Dutch and Spanish global networks of knowledge in the early modern period: structures, changes and limitations

Karel Davids
VU University Amsterdam

Paper presented at the International Workshop *Iberian-Netherlandish Knowledge Exchanges*, Barcelona, Institut d'Estudis Catalans. 27-28 November 2009

From the end of the sixteenth century onwards, the Dutch Republic became a hub in a global network of knowledge. A knowledge hub as a nodal point or crossroad in regular, long- and short-distance flows of knowledge where knowledge is being supplied, assessed, exchanged, stored or disseminated. Knowledge can flow through a variety of carriers, notably via the mobility of people or by means of the transmission of texts, natural objects or artefacts. The knowledge hub that emerged in the Dutch Republic at the end of the sixteenth century was spatially situated in a limited number of locations, notably the cities of Amsterdam and Leiden as well as some smaller towns like Enkhuizen, Middelburg, Rotterdam and The Hague. The Dutch Republic was of course not the first area in Europe to become a site of a nodal point in a global network of knowledge. Among its immediate predecesssors were the Southern Netherlands and the Iberian Peninsula. Antwerp, Louvain, Lisbon, Seville and Madrid preceded Amsterdam, Leiden and The Hague.

This paper aims to compare the Dutch and Spanish global networks of knowledge. It concentrates on one of the key questions of this workshop, viz. whether there were significant differences and similarities between the management of the Spanish and Dutch global networks of knowledge. The comparison will deal both with underlying patterns and mechanisms of these networks and their development through time, illustrated with examples from a variety of areas of what we may loosely call 'useful knowledge', notably navigation technology, cartography, geography, natural history and military and hydraulic engineering. First, I will demonstrate that, although the Dutch network showed some similarities with the Spanish one, and was to some extent connected to it and even modelled on it, it also differed from its predecessor in several important respects. Linking up with recent studies on exchange of knowledge in the Spanish and Dutch empires I will next argue that each of these global networks of knowledge had specific qualities favourable to the creation and circulation of knowledge, but also, when circumstances changed, ran up to its own peculiar limitations.

Longitude prizes and networks of knowledge

Let me start with a specific but highly illuminating example borrowed from the area of navigation technology. Shortly after his accession as King of Spain in 1598, Philip III offered a reward for anyone who would come up with a practical and reliable solution for the problem of

finding longitude at sea. This reward, the first specifically offered on this subject in a European state, consisted of a sum of 6,000 ducats plus a life annuity of 2,000 ducats and 1,000 ducats more for expenses. The task of assessing the merits of the proposals was entrusted to the Casa de Contratación (House of Trade). Most of the applicants of the ten proposals submitted until 1634 were Spaniards, but two of them came from abroad: a globemaker and mathematician from Flanders, Michel Florent van Langren and an astronomer from Tuscany, Galileo Galileï. None of the applicants ever received the prize. The only payments made were in the category of expenses.[1] Interest in the Spanish prize declined after the mid-1630s.

Hardly had the Spanish Crown offered its longitude prize than its opponent in the Low Countries, the Dutch Republic, made a similar move. On April 1, 1600, the States General of the United Provinces offered a sum of 5,000 guilders plus a life annuity of 1,000 pounds for anyone who would present an adequate solution for the problem of finding what the Dutch called 'the East and West'. A year later, the States of Holland likewise offered a longitude prize. This prize could be earned in stages: an applicant would receive 150 pounds if he had submitted an explanation of his method and was prepared to have it tested at sea, and a sum of 3000 pounds plus a annuity of 1000 pounds if six to eight skippers would attest that method was completely reliable. The reward offered by the States General was raised to 15,000 guilders in 1611 and to 25,000 guilders in 1660. The States of Holland were in 1738 prepared to pay as much as 50,000 guilders. Applications for a longitude reward continued steadily to arrive until about 1775. The total number of proposals submitted in the Dutch Republic amounted to almost forty. While the majority of the applicants came from the United Provinces itself, a substantial number hailed from abroad, especially from the Holy Roman Empire and the Kingdom of France. Among the longitude finders was once again an astronomer from Tuscany, Galileo Galileï.[2]

In contrast with Spain, the assessment of the proposals was not always entrusted to the same agency. The most common procedure was that States General of the States of Holland first asked ad-hoc committees of experts in the theory of navigation (*theoristen*) to assess the correctness of the underlying principles of a proposed solution and then, if a proposal had survived this theoretical scrutiny, called on experienced seamen (*practisijns*) to attest whether the suggested solution would work in practice. Ad-hoc committees of *theoristen* requested to advise on the merits of longitude proposals included scholars, teachers and surveyors such as Joseph Scaliger, Willebrord Snellius, Simon Stevin, Sybrand Hansz Cardinael, Franciscus van Schooten, Christiaan Huygens, Burchard de Volder and Petrus van Musschenbroek. Between about 1650 and 1730, the States General more than once referred an applicant to the Dutch East-India Company (VOC), which employed several in-house experts in navigation, the examiners of

pilots.[3] Although neither the States General nor the States of Holland ever awarded the longitude prize in full, they nevertheless more than once paid (or ordered other institutions to pay) considerable sums of money to would-be longitude-finders by way of expense allowances. The most successful claimant from this point of view was doubtless Jan Hendricksz Jarichs van der Ley, a former receiver-general of the Admiralty of Friesland, who in 1625 secured an annuity which up to its cancellation in 1655 generated for himself and his heirs a total income of 19,000 guilders.[4]

What do the stories about the Spanish and Dutch prizes tell us ? First of all, they reveal something about connections between the Spanish and Dutch networks of knowledge , albeit in a different way than one would expect. The introduction of prizes in the Dutch Republic was in fact not an immediate reaction on the creation of a prize in Spain. Demand from would-be longitude-finders for a patent or a reward from the States General or the States of Holland was already increasing from the early nineties onwards, i.e. well *before* the prize in Spain was offered. At least five competitors had entered the field by 1600.[5] The growth of this demand was a consequence of the rise of Dutch ocean shipping, in particular the beginning of a direct trade with Asia. In so far as there *was* a Spanish, or rather Iberian, connection, it was contained in the content of particular proposals rather than in the establishment of the prize as such. The most learned and accomplished of the early claimants, Petrus Plancius, based his ideas about finding longitude at sea by magnetic declination on path-breaking work by Portuguese and Spanish authors, such as João de Lisboa, Francisco Faleiro and Alonso de Santa Cruz.[6]

Longitude prizes are also illuminating from the perspective of comparisons. Both the Spanish and Dutch longitude prizes can be viewed as part of a knowledge hub. A public prize served as a focal point for flows of knowledge between claimants, experts, users and men in power, which did not just spin around in small circles but reached a much wider scale. As part of a knowledge hub, longitude prizes can tell us something about structural aspects of networks of knowledge, such as forms of remuneration and the nature of knowledge infrastructures.

Comparing the Spanish and Dutch prizes from these perspectives , we can notice that the networks of knowledge resembled each other in several respects but also that the Dutch network showed a number differences with regard to the Spanish one. While the prizes in both cases were initially set up by the highest agency of government and in both cases consisted of a monetary reward composed of a lump sum, a life annuities and, if need be, an expense allowance, the Dutch version showed more mutations than the Spanish one: not only did another government agency establish a prize of its own, the size of the reward increased stepwise in course of time. In the Dutch case, the assessment procedure involved a wider and more flexible set of clusters of

expertise than in the case of Spain. The process of testing of selecting of new proposals rested on a more varied infrastructure of knowledge.

Structures

Having used longitude prizes as an instrument to detect some connections, similarities and differences between Spanish and Dutch networks of knowledge, I would now like to raise the analysis to a more general level. This comparison will cover four structural aspects of networks of knowledge: the nature of knowledge infrastructures, the forms of remuneration, the criteria of access to knowledge networks and the degree of openness or secrecy of knowledge. Guiding questions are: what institutions or clusters of experts supported the supply, assessment, exchange, storage or dissemination of knowledge ? how were new contributions to the supply of knowledge rewarded ? to what extent was participation in networks of knowledge open or closed ? To what degree was access to knowledge itself open or closed ? For each of these aspects – which of course do not exhaust the range of possible questions - I will show what to my mind were the principal differences or similarities between the Spanish and Dutch networks of knowledge in the early modern period by proposing some general statements and then illustrating these with examples from various areas of knowledge.

The nature of knowledge infrastructures

The most obvious difference between knowledge infrastructures in Spain and the Dutch Republic can be found in the relative weight of state-controlled institutions. In the Spanish global network, all the key institutions supporting the production and circulation of knowledge since the sixteenth century were agencies of the central state, notably the House of Trade, the Council of Indies and the Royal Court. Most of the functions and facilities that sustained the creation and transmission of knowledge were directly or indirecly linked to these agencies: pilot-majors, cosmographer-majors, chronicler-majors, chairs of navigation and cosmography, chairs of mathematics, medical gardens, royal hospitals and the Academy of Mathematics**.** The leading centres of teaching of modern scientific and technical knowledge that arose in Bourbon Spain after 1715, namely the naval and military academies located in Madrid and various port cities - were likewise creations of the central state. The principal elements of the knowledge

infrastructure that did *not* operate under the aegis of the central state were monasteries, hospitals and colleges managed by religious organizations, such as the Franciscans and the Jesuits.[7]

The knowledge infrastructure in the United Provinces was more diverse than in Spain. There were some institutions supporting the production and circulation of knowledge that formed part of the apparatus of the central state, to be sure. Examples are the offices of examiners of pilots and naval officers created by several Admiralties in the eighteenth century, the nautical schools in Amsterdam and Rotterdam founded jointly by the Admiralties, the East-India Company and city governments about 1750 and the Committee on the Determination of Longitude and Improvement of Charts established by the Admiralty of Amsterdam in 1787. But there were much more functions and facilities that did *not* fall under the responsibility of agencies of the central government. The opposite numbers of the pilot-majors, the cosmographers-majors, the chairs of navigation, cosmography and mathematics who in Spain came within the jurisdiction of agencies of the central state, were in the Republic scattered over many different places: in semi-public chartered companies, like the VOC and the West-India Company, at universities and other institutes of higher learning sponsored and controlled by cities and provincial governments, but also in the form of lectureships sustained by funds provided by urban governments. Botanical gardens and professorships of botany in the Netherlands were created by cities or universities, not by agencies of the central state. The Dutch counterpart of the Academy of Mathematics in Madrid, the *Duytsche Mathematicque*, which offered courses on surveying and fortification, formed part of the university of Leiden.[8]

Moreover, while the Dutch Republic lacked educational institutions or collections supported by religious organizations, it had an abundance of people, especially in port cities and inland towns in the maritime provinces, who regarded the production and distribution of knowledge as a promising commercial venture. These 'entrepreneurs in knowledge' included great numbers of publishers, book sellers, surveyors, map makers, instrument makers, medical practitioners and teachers of navigation and mathematics.[9] The knowledge infrastructure in the Dutch Republic was therefore characterized by a great variety of facilities, a high degree of decentralization, low measure of coordination by state institutions and a relatively important role of market mechanisms..

Forms of remuneration

Why do people exert themselves to make new contributions to the supply of knowledge ? Incentives for the discovery or creation of new knowledge can take many different forms. The

forms of remuneration that operated in networks of knowledge in the early modern period, like today, were both of a material and immaterial nature. Examples of the former were patents, rewards and prizes, sponsorship by public or semi-public institutions or patronage. These forms of remuneration normally involved an element of material recompense. Remuneration also could take a less tangible form, such as the prospect of a service in return, an increase in reputation, a gain in power or an enhanced chance of salvation of one's soul.

Immaterial forms of remuneration are of course harder to measure than material ones. Still, we have various clues that suggest that these forms of remuneration actually must have exerted an influence. Many Catholic missionaries in the Iberian empires or Asia worked untiringly to gather and transmit data on the natural world without ever receiving a visible material reward. All those Franciscans or Jesuits collecting specimens, drawing maps and writing books and reports can hardly have been motivated by the prospect of improving their own income or wealth. Spiritual autobiographies and questionnaires composed by Jesuits in the sixteenth century studied by Luke Clossey and others rather suggest that the desire of salvation must have a powerful incentive.[10] Considering the fact that religious organizations like the Society of Jesus put a premium on the systematic acquisition, assessment, storage and dissemination of data on the overseas world it is highly probable that missionaries active in global networks of knowledge were also driven by the expectation of other innerworldly immaterial rewards such as an increase in reputation, the prospect of services in return and perhaps, a gain in power.

However, immaterial forms of remuneration was not only relevant in the Spanish case. Immaterial rewards presumably also could motivated actors in the network centered on the Dutch Republic. Why else, for example, should scholars such as Isaac Beeckman or Christiaan Huygens have preoccupied themselves with the problem of finding longitude at sea, whereas they never applied for a longitude prize and were hardly in need of patronage either ? [11] And the existence of 'cultures of exchange' (services in return) has been amply documented for circles of naturalists, such as the network of Carolus Clusius. [12] If there *was* any difference in the operation or relative importance of immaterial remuneration in the Spanish and Dutch networks, this difference, I would guess, first and foremost resided in a higher degree of institutionalization of immaterial rewards within the context of religious organizations in the case of Spain. The Dutch Reformed Church was in this respect no match for the Society of Jesus, or for any other Catholic religious order for that matter.

Among the material forms of remuneration, patents for invention emerged earlier in Spain – or more precisely in Castile – than in the Low Countries. Patents appeared in Castile at the end of the fifteenth century and became more frequent after the task of examining inventions

and granting patents in the kingdom was entrusted to the Council of Castile. The first patent granted by this Council dates from 1522. The Council of Indies soon began to grant patents as well. Nicolás Garcia Tapía has found that between 1478 and 1650 some 240 patent applications were submitted by Spanish and foreign inventors to the king or to the Councils of Castile and the Indies, of which 152 were actually approved. The number of applications submitted to the Council of Castile between 1522 and 1622 amounted to 140.[13] However, Castilian patents were seldom accepted in Aragon and the number of patents granted by the Council of Aragon remained dismally low until the early eighteenth century. The validity of patents granted by the Council of Castile was not extended to the entire territory of Spain until after the abolition of the Council of Aragon in 1716. [14]

In the Low Countries, patents for invention were regularly issued from the 1550s onwards. Granting patents was originally a prerogative of the sovereign lords of the Netherlands, Charles V and Philip II, who also happened to be Kings of Spain. After the Revolt, the power to award these privileges in the newly-established Dutch Republic became more widely diffused. Patents were actually granted at three levels of authority: the central governing body of the Republic (the States General), the estates of the separate provinces (Holland. Zeeland etc.) and town governments. Between c.1590 and the 1650s the largest number of patents was issued by the States General. After that, the States of Holland succeeded the States General as the principal patent-granting institution. This shift of primacy occurred shortly after the States General introduced the rule that a patent was only valid in a particular province of the Republic, if it had been confirmed by the estates of the province concerned. The formal barriers for transfer between provinces were much lower than between Castile and Aragon, however. In contrast with Castile, the total number of patent applications in the Dutch Republic is not known. We *do* know, however, that most of the patents granted by the States General and the States of Holland date from the period between c. 1580 and 1720: 553 and 224, respectively (which, understandably, partly concerned the same inventions). Another fourteen and 58, respectively, were granted between 1720 and 1795.[15] The procedure followed by these agencies to validate the merits of a new invention was not unlike that in Castile: it normally involved an assessment by officials, sometimes assisted by a group of experts.[16]

Both the Castilian and the Dutch patent systems acted as poles of attraction for knowledge flows from a much wider area than the state territory itself. The key difference was that in the Dutch case natives formed a much larger proportion of the would-beinventors than in the case of Castile. Whereas in the Dutch Republic between 1580 and 1720 some 65 – 80 % of all patentees originated from the country itself, in Castile between 1478 and 1650 only 56 % of the

patentees were Spaniards, while 17 % hailed from Spanish America and some 25 % from other countries in Europe.[17]

As the previous section on longitude prizes already suggested, people with new ideas could not only be tempted by patents or licenses of a similar nature. Rewards and prizes, sponsorship by public or semi-public institutions or patronage could offer powerful attractionsm, too. All of these forms of material award were in operation both in the Spanish and the Dutch networks of knowledge. In both cases, the major institutions charged with the regulation of trade and shipping between the home country and the overseas world, the House of Trade and the VOC, respectively, played a pivotal part in providing material support for the production and circulation of 'useful' knowledge.[18] The chief differences between the Spanish and Dutch cases appear to be, that in the Netherlands in the sixteenth and seventeenth centuries the production and circulation of 'useful' knowledge was also very actively promoted by city governments and that in the later eighteenth century the number of patents granted by state agencies was dwarfed by the number of rewards and premiums for innovations granted by a private society (the Economic Branch of the Holland Society of Sciences): 376 between 1778 and 1797 by the latter, against less than forty by the States General and the States of Holland.[19]

Criteria of access

Access to global networks of knowledge was in the Spanish case, on paper at least, less open than in the Dutch one. Spain appeared in this respect to maintain a much higher degree of exclusiveness than the Dutch Republic. Religion or national background were used as criteria to exclude particular groups from professions or positions where they could have participated in the production or circulation of knowledge. Jews and Muslims were forbidden to enter the Indies. A decree of 1552, which ruled that potential emigrants must provide proof from their hometowns or villages of their *limpieza de sangre*, made it almost impossible to evade this prohibition.[20] The statutes of *limpieza de sangre* also effectively barred converted Moors from entering the universities and the medical profession.[21] In 1609, the Moriscos, like the Jews more than a century before, were expelled from Spain altogether. Fear of spying led to a prohibition on the employment of Portuguese pilots in the India trade as early as 1515. Although the King relaxed the regulation on the admission of foreign pilots in the early 1580s, he strictly forbade the employment of English pilots since 1589 and of French and 'rebel Dutch' after 1595. [22] Yet, such restrictions do not imply that the Spanish network knowledge hardly attracted any expertise from abroad. Foreign interest in longitude prizes was not an isolated example. Engineers are also a telling case in point.

Even if, as García Tapia rightly has stressed, the vast majority of engineers in sixteenth-century Spain were Spanish, some 15 % of all engineers hailed from Italy and another 10 % were German, Flemish, French or English.[23]

Restrictions on access to knowledge networks on the basis of 'purity of blood' or national background were unknown in the Dutch Republic. The barriers that were in force, rested on religious criteria. The practice of other confessions than that of the Dutch Reformed Church was formally prohibited. The Dutch Reformed Church was the only recognized, public church. The most severe restrictions applied to Catholics, who made up a third or more of the population of the United Provinces. Being Catholic was not against the law, but "it was quite illegal to live and worship like one". [24] Transnational religious organizations that played a prominent part in the production and circulation of knowledge in Catholic Europe, such as the Jesuits, the Dominicans or the Oratorians, were not allowed to have a public presence in the Dutch Republic. Jesuit colleges or Oratorian schools could not exist. Membership of the Reformed Church was mandatory for professors at the newly-founded institutes of higher learning in the United Provinces, such as the universities of Leiden, Groningen and Utrecht and the Athenaeum Illustre in Amsterdam, though not for students. Many Catholics nevertheless preferred to study at Catholic universities across the border, like Louvain or Cologne, instead.[25]

However, formal restrictions on activities of Catholics did not imply that the knowledge hub in the Dutch Republic was disconnected from networks in the Catholic world. Dutch scholars and publishers exchanged knowledge with Jesuits all the same. When the Jesuit Martino Martini, for instance, en route from Macao to Europe, arrived in Batavia in 1652, he provided the governor-general and council of the VOC with precise information on the commercial and political conditions in China and showed them a description and atlas of the empire which he had recently completed.[26] Having travelled to Amsterdam aboard a Dutch East-Indiaman, he brought out this *magnum opus* as part 6 (*Novus atlas sinensis*) of the world atlas published by the firm of Joan Blaeu, who also served as hydrographer and examiner of pilots of the Chamber of Amsterdam of the VOC.[27] Jacob Golius, professor of mathematics and Oriental languages at the university of Leiden eagerly grasped the opportunity to talk with Martini, when he changed barges in the city, and later called on him for a longer conversation in Antwerp.[28] Books by Johan Nieuhof and Olfert Dapper on the activities of the VOC in China, published in 1665 and 1670, were partly based on publications by Jesuits such as Martini and Athanasius Kircher (whose China illust*rata* appeared in Amsterdam as well)[29] Nicolaes Witsen, director of the Dutch East-India Company, owed the new maps of China and Manchuria and notes on the population of the Chinese Empire

included in his *magnum opus Noord- en Oost Tartarye* to the Flemish Jesuit Philip Couplet, who had lived in China from 1658 till 1681 and then had returned to Europe aboard a ship of the VOC.[30]

Secrecy and openness

Moving from the access criteria to the knowledge itself we can observe that the degree of openness of knowledge in the Spanish network was de facto lower than in the Dutch case. Or to put it the other way around: knowledge in the Spanish network more often remained secret, or at least moved less widely, than in the Dutch network. Research of the past thirty years has uncovered the sheer profusion and originality of activities in science and technology carried out in the Spanish empire especially during the sixteenth and eighteenth centuries, in particular in such areas as natural history, medicine, geography, cartography and navigation technology. The insights reached by this recent scholarship, one hopes, should put the Black Legend about the obscurity and backwardness of Spain finally to rest. [31]

Yet, this fresh research has also revealed that some important contributions to these fields of useful knowledge did not appear in print at the time they were made, or at best only in an incomplete version, and that their circulation remained limited to a small audience. Many treatises by official teachers of mathematics in the late sixteenth and early seventeenth century were never published, for example, and the voluminous survey by Francisco Hernández on the flora of New Spain, completed in the 1570s, only appeared in a truncated version many decades later. [32] This 'underachievement' in the circulation of knowledge partly sprung from a deliberate policy of secrecy in the interest of the state, notably in the area of geography and navigation technology, but also had to with financial constraints: a growing shortage of money since the end of the sixteenth century put a brake on the distribution of the fruits of knowledge. [33]

In the United Provinces, openness of knowledge was de facto the rule until about 1750. Foreign travellers normally had no problem at all in collecting the information they wanted. They were pleasantly surprised that the Dutch were not as distrustful or secretive as people in other European countries. It was not until the second half of the eighteenth century that foreigners more frequently reported about obstacles being encountered when they attempted to get access to sites of technological interest and that, at last, prohibition orders on the export of technology appeared on the statute-books of the States General, the States of Holland and individual cities.

The persistence of this regime of openness until about 1750 was not the result of some high-minded principle about the value of the free flow of knowledge. Open access to knowledge was in the Dutch Republic never proclaimed an official goal of policy. Openness simply existed

as a matter-of-fact.[34] A few exceptions to the rule can be found before 1750, but most of them were of minor consequence. The principal exception for a while concerned the Dutch East-India Company. In 1619, the VOC obtained a privilege from the States General to the effect that no one would be permitted, without the express consent of the Directors, to publish or copy maps or descriptions concerning the area exclusively reserved for trade by the company. In reality, however, this policy of secrecy was abandoned less than twenty years later. Charts, maps and descriptions based on data gathered by the VOC circulated widely inside and outside the Netherlands in the later seventeenth and eighteenth century.[35]

Changes and limitations

In the previous parts of this paper I have compared the Spanish and Dutch global networks of knowledge from various structural perspectives: nature of infrastructures, forms of remuneration, criteria of access and degree of openness or secrecy of knowledge. This comparison has shown that in the Iberian case the circulation of knowledge was to a high extent managed by 'visible' hands of public institutions and religious organizations whereas in the Dutch case the management of the global networks of knowledge took place by a combination of 'visible' and 'invisible' hands – in other words by a mix of market and non-market mechanisms. In the Spanish network, material forms of remuneration such as patents and prizes became less attractive to inventors after the middle of the seventeenth century. The Spanish network proved to more restrictive in its rules of admission and showed less openness in the circulation of knowledge than the Dutch one. Although the Dutch global network of knowledge developed later than the Spanish one and partly built on the influx of knowledge from Spain, it also attracted inputs from England, France, Italy, the Holy Roman Empire and other countries and actually began to export huge amounts of 'useful' knowledge produced or collected in the Netherlands itself from the early seventeenth century onwards.

Both in the Spanish and the Dutch networks, the quest for knowledge was marked by a pronounced empiricist bent, as Antonio Barrera-Osorio and Harold Cook have shown in their recent books.[36] Yet, flows of knowledge in these networks were not restricted to mere movements of bits of information from locality to locality via the mobility of craftsmen, shipments of plants and medicines or the spread of printed materials. In the process of circulation, knowledge often also underwent a transformation from a particular, localized shape to the form of a general, propositional statement, or a collection of statements. Botanical

classification systems, reports on the properties of medicines or sailing directions containing information on patterns of winds, currents and magnetic declination, based on myriads of local observations, are cases in point. Besides, the presence of a strong empiricist tendency did not preclude the development of another, mathematical approach to nature, which contributed to the revolution in science that culminated in the Newtonian synthesis. The Dutch experience at least demonstrates that these tendencies could perfectly co-exist. The Netherlands was after all also home to a few masterminds of the 'mechanization of the world picture', such as Isaac Beeckman, René Descartes and Christiaan Huygens and it found itself after 1700 in the forefront of the spread of the Newtonian philosophy on the Continent.

Barrera-Osorio has argued that in the Spanish case the changing economic, financial and political circumstances in the first half of the seventeenth century led to a decrease of institutional support for the quest for natural knowledge, at least in Spain itself. 'Regarding the New World, activities such as natural history, cosmography, and technology were no longer necessary as they had been during the sixteenth century for the establishment of economic activities and political jurisdictions', he points out. In Spanish America, however, the empirical and collaborative practices which had emerged during the empire-building in the sixteenth century, were continued throughout the early modern period, albeit with a different purpose. The communities that had arisen in the American colonies 'had developed their own interests and activities in regard to the study and understanding of the New World', namely to use natural history and cosmography 'to create their own territorial and cultural identities'.[37]

Yet, a reversal in the Spanish trajectory seems appears to have occurred in the last decades of the eighteenth century. Like its Habsburg predecessor, the Bourbon central government assumed a leading role in the collection and transmission knowledge about nature in the overseas world. And the rationale behind this policy was remarkably similar to that of the Habsburg era. According to Daniela Bleichmar it all had to do with the 'the economic and political promise of natural history'. Between 1760 and 1808 the Spanish government sponsored no less than 57 history expeditions to its colonies. During these expeditions travellers did not only systematically collect all sorts of data on natural history but also carried out geographical explorations, made astronomical observations and produced maps and charts. The knowledge that was thus gathered and stored found its way throughout the Spanish empire via an extended infrastructure of knowledge.[38] The role of religious organizations, by contrast, was substantially reduced. The network of the Society of Jesus was entirely dismantled.

Developments in the Dutch case differed from the Spanish trajectory in three respects. In contrast with the marked slowdown observed in seventeenth-century Spain, the circulation of

knowledge centred on the nodal point in the Dutch Republic showed no signs of slackening in the seventeenth and eighteenth centuries. The existing knowledge infrastructure in the Dutch Republic, characterized by a great variety of facilities, a high degree of decentralization, a low measure of coordination by state institutions and a relatively important role of market mechanisms was clearly very capable to sustain this continued process of collection, assessment, exchanged, storage and dissemination of knowledge. The rise of commercial values detected by Harold Cook, joined with the persistent emulation between cities and provinces, were powerful forces that kept the Dutch global network of knowledge in motion.

Viewed as a whole, however, the Dutch network appears to have remained more 'centred' than the Spanish one. New hubs of knowledge in the overseas colonies did not arise until a very late stage. Outside the home country, the knowledge infrastructure in the Dutch empire long remained curiously underdeveloped. While Spanish America, for example, boasted the foundation of thirty universities between 1538 and 1810 along with numerous colleges, monasteries and hospitals[39], the Dutch settlements only managed to sustain a few institutions that served more or less continuously as centres for the collection and circulation of knowledge, viz. the hydrographical office, the hospital and the apothecaries' shop in Batavia and the Company's garden in Cape Town. This limitation may well be explained by the fact that the administration of the Dutch overseas settlements was entirely left to trading companies, without any meaningful interference by the state of religious organizations at all. It was not until the very end of the eighteenth century that colonial cities like Batavia and Paramaribo saw at last the emergence of similar communities with their own interest and activities in understanding their natural environment as in Spanish America 200 years before.[40]

Finally, the Dutch case also differed from the Spanish one in the absence of scientific expeditions at the end of the eighteenth century. Unlike the Spanish government (or the English, French and Russian ones for that matter), the Dutch state did not take an active part in the systematic collection and circulation of natural knowledge about the overseas world by setting up a programme of natural history expeditions and voyages of discovery. In the travellers' world of the late eighteenth century, the Dutch Republic was conspicuous by its non-appearance.

The divergent paths of the Spanish and Dutch global networks of knowledge suggest that the typical structures of these networks, depending on the circumstances, could bring their own benefits or limitations. Neither the visible hand in the Spanish network nor the mix of market and non-market mechanisms in the Dutch case had an *invariable* advantage in promoting the production and circulation of knowledge. The Dutch structures probably had the advantage in the seventeenth century, the Spanish ones in the sixteenth and the late eighteenth centuries.

Circumstances were crucial. That is a fruitful starting point for further comparative research on global networks of knowledge.

Notes

[1] Art Jonkers, 'Rewards and prizes', *The Oxford Encyclopedia of Maritime History*, vol. III (Oxford 2007) 433-436, p.434.
[2] C.A.Davids, *Zeewezen en wetenschap. De wetenschap en de ontwikkeling van de navigatietechniek in Nederland tussen 1585 en 1815* (Amsterdam/Dieren 1986), 69-74, 129-141, 178-182.
[3] Davids, *Zeewezen en wetenschap*, 73, 81-83, 132, 180, G.Vanpaemel, 'Science disdained: Galileo and the problem of longitude', in: C.S. Maffioli and L.C.Palm (eds.), *Italian sicentists in the Low Countries in the XVIIth and XVIIIth centuries* (Amsterdam 1989) 111-119, pp.113-124.
[4] Karel Davids, '"Weest EenDERLEY sins". Jan Hendricksz. ichs van der Ley (ca.1566-1639) en de eenheid in godsdienst en navigatie', in: Remmeldt Daalder, Frits Loomeijer and Diederick Wildeman (eds.), *Koersvast. Vijf eeuwen navigatie op zee* (Zaltbommel 2005) 132-141, p.135-136.
[5] Davids, *Zeewezen en wetenschap*, 69-71.
[6] Davids, *Zeewezen en wetenschap*, 70-71, 75, Art Jonkers, *North by Northwest. Seafaring, Science, and the Earth's Magnetic Field, 1600-1800* (Amsterdam 2000) 304-314.
[7] David Goodman, 'Science, medicine, and technology in colonial Spanish America: New interpretations, new approaches', in: Daniela Bleichmar, Paula de Vos, Kristin Huffine and Kevin Sheehan (eds.), *Science in the Spanish and Portuguese empires* (Stanford 2009) 9-34, pp.12-24, Maria M. Portuondo, 'Cosmography at the Casa, Consejo, and Corte during the century of discovery', in: idem, 57-77, Antonio Barrera-Osorio, 'Knowledge and empiricism in the sixteenth-century Spanish Atlantic world', in: idem, 219-232, Ma.Isabel Vicente Maroto, 'Los cosmógrafros españoles del siglo XVI: del humanista al técnico', in: Victor Navarro Brotóns and William Eamon (eds.), *Más allá de la Leyenda Negra. España y la Revolución Cientifica* (Valencia 2007), 347-369, p.351, Mariano Esteban Piñero, 'La institucionalización de la ciencia aplicada en España del siglo XVI. Un modelo cuestionado', in idem, 427-442, David C. Goodman, *Power and penury. Government, technology and science in Philip II's Spain* (Cambridge 1988) chapters 2 and 5.
[8] Karel Davids, 'Amsterdam as a centre of learning in the Dutch golden age, c.1580-1700', in: Patrick O'Brien, Derek Keene, Marjolein 't Hart and Herman van der Wee (eds.*), Urban achievement in early modern Europe. Golden Ages in Antwerp, Amsterdam and London* (Cambridge 2001) 305-323, Florike Egmond, 'Clusius and friends. Cultures of exchange in the circles of European naturalists', in: Florike Egmond, Paul Hoftijzer and Robert Visser (eds.), *Carolus Clusius. Towards a cultural history if a Renaissance naturalist* (Amsterdam 2007) 9-48.
[9] Karel Davids, 'Ondernemers in kennis. Het zeevaartkundig onderwijs inde Republiek gedurende de zeventiende eeuw', *De Zeventiende Eeuw*, 7 (1991) 37-48, idem. 'Een huis vol handboeken. Het Huis van Keulen en de vakliteratuur voor de zeeman', in: E.O. van Keulen, W.F.J.Mörzer Bruyns and E.K.Spits (eds), *'In de Gekroonde Lootsman'. Het kaarten-, boekuitgevers en instrumentmakershuis Van Keulen te Amsterdam 1680-1885* (Utrecht 1989) 44-60, Peter de Clercq*, At the sign of the oriental lamp. The Musschenbroek workshop in Leiden, 1660-1750* (Rotterdam 1997), Bert van Selm*, Een menighte treffelijcke boecken. Nederlandse boekhandelscatalogi in het begin van de zeventiende eeuw* (Utrecht 1987)
[10] Luke Clossey, *Salvation and globalization in the early Jesuit missions* (Cambridge 2008) 114-135.
[11] Davids, *Zeewezen en wetenschap*, 72, 135-137.
[12] Florike Egmond, 'Clusius and friends'.
[13] José Antonio Mateos Royo, 'State policy, institutional framework and technical monopoly in early modern Spain: invention patents in the Crown of Aragon during the seventeenth century*', History and Technology*, 25 (2009) 147-162, pp.149-150, Nicolás García Tapia, *Tecnica y poder en Castilla durante los siglos XVI y XVII* (Salamanca 1989) 195-201.
[14] Mateos Royo, 'State policy', 147-148.

[15] Karel Davids, *The rise and decline of Dutch technological leadership. Technology, economy and culture in the Netherlands, 1350-1800* (Leiden 2008) 401-404.
[16] Karel Davids, 'Patents and patentees in the Dutch Republic', *History and Technology*, 16 (2000) 263-283, pp.267, Antonio Barrera-Osorio, 'Knowledge and empiricism, in: Bleichmar, De Vos, Huffine and Sheehan (eds.), *Science in the Spanish and Portuguese empires*, 221-227.
[17] Davids, 'Patents', 268, Mateos Royo, 'State policy', 152.
[18] Cf. for instance Barrera-Osorio, 'Knowledge and empiricism' and Davids, *Zeewezen en wetenschap*, chapters 11 and 12.
[19] Davids, *Rise*, 410-416, 478-482.
[20] J.H. Elliott, *Empires of the Atlantic world, Britain and Spain in America 1492-1830* (New Haven 2006) 51.
[21] Goodman, *Power and penury,* 37.
[22] Goodman, *Power and penury,* 80-81.
[23] Nicolás García Tapia, *Ingeniera y arquitectura en el Renacimiento español (*Valladolid 1990) 41.
[24] Charles Parker, *Faith on the margins. Catholics and Catholicism in the Dutch Golden Age* (Cambridge Mass. 2008), 10.
[25] Willem Frijhoff and Marijke Spies, *1650 Bevochten eendracht* (The Hague 1999) 247-248.
[26] W.Ph.Coolhaas (ed.), *Generale missiven van Gouverneurs-Generaal en Raden van Indië* , 11 vols. (The Hague 1960-2004) vol.II., 606-607, letter Gouverneur Generaal en Raden to Heren XVII, 24 December 1652.
[27] J. Barten, 'Hollandse kooplieden op bezoek bij concilievaders', *Archief voor de Geschiedenis van de Katholieke Kerk in Nederland*, 12 (1970) 75-120, pp.86-87, B. Szczésniak, 'The seventeenth century maps of China. An inquiry into the compilations of European cartographers', *Imago Mundi*, 13 (1956) 117-136.
[28] J.J.L.Duyvendak, 'Early Chinese studies in Holland', *T'oung Pao*, 32 (1936) 293-344.
[29] Edwin van Kley, 'Qing dynasty China in seventeenth-century Dutch literature 1644-1700', in: W.F. Vande Walle en Noël Golvers (red.), *The history of the relations between the Low Countries and China in the Qwing Era (1644-1911)* (Leuven 2003) 217-234, pp. 220-221.
[30] Marion Peters, *'Mercator sapiens' (De wijze koopman). Het wereldwijde onderzoek van Nicolaes Witsen (1641-1717), burgemeester en VOC-bewindhebber van Am*sterdam (Groningen 2008) 154-161.
[31] See especially Navarro Brotóns and Eamon (eds.), *Más allá de la Leyenda Negra,* and Bleichmar, De Vos, Huffine and Sheehan (eds.), *Science in the Spanish and Portuguese empires.*
[32] Raquel Álvarez Peláez, 'Un Nuevo Mundo para la ciencia: el descubrimiento de la naturleza americana', in: Brotóns and Eamon (eds.), *Más allá de la Leyenda Negra,* 147-154, pp.151, Vicente Maroto, 'Los cosmógrafos españoles del siglo XVI', 351, Esteban Piñero, 'Institucionalización', 430, Goodman, *Power and penury,* 234-236.
[33] Alison Sandman, 'Controlling knowledge, navigation, cartography, and secrecy in the early modern Spanish Atlantic', in: James Delbourgo and Nicholas Dew (eds.), *Science and empire in the Atlantic world* (New York/London 2008) 31-51, pp.33-41, Esteban Piñero, 'Institucionalización', 430, Goodman, *Power and penury*, 262.
[34] Karel Davids, 'Openness or secrecy ? Industrial espionage in the Dutch Republic', *The Journal of European Economic History*, 24 (1995) 333-348, Davids, *Rise*, 388-400, 472-480.
[35] Kees Zandvliet, *Mapping for money. Maps, plans and topographic paintings and their role in Dutch overseas expansion during the 16th and 17th century* (Amsterdam 1998) 94-98, 128-130
[36] Antonio Barrera-Osorio, *Experiencing nature. The Spanish American empire and the early Scientific Revolution* (Austin 2006), Harold Cook, *Matters of exchange. Commerce, medicine, and science in the Dutch Golden Age* (New Haven/London 2007).
[37] Barrera-Osorio, *Experiencing nature*, 133-134.
[38] Daniela Bleichmar, 'A visible and useful empire. Visual culture and colonial natural history in the eighteenth-century Spanish world', in: Bleichmar, De Vos, Huffine and Sheehan (eds.), *Science in the Spanish and Portuguese empires*, 290-310, pp.297-280.
[39] Goodman, 'Science, medicine, and technology', 26.
[40] Karel Davids, 'Sources of technological change in the Dutch Guianas, c.1670-1860', in: A.Lafuente, A.Elena and M.L.Ortega (eds.), *Mundialización de la ciencia y cultura nacional* (Madrid 1993) 659-672, pp.669-670.