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INNOVATION, INSTITUTIONS AND MIGRATION: TRANSFER OF TECHNOLOGY IN DUTCH SHIPBUILDING, 500-1700

André F.L. VAN HOLK

“For a long time historians [and for that matter archaeologists] systematically underestimated the mobility of workers in pre-industrial Europe, on the assumption that individuals before the nineteenth-century industrialisation and urbanisation were essentially place-bound” (Reith 2009, p. 114).

Abstract

This paper focuses on innovation in shipbuilding. The central question is by what mechanisms innovation took place. Was new technology locally invented or was it transferred, from the outside, as exogenous knowledge? How did technology transfer work? Two main strands of reasoning will be followed. The tainted concept of migration will be revitalised. In addition, the role of guilds will be analysed. The role of guilds is crucial for understanding the system of the tramping journeyman, implying the sharing of new tacit knowledge. The step-by-step development of shipbuilding technology was stimulated by the guild system of transferring knowledge.

Keywords

Guild, innovation, migration, mobility, shipbuilding

Résumé

Cet article s’interroge sur la place de l’innovation dans la construction navale. La question centrale est de savoir par quels mécanismes elle s’effectue. La nouvelle technologie a-t-elle été inventée localement ou provient-elle de l’extérieur? Et comment ce transfert de technologie fonctionne-t-il?

Deux grandes pistes d’analyse seront invoquées ici : le concept de migration, la plupart du temps considéré d’un point de vue négatif, sera reconsidéré. Par ailleurs, le rôle des guildes sera analysé, puisqu’il est crucial pour comprendre le système du compagnonnage itinérant, qui implique le partage empirique de nouvelles connaissances. Le développement progressif de la technologie dans la construction navale a donc été vraisemblablement stimulé par un transfert des connaissances opéré à l’intérieur même des guildes.

Mots-clés

Guilde, innovation, migration, mobilité, construction navale

In this paper I would like to discuss the topic of innovation in shipbuilding. The central question I would like to address is: By what mechanisms did innovation take place? A group of economic historians, including Epstein (1994, 2009, 2013), Epstein and Prak (2009), Reith (2009), van Zanden (2009), Prak and van Zanden (2013) among others, as well as the maritime historian Unger (2013), have developed some interesting ideas about innovation and technological change. Another question is: Are these ideas applicable to innovations in Dutch shipbuilding?

A common line of reasoning in current archaeology is that knowledge develops in isolation, for example, as an evolutionary process. On the contrary, I will argue that innovation often takes place as a cultural process of exchange of information and ideas. Information does not spread by itself. For all kinds of exchange, human mobility is essential, at least in the premodern period.

1. TRANSFER OF TECHNOLOGY

If technology was transferred, how did it work? Basically we can differentiate between two types of technology transfer.

The first is by the spreading of ideas, which is termed diffusion (for example, through trade), and the second is by migration, a term designating the spatial movement of people (Burmeister 2000, p. 559; 2016, p. 42). Thus, a temporary or permanent change of residence is involved. The duration of the movement of people can take place on three different time scales. The first involves short-term contacts: trade is a good example. Secondly, migration could be temporary: for example, seasonal migration or the wandering of journeymen. The last form of movement is permanent migration: permanent colonisation or the settlement of people in new surroundings. More generally put, technology can be transferred by the mobility of people. This seems obvious for maritime archaeologists, but for most other branches in archaeology it is not. There, an ‘immobilist’ stand is often taken (Hakenbeck 2008, p. 17).

1.1. MIGRATION

As scholars of migration archaeology have pointed out (Hakenbeck 2008; Burmeister 2000, 2016), under the culture-historical paradigm in archaeology, migration was used as an

unproven explanation, as an axiom that did not have to be explained any further. As such, it was misused by German archaeologists for nationalistic purposes in the 19th and 20th century. The advocates of ‘New Archaeology’ totally abandoned the concept of migration because, from their systemic and evolutionary perspectives, historical events like migrations were attributed no explanatory power (Burmeister 2016, p. 49). Of course, the critic was right to condemn the theoretical and methodological deficits of earlier approaches to migration. In particular, the concept of archaeological cultures, their equation with ethnic groups, and the simplistic ways in which migrations were used to explain social change were criticised (Hakenbeck 2008, p. 14). But with this stand, a fundamental factor of human existence was forgotten: people have been on the move constantly and have taken their ideas and customs with them on the way.

Currently, archaeologists of migration are trying to revive the concept of migration (Burmeister, 2000, p. 548-552). Some of the new ideas are:

- Migration is a socio-cultural process that must be studied and not taken for granted;
- Migration can be group specific: gender, age or elite (selective migration);
- Group sizes can differ greatly: from small family-sized groups to larger conglomerations of society (versus presupposed mass migration);
- Migration can be a long term process, taking place over a long period of time in different phases (versus one moment in time);
- Migrating can encompass reverse migration.

One of the problems is that these processes are difficult to trace in the archaeological record.

1.2. CULTURE CONTACT

Human mobility might be the best way to achieve technological transfer, but we cannot reverse this statement. Culture contact does not automatically lead to the transfer of technology. For successful innovation by culture contact, there has to be a drive on the receptive side to adopt the innovation. A good example is a man with an *eharo* mask from Papua New Guinea: a sailing vessel is mounted on top of the mask (fig. 1) (Davies, Taçon 2013, p. 114). In reaction to early colonial contact, people of New Guinea tried to find ways to control or counteract the dominant colonial material culture by incorporating that culture into their own world, but clearly without the technological innovative impact. There are many more examples of culture contact between the ‘high technology’ of the western world and the intricate worldview of indigenous people. In these cases the western ‘superior’ technology is often mimicked.

2. EXAMPLES OF TECHNOLOGY TRANSFER

2.1. THE SPREAD OF THE NORDIC CLINKER SHIPBUILDING TRADITION: A CLASSIC CASE OF MIGRATION

From the 6th century BC onwards people of the coastal area of the northern Netherlands lived on manmade dwelling



Fig. 1: Man from Papua New Guinea wearing an eharo mask topped by an effigy of a ship (after Davies, Taçon, 2013, p. 114).

mounds built on the salt marshes, so-called *terpen* (province of Friesland) or *wierden* (province of Groningen). This salt marsh area was undiked and would flood temporarily (Nieuwhof 2010, p. 173). Excavations in the area have revealed that at the end of the 4th century AD the area was characterised by a completely new composition of material culture (i.e. in housing, metalworking, appearance of cruciform brooches, new pottery types of (Anglo-) Saxon style, introduction of formal cemeteries) suggesting the arrival of new inhabitants (Nieuwhof 2011, p. 56). Another, often overlooked, element of the new composition of material culture is the appearance of clinker nails (van Holk 2003, p. 301). In the 1960s and 1970s, however, in archaeological reasoning the culture-historical paradigm was rejected and with it migration as an explanation for this change.

Once it could be proven that the area was almost completely deserted in the 4th century AD, the idea of newcomers started to gain ground. The possible areas of origin of the new inhabitants are the regions between the Weser and Elbe, Schleswig-Holstein and possibly Scandinavia (Nicolay 2010, p. 125).

Among the finds excavated in the artificial dwelling mounds were clinker nails, dating from the 5th to the 9th century AD. It is not surprising that the new inhabitants took along with them their shipbuilding technology. More curious are some wreck finds of ships supposedly built in the Netherlands, dating from the 15th and 16th century, built in the Nordic tradition. It seems therefore that the map of the route followed by migrating people from the north has to be revised, because it is very likely that colonists not only populated Great Britain, but also settled the coastal area of the Netherlands. The newcomers continued to build ships the way they were used to do, with overlapping

strakes connected by clinker nails. So, in this case, it is not so much a technology transfer as a continuation of known technology, a continuation of a tradition of shipbuilding.

2.2. THE CASE OF THE COG: A REAL MULTI-CULTURAL TECHNOLOGICAL PHENOMENON

I would like to discuss two technological features of the cog: first, the combined flush and lapstrake hull; and second, cross beams in the form of through beams extending through the hull planking. This second feature, however, is not a general constructional feature of cogs.

In my opinion the bottom-based, flush bottom and lapstrake sides of the cog can be traced back to Roman barges built in the Romano-Celtic tradition (Hocker 2004, p. 77; van de Moortel 2011, p. 89). There are more common features that the cog shares with the Romano-Celtic tradition apart from the flush bottom and lapstrake sides: for example, the use of double-clenched nails, the caulking method and the mast step construction (see also Hocker 2004, p. 77; Adams 2003, p. 203). One can wonder about the long ‘gap’ between the Roman era and the first appearance of the cog, but when we take a closer look at vernacular craft, we will see that this supposed gap is filled by a continuous tradition of river craft showing the same planking arrangement up to the Middle Ages and even into recent times, for example, along the Danube (Sarrazin, van Holk 1996) and in Polish waters (Litwin 1991). This concept has been used for centuries, so the combination of flush bottom planks and overlapping side strakes is not an innovation at all. This does not mean that the cog as a total concept was not innovative.

In the last quarter of the 11th century AD through beams are introduced into northwestern Europe in several ship types, for example the Kolding cog (dendrochronologically dated to 1188/1189 AD) and the ‘Big Ship’ of Bergen (dendrochronologically dated to 1187/1188). It is interesting to note that the

Kollerup cog of 1155 AD does not feature through beams (Hansen 1944, p. 122; Bill 2002, p. 108).

It is most likely that the introduction of through beams made the building of bigger (higher sides) and more ships easier, especially for ships that were built shell-first. Hand in hand with other changes this resulted in a cheaper, more economical mode of production.

In the Mediterranean the use of the through beam in shipbuilding is widespread and it probably originated there (see also Bill 2002, p. 108). There are many examples from the 1st to 10th century AD, to name a few: Nemi, Laurons, Pantano Longarini; Yenikapi 5 (fig. 2), 11, 12, 14; Yassi Ada 1; Dor 2006 (Casson 1971; Bass, van Doorninck 1982; Throckmorton 1987, p. 94-95; Pomey *et al.* 2012; Navri *et al.* 2013; Pulak *et al.* 2015, p. 55-57; Jones 2017; Ingram 2018; Özsait-Kocabaş 2018). A stone relief depicting the port of Rome from around the 2nd century AD also shows through beams (Casson 1971, fig. 144 and 146). In northwestern Europe we have three examples of ships, predating cogs, equipped with through beams. The EP1-Taillebourg wreck was discovered in the Charente River and has a calibrated radiocarbon date of AD 145-420 (Rieth 2006, p. 78-83) and the County Hall ship, reconstructed with several through beams and dating to *circa* 300 AD (Marsden 1994, p. 109-129). The protruding beams of these vessels might be directly related to the Roman presence in northwestern Europe at that time since there are many examples of technology transfer in this region during the Roman Period.

I have to mention one other interesting find with through beams: the 7th century Port-Berteau II shipwreck, found in the Charente River near the Atlantic coast of France (Rieth 2000, p. 225-228). Is this an example of a regionally preserved trait from Roman times? Up to now it is an isolated find (for this period), so it is difficult to understand the meaning of this boat in the development of shipbuilding. It is clear that more research is necessary to solve this question. With reference to the Port-Berteau II wreck, an interesting hypothesis has been put

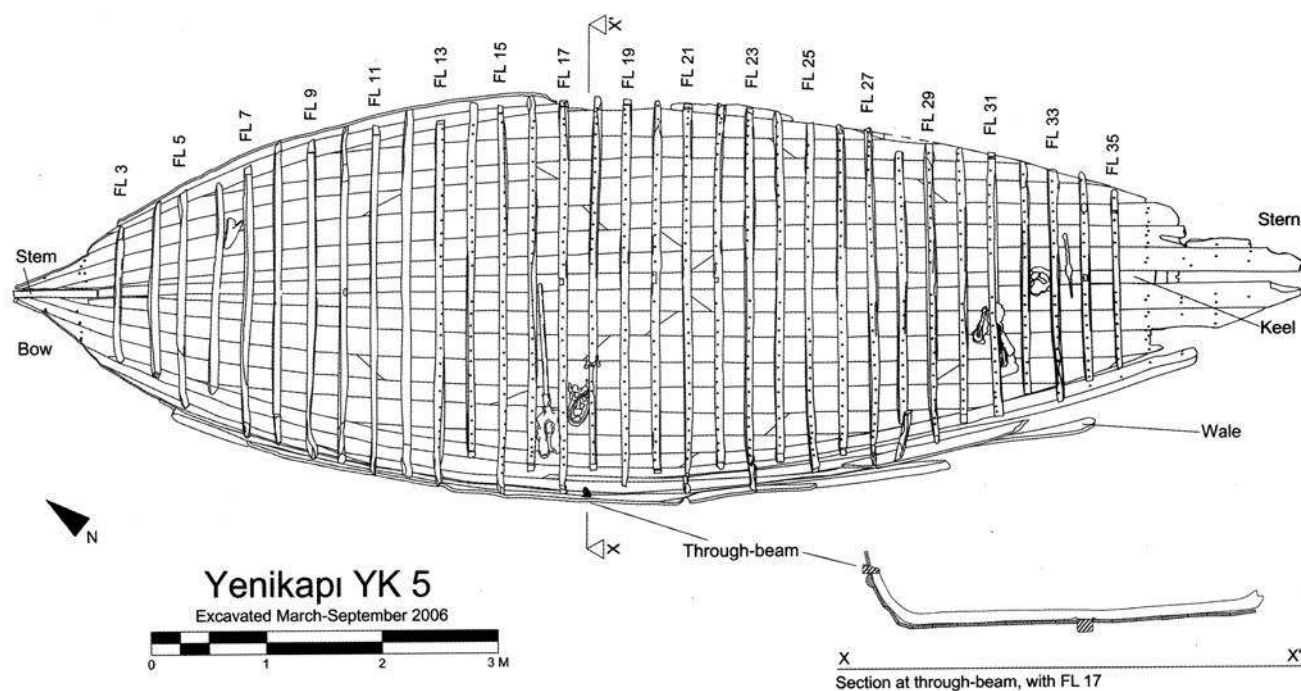


Fig. 2: Through beam of Yenikapi 5, 10th century AD (after Pulak *et al.* 2015, p. 55, fig. 17).

forward about the continental influence on the transition from shell to skeleton in Mediterranean ship construction (Pomey *et al.* 2012, p. 305-308). Concerning the through beam, this (reverse) influence is unlikely from a chronological point of view, because the oldest wrecks in the Mediterranean equipped with through beams (Nemi, 1st century AD and Laurons, *circa* 200 AD) predate their continental counterparts, except for EPI-Taillebourg. However, in this last case, we have the uncertainty of quite a broad dating range.

But how did the technology transfer work for the protruding beams in the cog? Or was there no transfer at all and was this feature preserved in local vernacular craft like Port Berteau II?

There could also have been a renewed transfer of technology. In that case we are left with several scenarios. There were contact zones in Spain and southern Germany and contacts over land and by sea. Contact zones in Spain were via the Muslim conquest of Al-Andalus and, later on, Italian shipbuilders that were brought to Iberia to establish a navy for the kingdoms of Castille (1037-1157) and Portugal (1139-1908) (Unger 1980, p. 130). In the 12th century, Frederick I Barbarossa was the Holy Roman Emperor, ruling over both northern Italy and southern Germany. Shipbuilding techniques could have crossed the Alps in this context (Vlierman 1997, p. 92). Last but not least and maybe more likely is the technology transfer by sea, especially during the Second Crusade in 1147, when a fleet of 190 ships from different parts of western and southern Europe sailed to Syria (Unger 1980, p. 129).

On the other end of the scale there were two developments going on in northwestern Europe: one is the demand for ships that could carry increasingly larger and heavier cargoes in the growing bulk trade, and the second, taking place at the same time, is the changing organisation of shipbuilding from dispersed shipyards in the countryside to concentrated yards in towns (Bill 2002, p. 110). This last process might have stimulated the sharing of knowledge and openness to new technologies, as this made more intense contacts between shipbuilders possible. Moreover, as towns can be seen as hubs in larger networks, flows of new technology from the outside were more frequent and easy.

To sum up, two traits (and even more) of the cog have their roots in the Romano-Celtic shipbuilding tradition (carvel bottom and overlapping sides) and in the different Mediterranean traditions (through beams). In the first case, there is a clear connection to the Roman occupation from the 1st to the 4th century AD, while the combination of a flush bottom and overlapping side strakes could have been preserved in vernacular craft. Two shipwrecks north of the Alps show protruding deck beams at an early stage, EPI-Taillebourg and County Hall, and the Roman influence is clear at least in the case of the County Hall wreck. This trait could either have been preserved in local craft (Port-Berteau II) or reintroduced in various other ways at a later stage.

2.3. INTRODUCTION OF THE LEEBOARD

This example concerns the short-term movement of people, i.e. trade. The feature involved is the leeboard and the introduction thereof into Dutch shipbuilding around 1600. Leeboards were used to counteract the leeway of flat-bottomed ships. The leeboard is a drop-shaped assembly of planks, the broader end of which can be lowered along the ship's side, while the

narrower end is attached by a bolt to the side of the vessel. The bolt is the pivot for lowering and raising the leeboard. Both sides of the vessel are equipped with a leeboard. The board on the lee side is always down, while the leeboard at the other side is raised. Most Dutch inland vessels were flat-bottomed, designed to sail in predominantly shallow waters. Moreover, for maximum cargo capacity, the hull form of vessels developed into an almost box-like shape – full bows, flat bottom and straight sides – resulting in very bad sailing capabilities. In order to improve sailing capabilities, especially when sailing close-hauled, leeboards were necessary. One can also put it another way: the introduction of the leeboard made it possible to build bluff-bowed, flat-bottomed vessels.

From around 1600 Dutch inland and coastal vessels were equipped with leeboards. Scholars do not agree on the exact date of the introduction of the leeboard, but it is obvious from iconographical evidence that before *circa* 1600 ships are depicted without, and thereafter with leeboards. This is reflected in the archaeological evidence.

The introduction of this new technology was very quick. A reason for this might be the way the shipbuilding industry was organised. Merchantmen were built on privately owned wharfs, often family-run businesses, with a master in command assisted by journeymen and apprentices (Unger 2013, p. 182). Shipbuilders in northwestern Europe were organised in guilds. These guilds were most common in Germany and the Low Countries (Unger 2013, p. 185). Guilds were sources of both education and innovation. The primary purpose of guilds was training skilled workers. Unintended by-products were invention and innovation (Epstein 2009, p. 52, 2013):

1. Education: guilds trained new carpenters. Education of new tradesmen was one of the principal functions of guilds. Typically, there were provisions for apprenticeships. Guilds promoted, preserved and institutionalised a handicraft tradition, passing on knowledge from individual to individual.

2. Innovation: craft guilds created an environment that was conducive to tacit, embodied, and incremental innovation, because:

- there were levels of freedom to allow for technical advance;
- ideas and practices of others were shared (and I would add, most importantly were discussed) within and across guilds;
- the market structure of many small firms was an incentive to technical change. A number of small firms could engage in a variety of small experiments, generating micro-inventions one after the other. Craft-based invention and the multi-centred, competitive institutional setting in which it was embedded came close to resembling an ideal market structure for innovation.

3. Migration, short term/long term: an important element of the guild organisation was tramping. During his tramping years a journeyman was able to learn about new methods and to pass them on in his next job in some other place, in this way stimulating the influx of new ideas from elsewhere (knowledge exchange). Technological transfer could only be successfully achieved through human mobility. Skilled migrant workers included mainly apprentices and journeymen, who travelled on a seasonal basis, or established masters, whose migrations were more often permanent.

Guilds were not opposed to technological innovation. In pre-modern manufacture, the nature of technological knowledge was largely implicit, which created the need for one-to-one training and meant that technological innovations had to be



Fig. 3: Model of shipwreck OE 34, Flevoland, Netherlands, showing the slender hull form in the stern (photograph IFMAF).

transferred by travelling craftsmen and engineers (Epstein 2013, p. 54-55). And that is exactly what guilds stimulated.

This perhaps accounts for the quick spread of leeboard use in the Low Countries, but what about the origin of the leeboard? At a conference on maritime archaeology in Penglai, China, I showed a picture of a Dutch vessel equipped with leeboards, a so-called *wijdschip*. I was immediately asked if I knew the origin of the leeboard? I gave the right answer in the opinion of the Chinese audience: it originates in China.

There is indeed a strong chronological argument to accept the idea that Dutch shipbuilders copied the leeboard from Chinese examples (Doran, 1967, p. 39-53). The first, more intensive, contacts of the Dutch with China date from 1595, while the Dutch East India Company (VOC) was founded in 1602 (Gaastra 2001, p. 21, 25). The VOC and the Jesuit order acted like “long-distance corporations” that contributed a lot to the accumulation of knowledge about Asia (Hertroijs 2014, p. 8).

Another point to keep in mind is that on their arrival in China, the Dutch were almost immediately impressed by the high standards of Chinese technology in general. The production of porcelain could serve as a good example of the superior techniques, and this product was imported in great quantities very soon after the first contacts. Other examples are the watertight bulkhead, described already by Marco Polo and applied in the 18th century by English shipwrights (Hertroijs 2014, p. 7). Hertroijs (2014, p. 4) emphasises that we should realise the mutual character of knowledge exchange between China and

the West and that we should preferably speak about the circulation of knowledge and technology.

At the same time, a development in the design of the hull form of Dutch vessels can be traced, which started in the middle of the 16th century. The slender medieval hull of, for example, the cog was modified to a more full-bodied hull form. A vessel that was excavated in the province of Flevoland can serve as an example: it is dated to the mid-16th century (fig. 3)(van Holk 2017). As can be seen in the underwater body of this vessel, the stern still shows the ‘medieval’ slenderness, while the bow shows a rather full form. In order to build a full bow and stern, leeboards were essential.

2.4. THE DEVELOPMENT OF THE *FLUIT*

The development of the *fluit* might be another example of the way that the guild system operated. The articulation of established practice was the norm for shipbuilding and for most of the premodern period worldwide. Technological development was a process of many small micro-inventions (Unger 2013, p. 173). Craft innovation was the outcome of small-scale and incremental practical experiment and of random variation (Epstein 2009, p. 70). This is exactly what could thrive through the closely-knit guild infrastructure.

The *fluit* is a three-masted seagoing merchantman of about 86 to 140 feet in length (24-39 m) with a cargo capacity between 55 (earliest examples) and 200 (later examples) last (equivalent

to 100 to 400 tons) dating to the 17th and 18th century (fig. 4) (Wegener-Sleeswijk 2003, p. 53-54, 66, 71, 97-99; Eriksson 2014, p. 11).

Their length was at least four times their width. In addition to their slenderness, they had a shallow draught. Another typical element of the hull form was the strong tumblehome (the inward curvature of the upper parts of the sides), resulting in a rather narrow deck. In a short time it became a 'bestseller' (not uncommon for books, but more so for ships). It became the most used merchantman on the North Sea and the Baltic (Wegener-Sleeswijk 2003, p. 20; Eriksson 2014, p. 10).

In historic sources it is mentioned that the *fluit* was the invention of the merchant Pieter Jansz Liorne. This is described by Theodorus Velius in his chronicle of the West Frisian town of Hoorn in 1604. According to Velius' interpretation, the first *fluiten* were built there in 1595.

At that time many skippers of the Dutch merchant fleet were Baptists (or Mennonites). As pacifists on the basis of their religious belief, they sailed without cannonry and thus saved weight, allowing them to build a longer, but not wider, ship, and a more slender vessel was the result. We might possibly attribute to the merchant Pieter Jansz Liorne the novel insight that the weight reduction could be used to give the fluyt a still more slender form. He did not invent the fluyt, but he was the sponsor of this experimental slender form, who took the financial risk to build vessels this way. The longer ship had more cargo capacity, while the same number of hands was needed to sail the vessel.

According to André Wegener-Sleeswijk (2003), who has written a comprehensive study about the *fluit*, the development

of this vessel should be seen as the outcome of a step-by-step development in building bigger and more slender ships that started much earlier. As predecessors, he mentions the *boot* and the (herring) buss.

Probably, so-called *verlangers* were the inspiration for the hull form of the *fluit*, along with the herring buss and the *boot*. From this point of view, the fluyt was not the result of an invention but of small, successive improvements in the shipbuilding industry. Dutch shipbuilders had started to lengthen several ship types: these ships were called *verlangers*. This tricky operation was necessary because of the economic revival in the northern Netherlands and the corresponding increased demand for cargo capacity that followed the collapse of the Spanish Armada in 1588 (Wegener-Sleeswijk 2003, p. 29-32, 39-48). This incremental development of technological innovation is typical of an industry organised in guilds.

2.5. FORE-AND-AFT RIG

This last example is about rigging. Again we encounter the refinement of existing designs, the exploration of the potential of new technology (Unger 2013, p. 175), and the previously mentioned step-by-step incremental development of tacit knowledge typical of an industry organised in guilds.

The spritsail was in use on Dutch inland vessels in the 16th century. At about the same time as the spritsail, a sail rigged on a forestay was introduced (Unger 1978, p. 55). This arrangement of a single mast and fore-and-aft sails was the type of rig that could be easily handled by one man. This new uncomplicated combination appeared on small boats used on rivers and estuaries.

In the 17th century this rig was introduced on seagoing vessels in combination with a square rig (Unger 1978, p. 56). The fore-and-aft rig had several advantages: easier handling (less hands needed); closer sailing to windward (making trips shorter); and greater manoeuvrability. Here we see a transfer of technology from small inland vessels to larger seagoing ones.

According to McGregor (1985, p. 166) the rig of Dutch *kofs* and galliots was adopted by the British, as there was a continual traffic of vessels between Dutch and British ports. This is an example of ships being an advertisement for themselves. Experiential knowledge was embedded in objects, and objects could travel and be observed.

3. CONCLUDING REMARKS

In this paper the importance of the movement of people, either in the form of (im)permanent migrations or as part of the guild structure (the tramping journeyman) of the shipbuilding industry, has been shown in respect to technological innovation.

In practice, technological transfer could only be successfully achieved through human mobility. Moreover guilds were not opposed to technological innovation (Epstein 2013, p. 55-57). According to Epstein (2009, p. 52), technological invention and innovation in the pre-industrial economy are still poorly understood. This is partly because of the difficulty in identifying the small-scale and anonymous innovations that dominated technical progress at the time. However, the problem is compounded



Fig. 4: A fluit, sailing close to the wind (detail), probably painted around 1680 by Claes Jansz. Rietschoof (Wegener-Sleeswijk 2003, p. 12, fig. 1).

by several long-standing assumptions about premodern manufacture, in particular by the view that from the 15th century onwards craft guilds, which provided European urban manufacture with its main institutional framework for over 600 years, were organised rent seekers systematically opposed to technical

innovation. On the contrary, the primary purpose of craft guilds was to provide adequate skills training through formal apprenticeship. Technological invention and innovation were a significant, albeit mostly unintended, effect of the crafts' support for the investment in skills.

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