This shows that the remedy was significantly effective in recovering system-level innovation performance. This result reveals that injunctions are the most significant source of imbalanced bargaining power between NPEs and manufacturers. This is consistent with the findings of studies by Lemley and Shapiro (2007) and Reitzig et al. (2010), which mention that injunctions are significant sources for NPEs to raise settlement fees from practicing firms.

Once an authority issues an injunction, the defendant must stop all business activity related to the infringing product or service. Costs the defendant must pay following an injunction are, therefore, not only the money already invested in the product or service implementation but also future sales revenue from the infringing product or service. When the expected costs incurred following an injunction are considered, such an act has the potential inflict the most damage upon the infringer. If an authority reduces the injunction rate in NPE lawsuits, the most significant risk facing the defendant is therefore systematically controlled. This reduces the negative effect of NPEs on system-level innovation performance.

Interestingly, this remedy also had an unfavorable effect: an increased system-level litigation volume, especially by NPEs. The negative coefficient with high significance between *inc_prob* and *tot_lit* in Table 7-a shows that the remedy brought about an increased system-level litigation volume. The reason can be linked to NPEs' strategy selection mechanism in dealing with patent infringers. In general, an NPE has two options: settlement or litigation. Injunctions play a significant role in enhancing NPEs' bargaining power for settlements but are not a direct revenue source. Thus, systematically reducing the injunction rate decreases NPEs profitability from the settlement option. This makes them less likely to select settlement as a profitable option compared to litigation. Accordingly, the overall litigation volume and litigation action by NPEs increased. This finding is supported by the findings shown in Table 7-b, which also shows that NPEs' litigation propensity *(npe_litp*) increases following the reduced injunction rate in NPE lawsuits.

This remedy should not be considered as a weak-patent right protection policy because the remedy in the simulation targets only NPE lawsuits. The injunction rate in non-NPE lawsuit cases is not affected by the remedy given in the model. Thus, the results should not contradict previous research showing that a stronger patent rights protection policy brings increased litigation and a higher injunction rate (Lanjouw & Lerner, 2001; Gallini, 2002). Furthermore, the simulation result is not in conflict with previous studies conducted from an economic perspective. In general, a pro-patent policy enhances the profitability of litigation as a strategy by increasing the probability of the plaintiff winning the lawsuit. Thus, patent owners are likely to select litigation when a weaker patent protection policy is applied. This explains why the pro-patent policy brought about increased litigation. According to the same logic, the lower injunction rate in NPE lawsuits makes NPEs believe that authority is less likely to issue injunctions against the patent infringer. This limits the settlement fee that the NPE can require from the patent infringer. As a result, NPEs face decreased profitability from the settlement option, which increases their motivation to select the litigation option because the profitability of the litigation option only depends upon the expected direct reward such as the damage payment by the patent infringer as a result of the lawsuit. The difference in strategy selection mechanism stem from differences in the patent's value to the NPE and non-NPE agents. In a patent infringement lawsuit, non-NPEs have chance to eliminate competitors from the product market or can earn a license contract as a result of the trial. For both economic and strategic advantage, they are more likely to engage in patent infringement lawsuits under a pro-patent policy. However, the NPE does not benefit from such a competitor elimination effect. Instead, they consider direct revenue stemming from legal disputes and settlements. Thus, value of patent rights to NPEs comes from their economic rather than strategic value. Therefore, a lower injunction rate may push NPEs to select litigation over settlement.

5.3 Exempting defendants from litigation costs in NPE lawsuits

The marginal positive coefficient between *ent_surv* and *exempt* in Table 7-a shows that exempting defendants from litigation costs in NPE lawsuits brought a slightly increased survival rate for *ENTs*. No significant relationship with *inv_vol* and *inv_lvl*, and a positive coefficient with *inv_num* shows that the remedy is marginally effective in recovering system-level innovation performance. Overall litigation volume (*tot_lit*) is positively correlated with *exempt*. This means that the remedy brings greater litigation overall. This is mainly driven by NPEs increased litigation propensity, a finding further supported by the positive correlation between *exempt* and *npe_litp* in Table 7-b. This is due to the fact that litigation costs contribute to NPEs' superior bargaining power against practicing firms, but is not a direct reward. Therefore, eliminating the financial burden by exempting defendants from litigation costs reduced the bargaining power of NPEs, which makes the settlement option less profitable and induces NPEs to select litigation as more profitable option.

When it comes to litigating against a manufacturer, the case should be based on the suspicion that the defendant has earned sales revenue by selling infringing products. If the accumulated sales revenue during the patent infringement period is sufficiently large, paying litigation costs to engage in a lawsuit would not be a significant financial burden to the defendant. Therefore, exempting litigation costs for the manufacturer may not be significantly effective in terms of balancing their negotiation power against NPEs. On the other hand, paying litigation costs would be a big financial risk to financially-constrained manufacturers. To these actors, exempting litigation costs could help them to avoid a fatal situation that brings about the closure of their business. However, such firms are also already likely to be in a too financially constrained situation to undertaker further R&D. Therefore, this remedy would not be effective to enable them to recover their innovation performance. In both cases, exempting litigation costs for defendants might not be helpful to enable recovered innovation performance. Based on this discussion, we pose several in policy suggestions to control the NPE effect.

First, enacting both the first and second remedy simultaneously would be a better solution to control the NPE effect. The second remedy was effective in recovering innovation performance but brought about a higher litigation volume at the same time. On the other hand, the first option was effective in reducing the litigation volume but only marginally effective in innovation performance recovery. We believe the complementarity of the two will provide a route to designing better remedies to deal with the NPE issue.

Second, policymakers need to be act with caution regarding the effect of the third remedy. The "exempting litigation costs of defendant in NPE lawsuits" is already being discussed in U.S. Congress through the "SHEILD act", and is ready to be placed on the "Anti-patent troll bill". These acts say that the authorities can award full litigation costs to the defendant in NPE litigation if the prevailing party cannot prove that the non-prevailing party has been infringing disputed patents. However, the simulation result indicates that this remedy would not as powerful as expected, as it can bring about an undesired effect—increased NPE litigation volume by promoting abusive lawsuits. When considering the remedy under discussion is obviously less powerful than the virtualized remedy in the model—given that the model allowed an unconditional litigation fee exemption for defendants in NPE lawsuits—the effectiveness of the remedy may be in question. Therefore, policymakers have to investigate the unfavorable effect more thoughtfully by considering such possible dynamics before introducing it as policy.

6 Conclusions

In the present study, we developed an ABM of the patent system/market aimed at determining the effect of NPEs on innovation society. We also explored the expected effectiveness of the three suggested policies for relieving the NPE effect by building-up sub-models that correspond to each option.

The simulation result showed a computationally realized scenario in which the suggested potential benefits of NPEs are negligible. First, NPEs offer a patent market activation effect by their aggressive patent rights acquisition, but this rarely related to technology transfer. Therefore, we cast doubt on the argument that NPEs' patent acquisition can encourage technology transfers or activate the technology market. Second, we could not find evidence for NPEs innovation promotion effect on financially constrained players in R&D. Because NPEs try to maximize profits by purchasing patents cheaply from inventors and selling them at overpriced values to practicing firms using their imbalanced bargaining power, the reward from NPEs to the patent seller for patent-right acquisition is unlikely to be sufficient to encourage the patent seller to engage in further R&D. This is consistent with the findings of the empirical study by Tucker (2012).

We also found out that NPEs can have a negative net impact on society-level innovation performance. Along with this result, we tested the effectiveness of the three legislative options that have been discussed in U.S. Congress to relieve the negative effects of NPEs. Because NPEs' business model is perfectly legitimate within the current patent system and is based on a patent strategy that also can be utilized by non-NPEs such as universities, public research institutes, or even practicing firms for their own sake, the remedies should make sure to find a balance in the bargaining power of NPEs and practicing firms.

The simulation result implied that injunctions are the most feared aspect of patent infringement lawsuits by practicing firms, and therefore, it enhances the bargaining power of NPEs significantly. Damages payments to the NPE were not as risky as injunctions. Practicing firms also risk being burdened by litigation costs, but these are not as big a risk as an injunction. Therefore, the present study suggests that controlling the injunction rate in NPE lawsuits would be the most effective primary remedy to find a balance in negotiation power between NPEs and practicing firms and, therefore, to relief the negative impact of NPEs on society-level innovation performance. However, the result also showed a possibility of overall increased litigation volume, which is an undesired effect. This is mainly caused by increased litigation propensity on the part of NPEs. The remedy systematically reduced the risk facing defendants from injunctions. At the same time, the NPEs bargaining power is significantly decreased, which made the settlement option less profitable without changing the profitability of the litigation option. It eventually enables NPEs to select litigation as a primarily profitable option compared to settlement when compared to the scenario in which no such policy was introduced. Discounting the amount of damages that would be awarded to NPEs was not effective in recovering innovation performance, but did have the effect of reducing overall litigation volume. It reduced the profitability of the litigation option against infringers since the damages serve as a directive revenue source that can be expected when an NPE is involved in a lawsuit. These two simulation results provide the possibility that a policy maker can have a more effective remedy by mixing the two due to their mutual complementary effect.

Exempting defendant litigation costs did not change system-level innovation performance, but rather increased overall litigation volume. This suggests that the third option should be more carefully studied, especially potential undesirable effects such as those observed on in the simulation, before it is actually introduced into the patent system.

7 Further Developments

In the present study, we examined NPE dynamics using a computational approach. The model helped us to overcome previous limitations in conventional research approaches for studying the NPE effect. We also were able to draw several implications for policymakers to enable better policies to be designed in controlling the NPE effect. Beside such results, we also have several points that can be refined in future research.

First, as described by the concept of patent portfolio matrix in the model, a product is defined as combination of determined technological elements, which is closely related to the concept of architectural innovation as well as incremental innovation (Henderson & Clark, 1990), but the concept of disruptive innovation is not clearly captured by this model because the innovation type is not necessarily categorized and differentiated for the purpose of the present research. However, we believe that categorizing type of innovation and then modeling them would make the model more useful for covering an increased range of general research issues in patent policy or patent system dynamics.

Second, inventors used to collaborate in new technology development through joint ventures, joint R&D investment, and so on in the real world. The resulting R&D outcomes can be patented and shared by the collaboration participants. NPEs also can engage in R&D collaboration with technology-intensive firms by providing a budget for R&D activities for the purpose of acquiring the resultant patents, which can then be utilized for future business. For the sake of model simplicity, the present model does not capture the collaboration mechanism. Considering such R&D collaborations by NPEs would be another interesting topic for further research.

Third, the virtual patents in the model do not have some microscopic features of real patents, such as “scope of claim”, “citation” and “multiple-ownership on the patent”. This is because the present research focused only on finding emerging macroscopic dynamics by NPEs by employing only exclusive rights on patents in the patent system. For the reason, we did not include such microscopic features or statistics of patents into the present model. However, we believe that if a revised model covers such details, a further expanded computational study covering not only patent system dynamics but also the patent strategy of individual firms would be available.

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Figure 1. Concept of patent matrix and matrix operation for each patent strategy

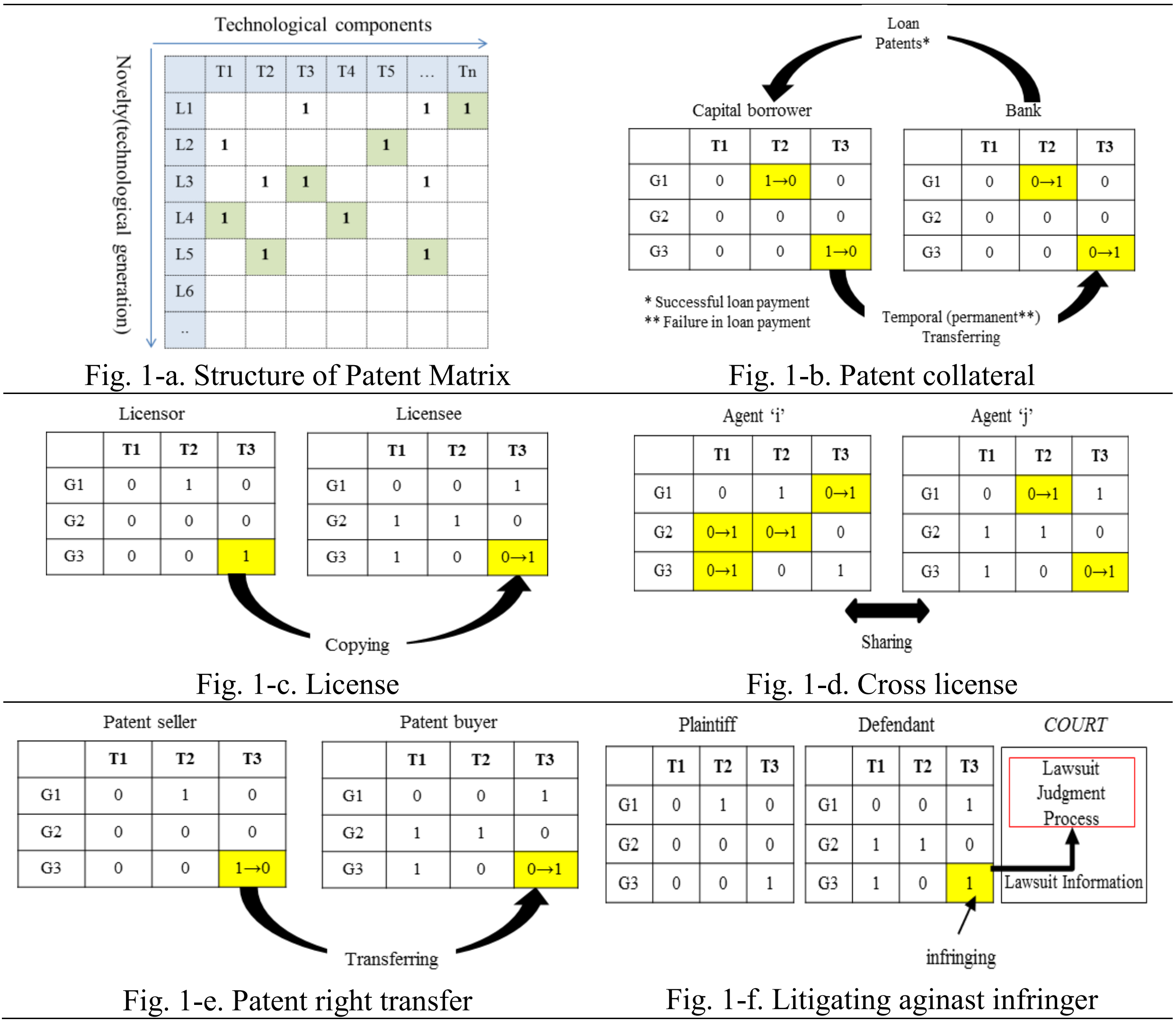


Fig. 1-a. Structure of Patent Matrix

Fig. 1-b. Patent collateral

Fig. 1-c. License

Fig. 1-d. Cross license

Fig. 1-e. Patent right transfer

Fig. 1-f. Litigating aginast infringer

Figure 2. State-transition rule diagram

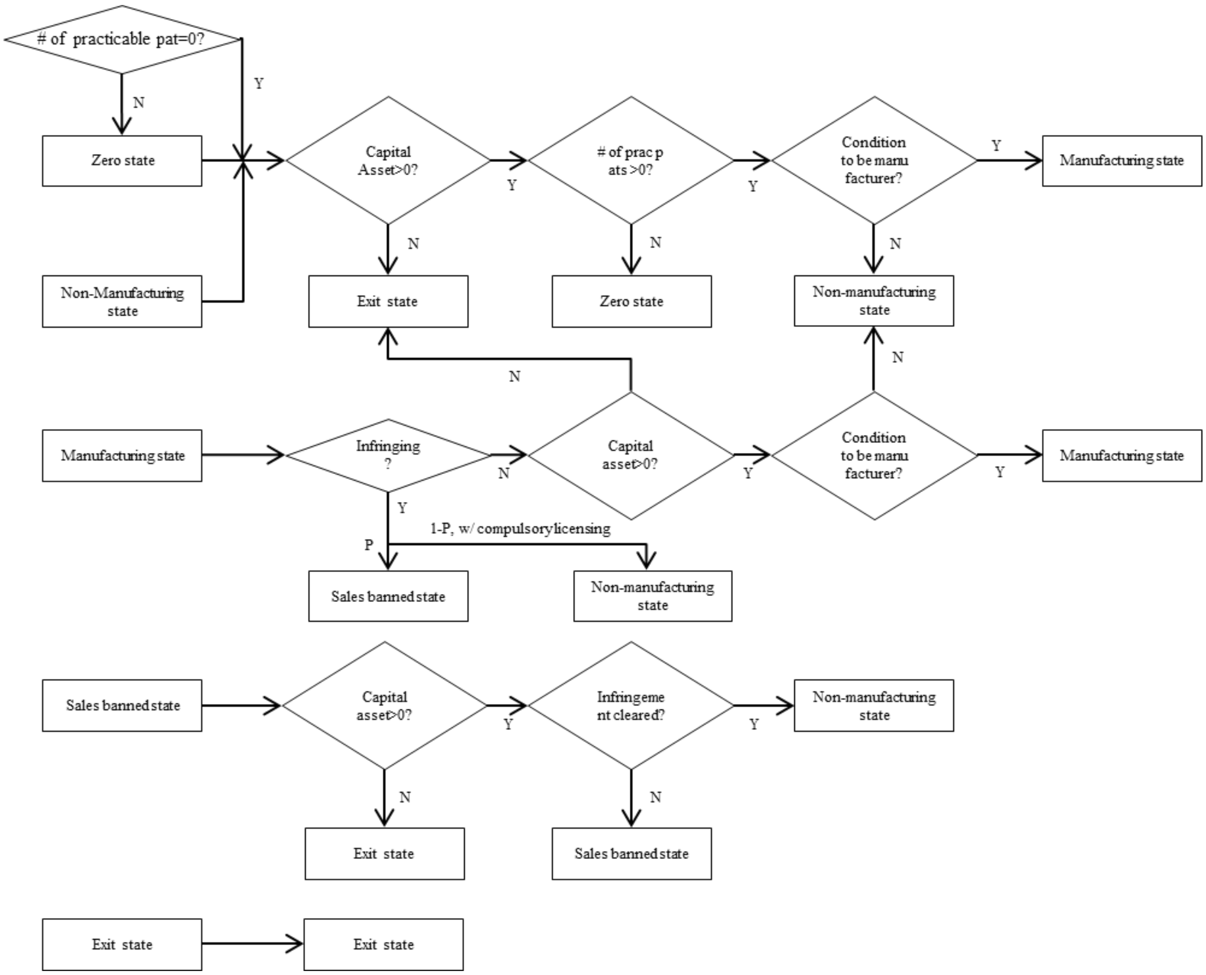
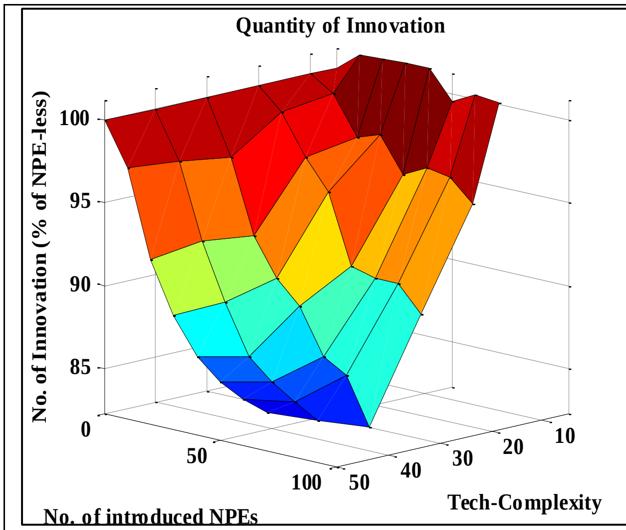
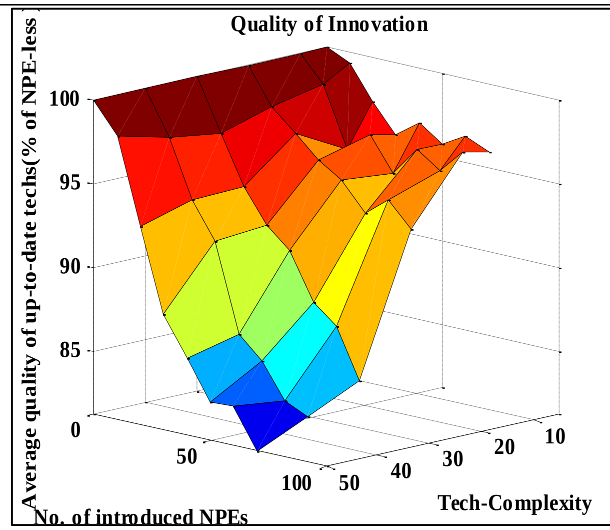


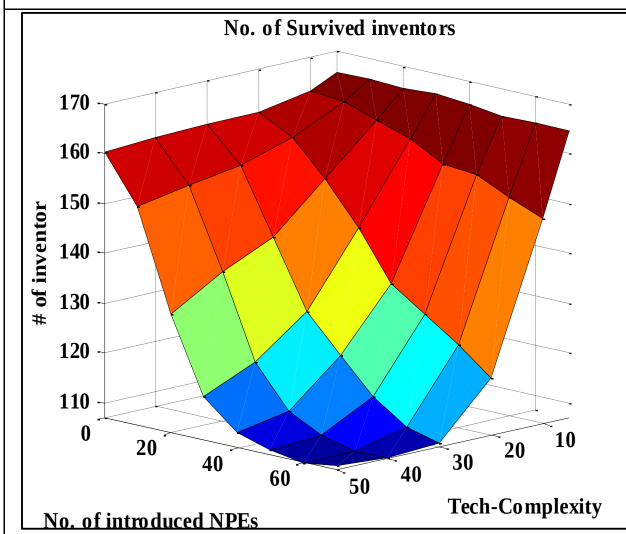
Figure 3. Simulation result (1): System level innovation performance



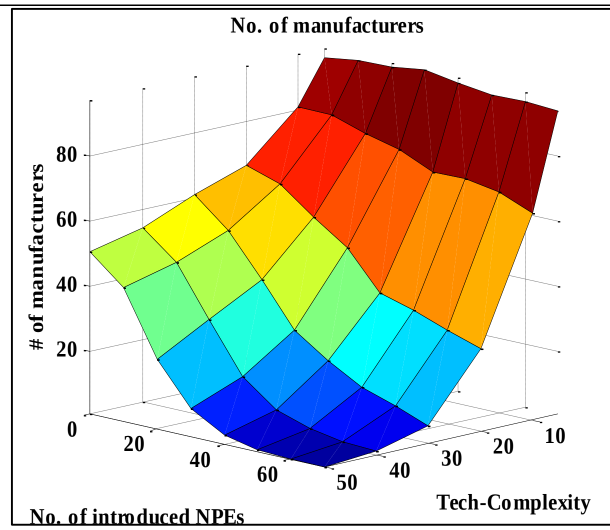
(a) Total number of created innovations*



(b) Average quality of up-to-date technologies*



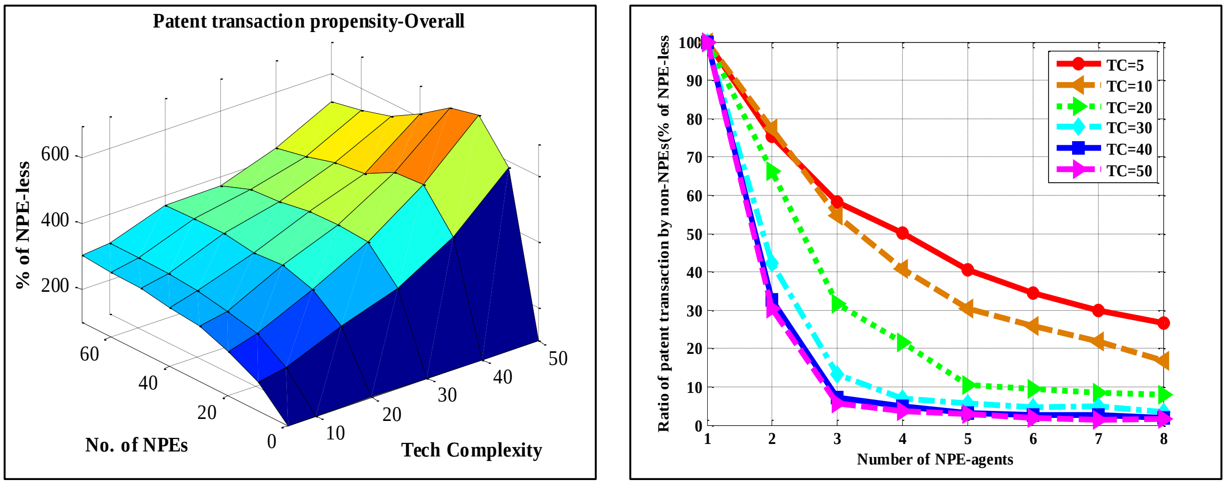
(c) Number of survived *ENTs***



(d) Number of Manufacturers**

*: NPE-less system is normalized to 100%, **: Absolute value

Figure 4. Simulation result: Patent market activation effect and technology transfers



(a) Patent transaction propensity by NPE agents and technological complexity

(b) Ratio of patent transaction by non-NPEs (Technology transfer)

Figure 5. Mean value of difference between *Nb* and *Na*

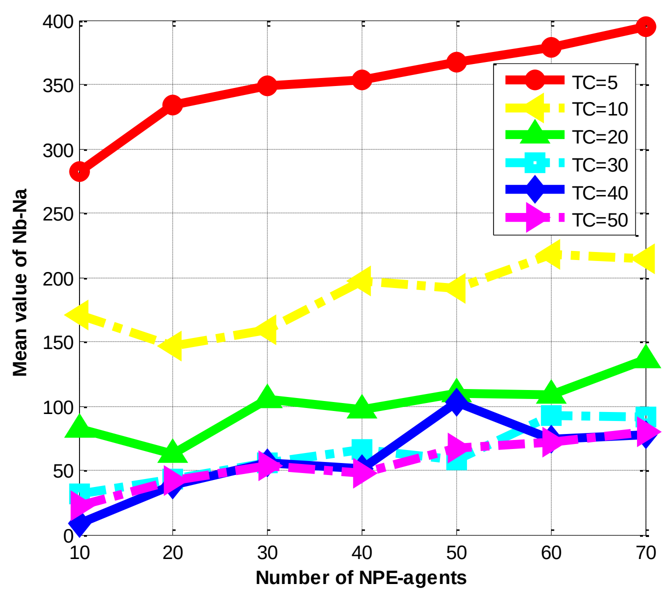
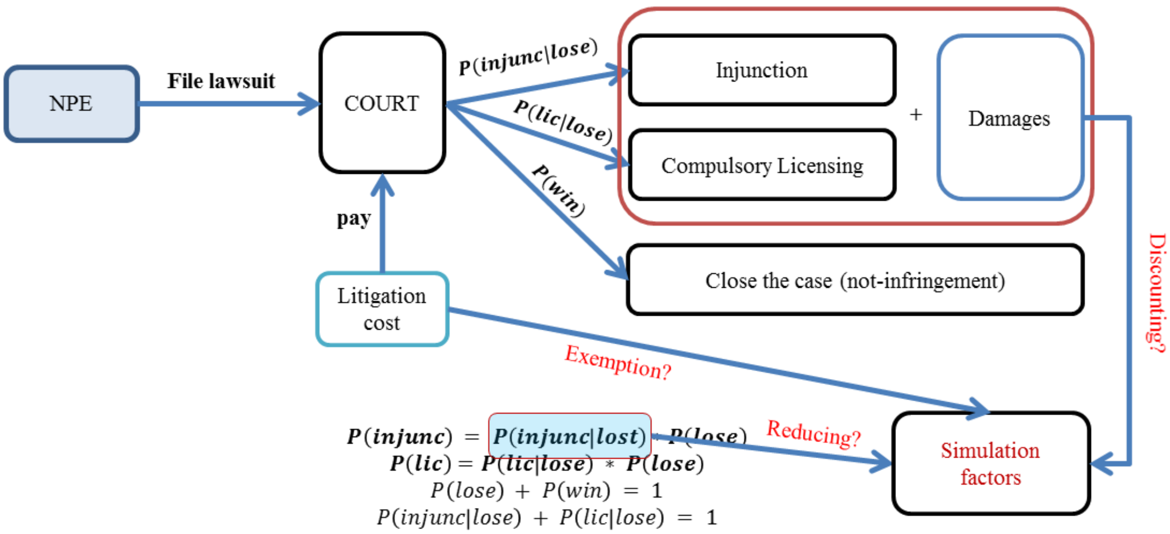


Figure 6. Sub-models for the three remedies



inc_prob = P(injunct|lose) = probability that the *COURT* issues injunction against the defendant agent

P(lic|lose) = 1−P(injunct|lose), P(win),P(lose) = probability that the defendant wins/loses from the lawsuit

Appendices A: Sub-model description

1) Market Power, Market Share, and Sales Revenue

The model introduces an index named Market Power (*MP*), which captures the relative technological competency (*TECH*) and marketing experience (*MKT*) of an agent to measure said agent's aggregated competitiveness in the product market.

$$MP = \{\omega MKT + (1-\omega)TECH\}f_{F,T}$$

$$MKT = \frac{mkt_{i,t0}}{\max\limits_{\forall j}\{mkt_{j,t0}\}}, TECH = \frac{1}{N0}\sum_{k=1}^{N0}\frac{TECH_{k,i,t0}}{\max\limits_{\forall j}\{TECH_{k,j,t0}\}}$$

ω: Weight of marketing experience on Market power, $mkt_{i,t0}$: accumulated market experience of agent i at t = t0
N0: # of necessary technological components for production implementation
$mkt_{i,t0}$: Accumulated marketing experience of agent "i" at t = t0
$TECH_{k,i,t0}$: Technological generation of the lasted technology in group k practicable by agent i at t = t0

A probability function $f_{F,T}$ that captures the possibility the agent actually can get into *MN* is introduced to consider the expected value of *MP* as well. The probability is described by the probability that a certain amount of capital assets can be invested into building a factory (f_F) and whether or not the agent can practice all the required technology for product implementation (f_T). Each term is squared for conservative consideration. In addition, f_F and f_T are assumed to be mutually exclusive.

$$f_{F,T} = f_F \cdot f_T$$

$$f_F = \begin{cases} 1, & \text{agent(i).factory} = 1 \\ \min(1, (\frac{agnet(i).asset}{F0})^2), & otherwise \end{cases}, \qquad f_T = \{\frac{1}{N0}\sum_{k=1}^{N0}\delta_k\}^2$$

δ_k: 1 if the agent can practice technology in group k, 0 otherwise

The agent's (expected) market share (*MS*) is calculated by the relative value of *MP* of the agent to all the existing manufacturers. Agent's (expected) sales revenue is calculated by multiplying *MS* and M0.

$$MS_{\mathrm{i}} = \frac{MP_i}{\sum_{k=1}^{j} MP_k}$$

k: index of manufacturer, j: number of manufacturers, i: focal agent

2) Revenue Calculation

Each agent calculates its net revenue by taking account of all the possible revenue and costs. Manufacturers earn sales revenue (*Sales*) and *UNIV* receives an R&D budget (*RND*) at every turn. Agents that have a factory pay *Fm*. All agents must pay *OP*, which takes a certain percentage of retaining capital assets ($\mathrm{M_{i,t-1}}$). Finally, patent-owning agents pay a patent renewal fee proportional to the value of owned patents. The total fee for patent renewal is calculated by multiplication of *Cr* and the number of patents the agent owns (N_p).

$$\mathrm{M_{i,t}} = \mathrm{M_{i,t-1}} + \mathrm{Sales_{i,t}} + RND - F_m - \mathrm{OP} \times \mathrm{M_{i,t-1}} - \mathrm{C_r N_p}$$

RND > 0 if and only if agent is an *UNIV*

$\mathrm{M_{i,t}}$: capital asset of agent 'i' at t, $\mathrm{Sales_{i,t}}$: Sales revenue at t, RND: supplied RnD budget by system
OP: operating cost ratio on retaining asset, $\mathrm{C_r}$: patent renewal fee per a patent, $\mathrm{N_p}$: number of owning patents

3) Damage revenue calculation

The patent system generally requires the patent infringer to pay damages. The model adopts "reasonable royalty method using benchmark royalty," which is a widely used method for damage calculation in the real-world (Fisher & Henkel, 2012; Epstein, 2012; Goldscheider, Jaroz, & Mulhern, 2002). The infringer is assumed to have licensed the technology and have paid *Rs* to the patentee during the infringement period.

$$D0(j) = \sum_{t=\max\{1, t0-L0\}}^{t0} Sales_{j,t} \times R_s$$

D0: Amount of damage, *t*0: The litigation filed time, *L*0: Infringement period, *j*: infringer index

4) Expected royalty revenue (cost) to licensor and licensee

Two agents in a license-contract available situation calculate the expected royalty revenue or cost for the suggested license contract period. The license contract in the model has a fundamental rule that if the licensee cannot pay the royalty during the license contract period, the contract is terminated. The termination probability (p) becomes f_T with 80% as its maximum in order to consider the case that the licensee uses alternative technology even though it can practice all necessary technology including the licensed technology. This is because the technological assets of the licensee are publicly accessible in the patent system, and it is also an important indicator of whether or not the potential licensee can actually be a manufacturer. With these conditions, the royalty cost/revenue generation is modeled into Fig. AP1.

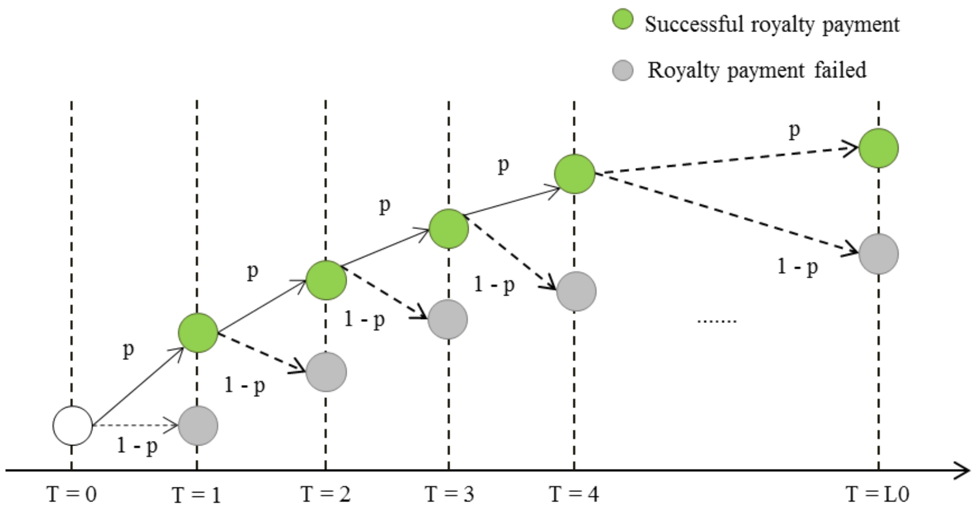


Figure AP1. Model of royalty revenue/cost generation

If potential licensor is a non-NPE agent, the royalty rate takes R_s. However, NPEs can set higher a royalty rate by capitalizing on their stronger negotiation power (Henkel & Reitzig, 2008; Golden, 2007; Henkel & Reitzig, 2008; Lu, 2012). The expected sales revenue of the licensee and successful-royalty payment probability is fixed to the expected value at one period after the license contract launched. The expected sales revenue of license at t = t0 + 1 is simply calculated by expected *MP* and *MS* of the licensee if the target technology is licensed. The license period (Lp) takes a smaller value between benchmark license period (*LPs*) and patent life remaining to expiry. With all mechanisms, each party's expected total royalty cost and revenue at the negotiation moment can be calculated by the following formula:

$$E(RY) = \sum_{t=t0+1}^{t0+Lp+1} E(Sales_{j,t0+1}) \times r \times p^{t-t0}, \text{ p=Min } (0.8, f_T)$$

E(RY): Expected royalty revenue/cost, $E(Sales_{j,t0+1})$: expected sales revenue of licensee at t = t0 + 1

r: suggested royalty rate by licensor, p: probability of the licensee pay royalty successfully at t = t0 + 1

Through the license contract, the licensee can expect increased *MP*, and therefore, expect sales revenue, along with the expected royalty cost. On the other hand, the licensor should consider the expected sales revenue loss by the market penetration of the licensee using the licensed technology. With all these dynamics, each party calculates expected net revenues from the licensed contract.

5) Expected profit from a cross-license

A cross-license becomes an available settlement option in a patent infringement lawsuit (Alberto, 2007; Shapiro, 2001) if and only if both involved agents are manufacturers. Once the two settle on a cross-license, they share up-to-date technologies for every technological element among their owned patents with zero royalties. Due to the updated patent portfolio, they can expect changes in *MP*, *MS*, and sales revenue without any direct revenue or cost generation by the royalty. The cross license contract period is defined as the average value of the license contract period of each individual cross-licensable patent.

6) Expected profit from patent rights transfer

The expected profit by patent rights transfer is calculated with the following components: (1) patent price, (2) patent renewal cost, and (3) change in expected sales revenue from the transaction. The modified license contract model described in Fig. 4 is used for patent pricing. In the valuation, the royalty is set to *Rs* and the remaining turn to the target patent's expiry becomes the license contract period. The probability that the licensee successfully pays a royalty to the licensor is set to 50%. This is because the patent buyer's lump-sum payment for the transaction makes the patent seller neutral in the probability evaluation. The model considers three patent price candidates. The patent price calculated by *Rs* for the two negotiating agents (P1), for an averaged-agent in the system (P2), and total patent renewal cost to expiry (P3). P2 is introduced in order to take account of the patent seller's opportunity cost, which means alternative revenue by selling patent rights to another potential patent buyer. The model defines the alternative patent buyer as an 'averaged agent' who has marketing experience and technological competency averaged over all existing agents. The total expected patent right-renewal cost becomes the bottom-line of price of the patent. The patent seller takes the maximal value among P1, P2, and P3 as price of patent for revenue maximization.

$$\mathrm{P}_1 = \sum_{k=1}^{L0} 0.5^k \left(Sales_{j,t0+1}\right) \times R_s\,, \mathrm{P}_2 = \sum_{k=1}^{L0} 0.5^k \left(Sales_{avg,t0+1}\right) \times R_s\,, \mathrm{P}_3 = L0 \times C_r$$

$$\mathrm{P} = \mathrm{Max}\ \{\mathrm{P1}, \mathrm{P2}, \mathrm{P3}\}$$

j: index of negotiating agent (patent buyer), *avg*: average agent,

*L*0: left turn to the patent expiry, C_r: annual patent renewal cost

If a patent seller is an NPE, it has the option of litigation against neighboring agent. NPEs can increase the value of a patent above its fair value by considering expected litigation costs that the opposite agent may expect (Lemley & Shapiro, 2007). The opposite's expected litigation cost is calculated by (1) the expected amount of sales revenue that can be lost by injunction with the assumption that the defendant's stream of sales revenue would be maintained at least at the amount of the defendant's current sales revenue, (2) the expected amount of damages that will be paid to the NPE if the defendant is recognized as an actual patent infringer, (3) litigation costs such as lawyer fees or administrative costs for the trial. The model sets litigation costs as a fixed value (*Lc*) and the default probability of the defendant agent losing in the trial is set to 50%. Also, the default probability that *COURT* issues injunction is 50%.

$$C_{lit,j} = 0.5 \times \left(D0 + 0.5 \times P_{life} \times \mathrm{Sales_{j,t0}}\right) + Lc$$
$$\mathrm{P_{patent,}} = P + \left(C_{lit,j} - P\right) \times RAND(0,1), \text{if agent is NPE}$$

j: Non-prevailing party, $C_{lit,j}$: expected litigation cost taken by j, $D0$: Expected damage, Lc : litigation cost, P: Fair value of the patent, *RAND*(0,1): a random value within [0,1], P_{life}: left time to the patent's expiry

7) Expected profit (cost) of the litigation option

Once a patent infringement lawsuit is filed, the prevailing agent can expect increased *MS* by the exit of the infringer from the product market due to an injunction. It is also able to expect damages paid by the infringer with default litigation costs. The non-prevailing agent considers the general litigation costs, expected sale revenue loss following the injunction, and damage payments as expected litigation cost. To extract the probability of each possible event (win or lose from trials), two agents explored the number of prior arts in the system within a limited search range (number of other agents). Due to the probabilistic difference in finding prior arts between the two, they evaluate the probability of each event differently. For the quantification, the following assumptions have been established further:

- The sales volume that the patent holder can earn during injunction's valid period is fixed to the expected sales volume at t = t0 + 1.
- More prior arts give reduced probability that the defendant will lose from the lawsuit.

The second assumption is intended to reflect the fact a patent's that invalidation process is commonly grounded by objections related to prior art (Allison & Lemley, 1998). From this rationale, the patent holder thinks he is more likely to win from the lawsuit as a lower number of prior arts exist, it is recognizing ($\mathrm{n_{pri,i}}$). With the same logic, the probability of the defendant not being recognized as a patent infringer is proportionally determined by the number of recognized prior arts ($\mathrm{n_{pri,j}}$). The lower and upper bound of the probability is set to 10% and 90% respectively. Therefore, the expected profit or cost from litigation is provided by the following equations:

$$\mathrm{p_{win,i}} = 1 - \frac{1}{1 + 9e^{-0.44n_{pri,i}}},\ \mathrm{p_{win,j}} = \frac{1}{1 + 9e^{-0.44n_{pri,j}}}$$

$$\mathrm{E_i} = p_{win,i}\{L0(\mathrm{sales}_{i,t0+1,win} - \mathrm{sales}_{i,t0}) + D_0\} + (1 - p_{win,i})\{L0(sales_{i,t0+1,lose} - sales_{i,t0})\} - L$$

$$\mathrm{E_j} = (1 - p_{win,j})\{-L0 * \mathrm{sales}_{i,t0} - D_0\} + p_{win,j}\{L0(sales_{i,t0+1,win} - sales_{i,t0})\} - L$$

L: litigation cost, $L0$: injunction valid period, i: patent holder, j: defendant, D_0: Expected damage

8) Patent strategy selection and negotiation algorithm

An agent evaluates the profitability of all the executable patent actions by calculating the respective expected profit. If none of the strategies have a positive expectation value, the agent skips the strategy selection. Otherwise, it commences an interaction with neighbors from the most profitable option. Neighbors calculate their expected profit from the suggested option by the opposite party. When both agents have positive expected revenues from that option, they make an agreement. If a neighbor is infringing a patent, the patent holder takes advantage in negotiation by selecting the most profitable strategies in the form of a package. For example, when the patent holder finds that selling patent “A” and licensing “B” is the most profitable strategy against the infringer, it offers the selected transaction package in form of “take it or leave it” without negotiation. If the patent holder is infringing the neighbor’s patents as well, cross-licensing becomes an available option for settlement. In the case that a neighbor is not an infringer, the patent holder considers whether or not it might need the patent holder’s patent (seek pure technology transfer). They negotiate the method of patent transactions for the individual patent. Finally, the patent strategy is agreed in the form of an individual contract on each single patent. NPEs follow the same rule except cross-licensing, and licensing-in becomes an unavailable action-set because they cannot be a manufacturer in this model and have no motivation to license in another’s technology. Also, due to the fact that the NPE’s business model entails earning revenue by threatening infringers with a lawsuit, NPEs do not engage in pure technology transfer, which is based on a non-patent infringement case. NPEs acquire currently-infringed patents from various patent holders in the system. To maintain higher bargaining power against infringers, NPEs only purchase patents that have fewer than five prior arts, which results in the winning probability in lawsuit process becoming over 50% in the model.

9) Trial process by *COURT*

The probability of the plaintiff losing from trial is proportional to the number of prior arts. The lowest probability that the plaintiff loses is set to 10% and maximum probability is set to 90%. The probability function follows a logistic function that reaches 50% at five prior arts. When the plaintiff wins the trial, *COURT* calculates damages that the infringer must pay to the plaintiff based on “reasonable royalty method,” and it can change the state of the defendant agent to *BAN* with a certain probability (Default probability 50%). If the *COURT* does not issue an injunction, the lawsuit is cleared by a mandatory license contract between the infringer and patent holder on *Rs* for the infringed patents.