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Historical review on the patterns of open innovation at the national level: the case of the roman period

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Abstract

As a result of the open innovation dissemination, the necessity of open innovation is being magnified in the theory of national innovation system. Nevertheless, research on the relationship between the open innovation and national innovation system is insufficient so far. Therefore, this research aims to analyze the open innovation cases of Roman era with the framework of national innovation system. We discovered and analyzed the case of Roman era such as Acquisition, In-sourcing, Collaboration, User innovation and Spin-off among the several type of open innovation. We expect that this research can help the establishment of future national innovation policy.

Keywords: Open innovation, National innovation system, Roman era

Background

The concept of open innovation has been recently hailed to be a new R&D strategy following the diversification of consumer demands and corporate competition, and the need for responsive and continuous innovation that they require (Chesbrough; 2003). The recognition of open innovation has been expanding widely among corporations (Schiele; 2010), and there has been a continuous demand to realize the concept in a national level (Vanhaverbeke and Cloudt, 2006; West et al. 2006). For a nation to realize such innovation, it is forced to rely on external resources (human, technology, capital, etc.). However, a national innovation system (NIS), which actively creates and disseminates knowledge, can overcome its initial lack of resources, manpower, and knowledge and pursue its forerunners by the virtue of rapid and effective acquisition of technology (Freeman, 1987; OECD; 1992). Consequently, Chesbrough (2003) has presented a model of the relationship between the NIS of the United States and open innovation as well as analyzed that the changes in the NIS of the United States has catalyzed the emergence of open innovation. Several advanced nations, including the OECD member states, have focused on the strategy of open innovation to strengthen and improve the capacity for science and technological innovation on national level. In addition, they have been carrying out relevant activities accordingly (Jang and Lee; 2009).

However, the literature on the relationship between NIS and open innovation remains limited (Wang et al. 2012; De Jong et al. 2010). The majority of the studies on

the literature regarding the NIS has focused only on the structure, function, effect, and types of such system (Lundvall, 1992; Lee, 2009). Likewise, the majority of the studies regarding open innovation has focused solely on presenting case studies centered around corporations (Chesbrough, 2003; Gassmann and Reepmeyer, 2005), the relationship and the effect between innovation and R&D collaboration (Amara and Landry 2005; Kline, 2003; Lichtenthaler, 2008), as well as the results and the effects of R&D with regards to the types of partners in collaboration (Eom and Lee, 2010; Belderbos et al. 2004).

Thus, this study shall present a historical case study analysis of the application of open innovation in NIS and derive points of reference to the examples of open innovation being applied in the context of the NIS. This study has selected the Roman period as the subject. The Roman period refers to the ancient civilization that had started from a small village in the middle of the Italian Peninsula, eventually growing into a gigantic empire spanning the entire Mediterranean Sea. This study shall look at the examples of open innovation during the building of such a great empire and present its analysis based on the NIS.

This study consists of the following parts. Chapter 2 shall look at the concepts of NIS and open innovation as well as the historical significance of the Roman period. Chapter 3 will present the individual case studies. Chapter 4 will present the conclusion of the study and the recommendations for future researches.

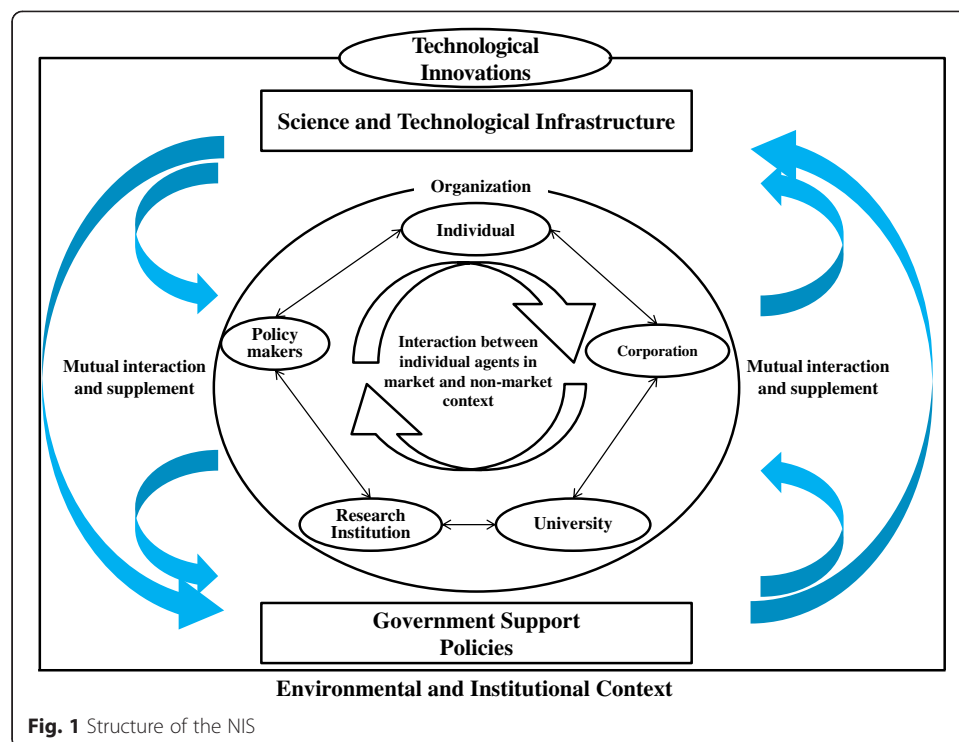
Previous literature

NIS

The NIS theory is developed from the historical experience that the technological innovation of a nation is dependent not only on the scientific and technological capability of a nation but also its socio-economic conditions. The theory was conceived from the analysis on why the Japanese economy during the 1980s showed greater growth compared to United States and Europe (Lee et al., 2007). The definitions given to the NIS include “the network between public and private organizations that conduct technological development and interactions to acquire, improve, and disseminate new technology (Freeman, 1987),” “all parts of economic system and institutional organizations, which affect exploration, inquiry, and learning (Lundvall, 1992),” as well as “national systems that determine the speed and direction of technological acquisition, their incentive system, and competitiveness (Patel and Pavitt, 1994).” Across all definitions, however, the NIS adopts a systemic approach to overcome the limitations posed by a linear approach to technological innovation process (Seo, 1998). Such a systemic approach upholds that the overall success of an economy is not dependent on how specific official institutions (corporations, research institutions, universities, etc.) perform, but rather, it is dependent on how they interact as constituents of an overarching system that creates and uses knowledge and how they interact to social institutions such as values, norms, and laws (OECD, 1997). OECD (1999) has mentioned that the NIS is composed of corporate networks, research institutions, support institutions, and scientific systems that are centered around corporate-driven reforms, and it is dependent on their interactions. Specifically, the OECD

mentioned the need for an organizing entity that establishes technological and innovation policies, conducts R&D, provides financial support to R&D, and fosters human resource development, technological dissemination, and entrepreneurship (OECD, 1999). The NIS is made up of three major elements, including technological innovation process, closed system elements, and open system elements (Lee, 1996). By subdividing them, important elements, such as innovative agents (made up of groups such as corporations, universities, research institutions, policymakers, and individuals), their networks (such as interactions in market and nonmarket context) (Koo et al. 2012), and dynamic interactions (Lim, 2003, 2006; Lee et al. 2012) shall be included. Thus, the NIS is a collection of entities that produce, disseminate, and adopt new technological knowledge, and the activeness of the collaboration and dissemination made through the interactions of the constituents in the system can be counted as a sign of an outstanding NIS (Moon, 2006; Hong, 2007). By doing such, the NIS carries out functions, including creating knowledge, setting directions for future inquiries, providing resources, deriving externalities, and promoting the formation of markets (Johnson and Jacobsson 2003). To better understand the interactions among the elements, an NIS model and its infrastructure must be presupposed (Lee and Song, 1998). Lee and Song (1998) has proposed a model of the infrastructure, which is subdivided into five areas, including technological innovation system in the private sector, government policy, international economy and technological environment, domestic economy and institution, as well as domestic science-technology infrastructure. In the technological innovation system of the private sector, entities such as corporate users, corporate producers, material and component corporations, corporate competitors, and final consumers are considered as the source of technological innovation and an affecting element. The types of government policy include technological demand policy, supply policy, dissemination policy, and R&D investment policy, while government R&D investment and policies serve to support or promote technological innovations (Hong and Lim, 1999). The elements in international economics and technological environment include the demands and the needs of the clients and buyers in the overseas export area, as well as the characteristics and learning patterns of the local businessmen's foreign investment activities. The elements relevant to the domestic economy and institutional context include social awareness on the technological innovations of financial support norms, which is the degree of conservativeness based on the reaction to technological innovations in finance institutions, while the elements in the domestic science and technological infrastructure include information dissemination, linkage, and support organizations (Lee and Song, 1998; Hong and Lim, 1999).

Figure 1 presents a summary of the structure and the constituents of the NIS. The constituents of the NIS, the institutional context, the domestic economy and policy environment, as well as the international economy and technological environment (Lee and Song, 1998; Hong and Lim, 1999; Song, 2009) form the environmental and technological context, which serves as a framework for technological innovations. Also, the internal circle is made up of science and technological system (Lee and Song, 1998; Hong and Lim, 1999; OECD, 1999), the agents of innovation (Lim 2006; Koo et al. 2012), and their interactions (Lee, 1996; Hong and Lim 1999; Lim, 2003, 2006; Koo et al. 2012),

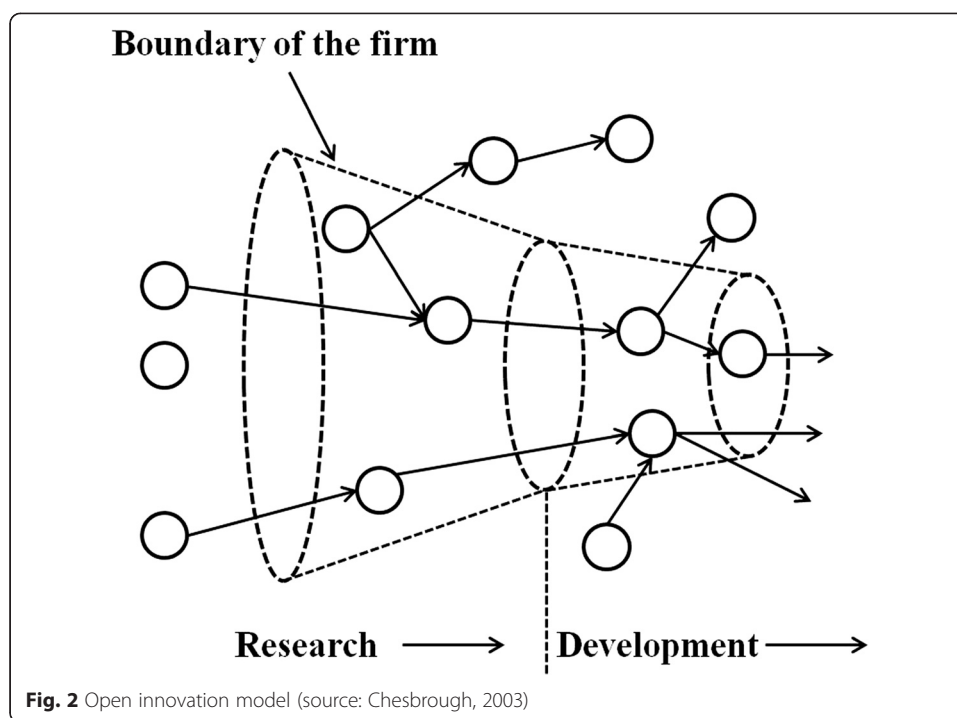


while the relationships among individual constituents form the external circle. Figure 1 shows the process that leads to innovation through the mutual interaction and supplement among innovative agents, the science and technological infrastructure, and government support policies.

Open innovation

According to Chesbrough (2003), open innovation is defined as the usage of knowledge inflow and outflow from the corporation to accelerate internal innovations and maximize their value by enlarging the market for external utilization (Fig. 2). Thus, it is a paradigm of innovation that uses external ideas in addition to domestic ones to commercialize the firm's technology as well as to open external and domestic ones when establishing a foothold into the market. Considering this, open innovation is an overarching integration of the acquisition, transfer, and commercialization strategies in technologies and products.

With the emphasis on the importance of open innovation, there have been various studies in several dimensions such as firm, industry, and NIS. Firstly, in the dimension of firm, the analysis on the acquisition of technology and commercialization strategies, R&D efficiency, corporate interactions and strategic profit analysis, as well as technological innovation assessments show the positive effect of open innovation (Amara and Landry 2005; Arora et al. 2001; Chesbrough, 2003; Gassmann and Reepmeyer, 2005; Kline, 2003; Lichtenthaler, 2008). The analysis on the R&D achievements and effectiveness in accordance with the types of external partners in collaborative activities are being conducted actively



(Belderbos et al. 2004). Han and cho (2015) find the determinants of successful platform business, through the case study of KakaoTalk, a representative fast growing social platform in Korea. Secondly, in the dimension of industry, empirical studies on the effects of collaborative activities and factors that influences the efficiency of R&D, are being conducted through case studies (Eom and Lee, 2010). Technology planning in accordance with finding collaborative partners in the related industry has been established itself as a research area of open innovation (Jeon et al. 2011). Christensen et al. (2005) insisted that the success of open innovation can differ across technologies and industries. Thirdly, in the dimension of NIS, diverse policies for increasing the open innovation of firms are introduced through networking, collaboration, corporate entrepreneurship, and R&D (De Jong et al. 2008). Santonen et al. (2007) proposed the innovation triangle framework which consolidates the national open innovation system for supporting the Finnish national system of innovation. Yun et al. (2015) expanded the research on open innovation policy in that it estimated the effects by simulations through an NIS causal loop diagram and system dynamics. This study established that open innovation policies aim at the production as well as the distribution and consumption of knowledge and technologies. Patra and Krishna (2015) explored the structure of linkages of foreign R&D centers with institutions in India.

Innovation-related journals, such as Research Policy, R&D Management, Technovation, Technological Forecasting and Social Change, Academy of Management, and Creativity and Innovation Management have engaged on active researches as well. Major forms of advanced researches can be organized as shown in Table 1, while the types of

Table 1 Several literature Reviews on Open Innovation

Dimension	Subject	Reference
Firm	Importance of technology market	Arora et al. (2001)
	Relationship between innovation and R&D collaboration	Amara and Landry (2005), Kline (2003), Lichtenthaler (2008)
	Open innovation case studies in corporations	Chesbrough (2003), Gassmann and Reepmeyer (2005)
	Determinants of successful platform business, through the case study of KakaoTalk	Han and cho (2015)
Industry	R&D achievements and effectiveness in accordance with the types of external partners in collaborative activities	Eom and Lee (2010), Belderbos et al. (2004)
	Selecting collaborative partner	Jeon et al. (2011)
NIS	Diverse policies for increasing the open innovation	De Jong et al. 2008
	Innovation triangle framework which consolidates the national open innovation system	Santonen et al. (2007)
	Open innovation policies aim at the production as well as the distribution and consumption of knowledge and technologies	Yun et al. (2015)
	Structure of linkages of foreign R&D centers with institutions in India	Patra and Krishna (2015)

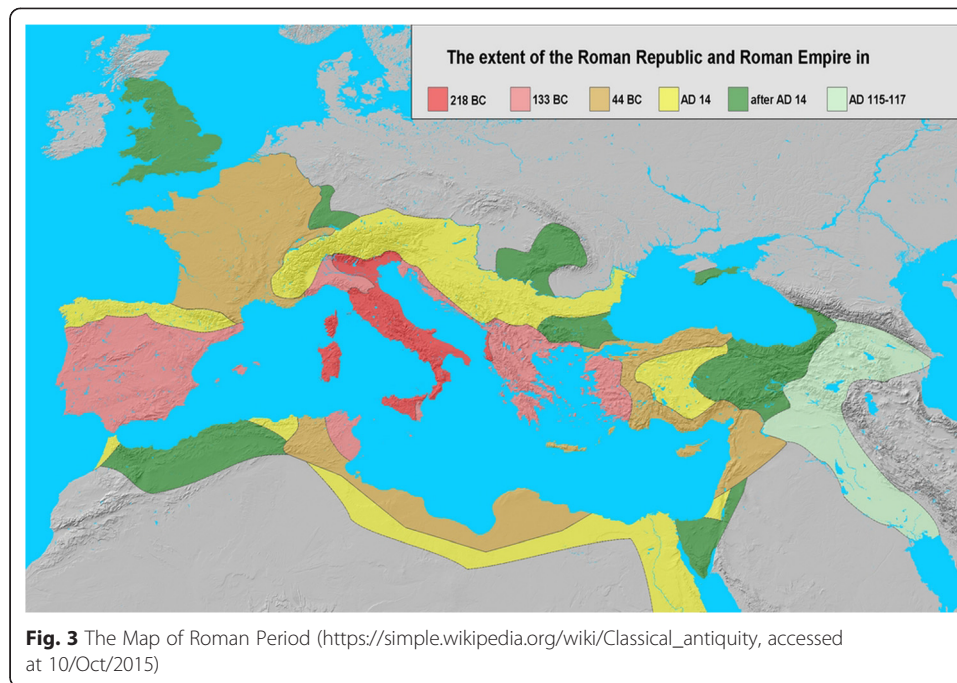
open innovation can be organized as shown in Table 2. However, the majority of the researches are solely focused on case studies centered on corporations, and national level researches remain limited.

Roman period

Ancient Rome is a civilization that began as a city-state following the settlement of Latins near the Tiber River on 8th century BC, which eventually rose to become a gigantic empire spanning the entire length of the Mediterranean Sea (Kim DS, 2004) (Fig. 3). Over the centuries of its expansion, it progressed from a monarchy to a republic and eventually to an empire. At the time of the 7th century BC, Rome was a prosperous city-space and the center of the surrounding region, ruled by a king (BC 753–509).

Table 2 Types of Open Innovation and Contents

Method	Concept	Cases
In-sourcing	Exploring external technology or know-how	"C&D" strategy of P&G
R&D collaboration	R&D collaboration with external organization (e.g. university)	"Lablet" of Intel
Acquisition	Acquisition of a company or a product	M&As of Cisco
User innovation	Innovation that is performed by the user and not the supplier	Medical Instrument, Toy, Game
Technology licensing	Licensing internal technology outside (sic. \outward licensing of internal technology)	MIPV" of MS
Spin-off	Spinning off internal organization	"New venture group" of Lucent
Joint venturing	Investing venture with venture capital (VC)	Venturing between HP Lab and VC
Openning (sic. opening) project	Openning (sic. opening) project or source to the public	Linux

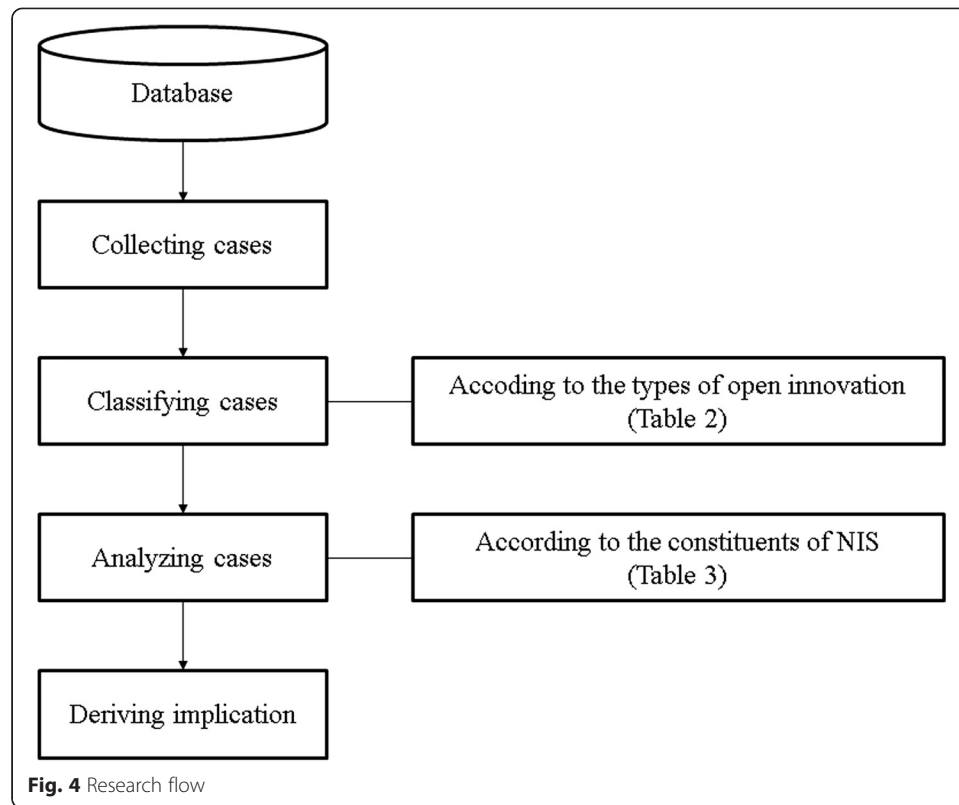


On 5th century BC (510 BC), the monarchy collapsed, and a republic was established with the collaboration of the nobility and the common people. When Octavianus accepted the title of Augustus from the Senate at the end of the 1st century BC, he became the first emperor of Rome. The early days of the Roman Empire were called “Pax Romana,” a time of unprecedented peace and prosperity enforced by the dominance of the empire (Kim DS, 2004). Its openness to the culture and religion of its subjects led to prosperity and integration of its lands, and many different cultures of the Ancient period were assimilated, integrated, and spread among the various constituents of the multicultural and polytheistic empire, including Greece, the Orient, the Semites, and the Western Europe.

The empire, as a result, contributed heavily to the progress of law, politics, arts, literature, architecture, technology, and language of the West. Afterward, the empire eventually split into East and West, the West collapsing on 476 AD, the East (Byzantine empire) on 1453 AD.

Research framework

For analyzing the cases of open innovation in Roman period from the viewpoint of the NIS, research flow is shown in Fig. 4. Firstly, from various database about the Roman period, cases of open innovation are collected. Secondly, collected cases are classified according to types of open innovation as shown in Table 2. Thirdly, classified cases are analyzed based on the constituents of NIS. Four major factors of NIS are derived based on the literature review of NIS as shown in Table 3: innovative agent, technological innovation activities, government support policies, environmental and institutional context. Various cases of open innovation of Roman period are analyzed with respect to these four constituents. Finally, implications of Roman period with respect to NIS of open innovation are derived.



Case study

The type of acquisition: integration of Non-Romans

A case of open innovation through acquisition may be found in the efforts to integrate non-Romans in the subjects of the empire. Ancient Rome accumulated many subjects through countless number of battles, and unlike other tribes in the Italian Peninsula, it made a conscious effort to integrate its former enemies into the group, even offering citizenships. Also, it recognized the religion and political structure of the subjects. Caesar instituted a policy in which non-Romans with medical skills would be allowed to become a citizen of Rome in exchange for 10 years of medical service in the country, drawing many talented doctors into Rome regardless of race, skin color, place of birth, or social standing. Rome established an environment that allowed not only doctors but also many other talents to be drawn actively from various professions, through which the people of the subject areas rose to nobility and even to the throne. For example, Hispania-born Ulpius Traianus, commander of the X Legion Fretensis during the Jewish–Roman War and the eventual father of the emperor Trajan, and Julius Agricola, a general from Gaul who was assigned to Britannia, managed to rise to the ranks of the nobility. Also, Trajan (ruled from 98–117) was an emperor from a subject province who led the empire to the height of its territory and widely considered as one of the greatest emperors of the empire. Septimius Severus (193–211), hailing from a subject province in Northern Africa, also rose to the throne. Thus, the ancient Rome formed many policies and institutions to integrate the non-Romans and make use of their talents, and as its territory and the number of non-Romans in its borders grew larger, it

Table 3 Constituents of NIS

Constituents	Definition	Subfactors	Researchers
Innovative agent	Organization who carry out innovation in a certain area	Corporate organizations, noncorporate organizations (universities, research institutions, policymakers etc.), individual	Freeman, 1987; Lundvall, 1992; Nelson and Rosenberg, 1993; OECD, 1999; Hong and Lim, 1999; Lim, 2003; Koo et al., 2012
Technological innovation activities	Process in which an agent learns and carries out newly known product designs or production processes, regardless of being the first to do so or not	An agent-driven activity that features agents such as corporate users, corporate producers, material and component corporations, corporate competitors, and final consumers.	Freeman, 1987; Lee, 1996; Lee and Song, 1998; OECD, 1999
Government support policies	Government policies designed to support or foster technological innovations	Technological demand policy, supply policy, dissemination policy, R&D investment policy, small and medium enterprise innovation policy, and local innovation policy, etc.	Lundvall, 1992; Lee and Song, 1998; Hong and Lim, 1999; Seong and Song, 2007; Song, 2009; Lee, 2013
Environmental and institutional context	The institutional context in which a suitable environment and the basis of active technological innovation can be established.	Social infrastructure, such as financial support, patent and educational policies, culture, production structure, market structure, competitive environment such as international situation, science and technology information network, information integration, support organizations, and R&D facilities	Freeman, 1987; Lundvall, 1992; Lee, 1996; Lee and Song, 1998; Song, 2009; Koo et al. 2012; Lee, 2013

adopted the *jus gentium*, an international law applicable to everyone, both Roman citizens and non-Romans, in the territory.

Open innovation through acquisition, in the form of integration of non-Romans, can be seen as a case study of innovation in national defense and medical system by acquiring talented doctors and soldiers. Table 4 shows the analysis of Rome's acquisition or integration of non-Romans, from the context of the NIS.

Table 4 Case Study Analysis on the Acquisition-type Integration of Non-Romans

NIS Constituents	Description of case
Innovative Agent	Government of Ancient Rome (centered around diplomatic agents)
Innovative activity	Developing and reforming the manpower inflow system through acquisition-type innovation in which talented manpower are acquired in exchange for certain rewards Because of the inflow of talented soldiers, doctors and educators, innovation of education, and medical system (especially military hospitals) were made possible.
Government Support Policies	Assigned citizenships to talented doctors in exchange for 10 years of medical service, with the goal of acquiring talented doctors regardless of social standing, race, and birthplace.
Environmental and institutional context	Created and applied <i>jus gentium</i> to all citizen within the territory in an equal manner. Established an institutional environment in which talented individuals, regardless of their birthplace, could rise to nobility and office.

The type of in-sourcing: calendar reform

Ancient Rome initially used a lunar calendar. Julius Caesar, after his conquest of Egypt, ordered the reformation of the calendar into a solar calendar in an example of open innovation through in-sourcing. The pre-Julian lunar calendar was adopted by the 2nd king of Rome, Numa, on 7th century BC and featured 355 days in a year, with leap months added to balance out the days once every few years. The corrections to the calendar was made by the priests of the era in an arbitrary and unscientific fashion. After the conquest of Egypt, however, Rome adopted and reformed the Egyptian solar calendar into what is now known as the “Julian Calendar.” Over the course of reform, Egyptian astronomers and Greek mathematicians were called upon to form a research team for the calendar, whose insight into the scientific nature of the calendar allowed them to provide valid amendments to the process. The Earth takes 365 days and 6 h to make a full orbit around the sun, and the solar calendar as a result takes 365 days as the length of a year. The six-hour difference was corrected by a single day being inserted between the 23rd and the 24th of February every four years, and the resulting “Julian Calendar” was put into effect over the entire territory of the empire, providing a standard for the reckoning of time. This “Julian Calendar” was used until the amendments made by the pope Gregory III on 1582.

This example of in-sourcing open innovation can be seen as an innovation of time system (or calendar), in which the superiority of the subject land’s calendar was recognized, amended through scientific methods and finally put into effect, standardizing all existing calendars into a single system. Table 5 below shows the calendar reform, broken down into subtypes of the NIS.

The type of collaboration: roman alliance

As an example of open innovation through collaboration, Rome had formed a number of alliances with its surrounding nations. There is a saying that “Rome was built in a day,” and this shows that the power of Rome was not formed singularly by the way of military conquests, but rather through an ongoing historical process over the span of centuries through the method of alliances with the surrounding nations. The start of

Table 5 Analysis of Calendar Reform as an In-sourcing-type Open Innovation

NIS Constituents	Description of case
Innovative Agent	Government of the Ancient Rome (centered around scientific and technological agents)
Innovative activity	<p>Innovation through in-sourcing by the replacement and adoption of a solar calendar in the place of the existing lunar calendar and its unscientific corrective mechanisms to provide the standardized time and precision</p> <p>Standardization of time through the usage and distribution of precise and scientific calendar</p>
Government Support Policies	Policies recruiting and supporting the scientists and mathematicians (basic scientists from Egypt and Greece) for the reformation process.
Environmental and institutional context	<p>By taking in various academic knowledge (engineering, mathematics, science, philosophy, etc.) from the conquered lands, academic progress had already been in motion.</p> <p>Rome had already received talented individuals in a wide field of knowledge, including the basic sciences, and had formed a talented pool of researchers beforehand.</p>

the alliance-building can be traced to the end of the 6th century BC, when the Roman Republic had just been formed. The first alliance that the fledgling republic had sought was the Latin League, made up of regional nations in the Latium area. Latin League was an alliance that formed and headed the Kingdom of Rome as a means to provide a common offering to the god, Jupiter, on the Alban Mount. However, the league was reformed by the Treaty of Cassius on 493 BC, which was outwardly a treaty of equality and reciprocity but had, in reality, elevated Rome onto the head of the league. The Latin League formed the springboard from which Rome initiated the conquests of Etruscans, Sabines, Aequians, and Volscians. The members of the league, however, voiced their opposition to the League, which had increasingly become a tool for the Romans, and began to deviate and oppose the league and the Rome at times of their weakness. To mitigate these opposition, Rome began to reform the alliance, binding the member states with bilateral treaties and prohibiting individual treaties among the member states. Those nations, which accepted these reforms, received Roman citizenship as a member of the Roman nation. Also, the opposition were destroyed and their politicians banished from the territory. Over the course of these alliances, Rome allowed self-governance for the member states, and coupled with a series of successful wars, it established itself as the ruler of the Italian Peninsula. Figure 5 shows the relationship structure in the Latin League and the Roman Alliance after the reformation.

With collaboration-type innovation and internal reforms, Rome established an effective system of collaboration between nations with Rome at its helm. Also, through these alliances Rome was able to acquire talented manpower into Rome, and acquired the drive to sustain continuous territorial expansions. Table 6 shows the analysis of the collaboration-type innovation in the NIS standpoint.

The type of user innovation: adopting military technology from surrounding nations

As a form of user innovation, the Rome adopted military technology from the surrounding nations. The military of Ancient Rome was based on the weapons and the tactics of the Greeks. For example, the basic combat formation of “Phalanx” with long spears and circular shields was derived from the Greeks. However, with territorial

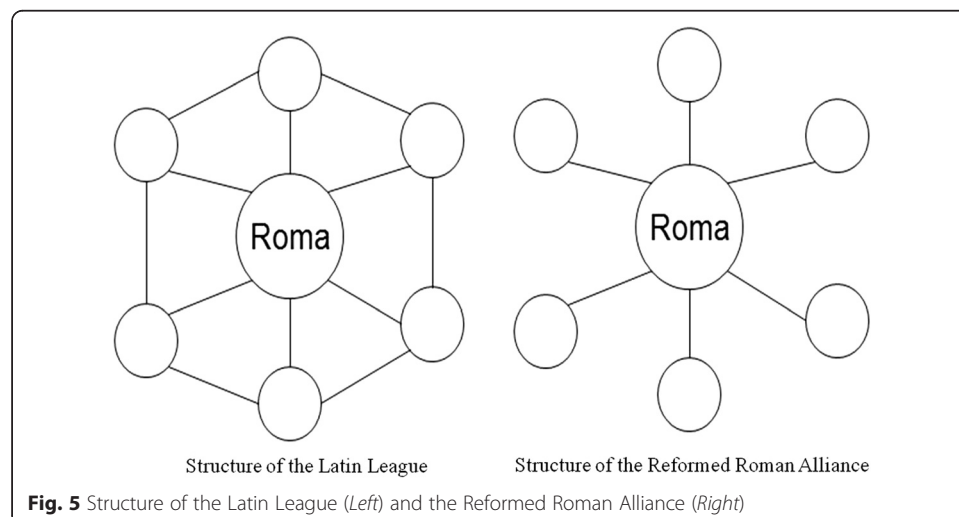


Table 6 Collaboration-type Roman Alliance Analysis

NIS Constituents	Description of case
Innovative Agent	Government of Ancient Rome (centered around diplomatic agents)
Innovative Activity	Collaboration through the formation and the reformation of collaborative systems (Latin League) among the member states to manage the territorial wars and subjects effectively. Restructuring of relationship between Rome and member states, and among the member states themselves to mitigate the opposition to the previous collaborative activity and maintain loyalty (Roman Alliance)
Government Support Policies	Through mutual equality treaties among the member states, centered around Rome, the member states were assigned the same profits (spoils, military provisions, and allowances from war), rights (citizenship with suffrage, marriage rights, etc.) and duties (conscription and participation) Allowed bilateral treaties between Rome and member states only, and not among the member states
Environmental and Institutional Context	The planned territorial expansions to both southern and northern areas in the Italian Peninsula and support from the surrounding nations played heavy importance in combat personnel and logistics support Surrounding nations preferred alliances with the powerful Rome, but some dissent and opposition were shown because of the unfair relationship

expansions and the resulting variations in terrain, the military techniques of the Greeks proved to be insufficient. The Roman capacity for openness showed itself in military situations as well. In mountainous regions, long spears were discarded after their limitations were recognized, and short swords were adopted in their stead. The short swords in question were the modified versions of the Iberian “Gladius.” Also, recognizing the dangers of javelins used by the Samnites, the Romans adopted the javelin “Pilum,” which eventually was developed into the “Plumbata,” which was light enough for a soldier to carry multiple shafts. As the equipment of the army underwent changes, the combat and defense formations and techniques changed subsequently as well. Figure 5 shows the contrast on the pre-user innovation equipment and combat formations with the ones after the innovation.

These examples of user innovations show a specialized variety of innovation in the military systems following the territorial expansion and the increased varieties in terrain. Overall, it can be seen as an example of a general innovation in national defense, through the acquisition of new weapon systems and defense planning. Table 7 presents the analysis of the user innovation in the NIS standpoint.

The type of spin-off: building roads and cities

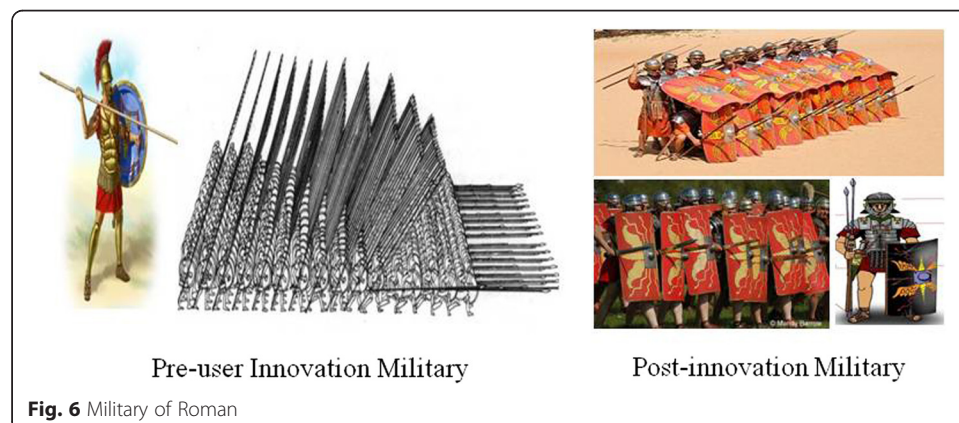
Through a series of innovations and technological influx from the Greeks and the surrounding nations, the Roman architecture technology, along with its military, became the centerpiece of the outstanding technology that the Romans possessed. The Roman architecture, in particular, adopted precise and rigorous plans and proportions from the Greeks and featured significant architectural elements like composite and Tuscan columns, a new way of arranging shafts and capitals, and dome technology from Etruscan arches. Figure 6 shows the examples of Etruscan structures. These technology were applied not only in the Rome proper but also in the conquered lands. Recognizing that the roads signify the commitment to territorial alliances, Rome built many roads that were all linked to Rome, through which

Table 7 Analysis of User Innovation Type and adoption of Military Technology from Surrounding Nations

NIS Constituents	Description of case
Innovative Agent	Government of Ancient Rome (centered around military agents)
Innovative Activity	User innovation from the recognition of limitations in existing weapon systems and adopting, modifying, and making use of foreign weapon systems Caused innovation to spread to the military systems in general, affecting various areas such as military strategy
Government Support Policies	Assimilating skilled military personnel from conquered lands or issuing tailored strategies to legions
Environmental and Institutional Context	The increased pace in territorial expansion and war made the usage of the existing Greek systems risky. All military personnel (leadership and soldiers) were aware of the threats posed by the weapon systems of the natives, which were tailored to the battlefield conditions.

political, military, administrative, cultural, and technological ideas were disseminated to the conquered lands. The roads in Rome, made of concrete, were notable for their sturdy construction and were used even after a thousand years from the fall of the empire. The efficient road network stretched to 50,000 miles in length, constantly playing its part in enlarging the hegemony in Rome and its sphere of influence. For example, the Via Appia (312 BC), linking Rome and Capua, is still in use today (Jung JY, 2007). Roman construction in conquered lands allowed their engineering skills (roads, buildings, sewage, etc.) to spread to the conquered lands, and the resultant urban renewal projects allowed the conquered lands to fulfil its purpose as a model of Roman self-governance, rear area defensive base, and economic center of the region (Fig. 7).

These examples of spin-off technologies can be seen as an example of innovation which allowed the formation of Roman network, through which technological and cultural disseminations and administrative support could be efficiently conducted. Through these innovations, an infrastructure was built that allowed for the flow of various knowledge, economic resources and technology. Table 8 shows the examples of Roman spin-off type road and city-building projects.





Etruscan Arch



Circular Dome

Fig. 7 Building Structures of Roma

Discussion and conclusion

Theoretical and managerial implications

This research attempted to analyze the case studies of open innovation in the Roman period from the NIS standpoint, with the aim of understanding the relationship between open innovation and the NIS. Through this, the study focused on the national examples of open innovation, instead of the corporate-centered examples that had featured heavily in literature. In particular, among various different types of open innovation, the Roman equivalents of acquisition, in-sourcing, collaboration, user innovation, and spin-off types were analyzed over the course of this study. By reviewing the literature on the NIS, the constituents and the organization of the NIS has also been reworked for application to the Roman Period. The constituents of the NIS were organized into four major subtypes: the innovative agent, innovative activity, government support policies, as well as environmental and institutional factors, and the summary of the case studies are provided on the Table 9. This result is expected to help present policy officers make the 'Open' NIS. For example, with respect to innovative agent, various organizations such as diplomacy, science and technology, military can conduct open NIS. In the case of acquisition in NIS, encouraging innovations in various fields are needed such as education and medicine through the influx of talented

Table 8 Spin-off-type Road and Urban Construction Analysis

NIS Constituents	Description of case
Innovative Agent	Government of the Ancient Rome (centered around territory management)
Innovative Activity	By applying the Roman style of road and urban construction in the conquered lands, architecture technology could be spun off to the conquered lands Formed networks in the conquered lands that allowed them to receive various military, political, administrative, cultural, technological knowledge and regulations and at the same time serve as a strategic base for administration
Government Support Policies	Adopting and disseminating superior technology of the subjects Providing support to outsourcing policies targeting locals to utilize the technology of the subjects directly.
Environmental and Institutional Context	Relative superiority of architecture and cityscape engineering technology in surrounding nations (Etruscan civil engineering and construction, Greek planning, etc.) Rome required various architectural technology (construction as well as civil and cityscape engineering), because it was still in its developing stages at that point

Table 9 Analysis of Case Study of Open Innovation from the Standpoint of the NIS

NIS constituents	Open innovation type				
	Acquisition type	In-sourcing type	Collaboration type	User innovation type	Spin-off type
Innovative agent	Diplomacy	Science and technology	Diplomacy	Military	Territorial management
Innovative activity	Encouraging innovations in various fields such as education and medicine through the influx of talented personnel and non-Romans in exchange for citizenship	Adopting and reforming the scientific and precise solar calendar as well as the basic scientists from the conquered lands, thereby standardizing the time	Establishing collaborative systems and reforming such networks to provide combat support and efficient management of conquered territories	Innovations in military system through territorial expansions and wars, such as adopting suitable weapon system and combat formations or reforms in strategy and tactics	Adopting foreign technology to urban construction projects in conquered lands, and fostering architectural reforms throughout the territories by disseminating relevant technology to subject lands.
Government Support Policies	Enacted a policy to assign obligations for medical service in certain areas with citizenship	Provided support to mathematicians and earth science personnel regardless of their home nation or birthplace	Assigned equal profits, rights, and duties to the subjects and prohibited treaties between subject nations	Assimilated and adopted superior military elements into the ranks and assigned suitable strategies tailored to individual legions.	Assimilated superior technology or technicians from subject lands and assigned outsourcing projects to these technicians when the construction requires their specialty
Environmental and institutional context	Established a social environment in which all capable men can rise into the office and enacted <i>jus gentium</i> , a law that is applied equally to all citizens regardless of their background	Influx and adoption of various academia due to territorial expansions and conquests, research teams formed in various areas	The Surrounding nations were, in overall, positive about having an alliance with Rome, and many approved the openness of Rome.	The increase in the pace of combat in both southern and northern regions, and maintaining existing systems were risky	Surrounding nations had superior technology in architecture and construction technology, making adoption of such technology feasible

personnel and non-countries in exchange for citizenship. Table 10 shows the summary about types and cases of open innovation in corporate and national perspectives.

While the majority of the literature focused on a corporate-level analysis of open innovation, this study attempted to provide a national-level analysis through the standpoint of the NIS, with the following significant points. First, this study shows that any analysis of open innovation must be made according to the size of the innovative agent. There were many cases of open innovation with various sizes in the agents, and these examples affect their development. The analysis may be made not only in the standpoint of national entities but also in local and global innovation systems, and through such analysis, significant lessons may be learned from the development process of the agents involved. Second, by referring to the cases of open innovation in the NIS of the historical powers, this study shows the importance of a suitable innovation system to the individual nations for a modern nation to join the ranks of the powerful. In the

Table 10 Types and Cases of Open Innovation in Corporate and National Perspectives

Method	Company level		National level
	Concept	Cases	Cases
In-sourcing	Exploring external technology or know-how	"C&D" strategy of P&G	Caesar's Calendar Reform
R&D collaboration	R&D collaboration with external organization (e.g., university)	"Lablet" of Intel	Roman Alliance
Acquisition	Acquisition of a company or product	M&As of Cisco	Embracing non-Romans
User innovation	Innovation that is performed based on user and not the supplier	Medical Instrument, Toy, Game	Adopting military technology from surrounding nations
Spin-off	Spinning off internal organization	"New venture group" of Lucent	Roman road and urban construction

NIS, the factors that affect the innovation, such as culture, institution, as well as scientific and technological infrastructure are becoming ever more diverse and developed. To keep up with these changes, a suitable NIS must be sought to pinpoint the direction of the innovation.

Limitations and future research

Although there are some meaningful implications in this study, our research has some limitations. This study cannot reliably provide a framework of analysis to other nations because of the continuous evolution of the process and the differences in the NIS of individual nations. Also, the framework for the analysis of the NIS, which is used in this study, does not represent precisely the changes in civilization at the time of Ancient Rome. Thus, for future studies, the changes in civilization and the characteristics of the NIS must be derived and applied in addition to those of the Ancient Rome. Also, other case studies on various types of open innovation in a national level must be discovered and analyzed, and the lessons for the nation in question must be derived as well.

Competing interests

The authors declare that they have no competing interest.

Authors' contributions

JHJ carried out the open innovation studies and drafted the manuscript. SKK carried out the national innovation system studies. JHK carried out the Roman period studies. All authors read and approved the final manuscript.

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