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SCULPTURA IN ÆS.

*Sculptor noua arte, bracteata in lamina*

*Scalpit figuras, atque prelis imprimit.*

Figure 1. Jan Collaert I after Jan van der Straet, "The Invention of Copperplate Engraving", in *Nova reperta*, published by Philips Galle, c. 1600. Engraving, 27 x 20 cm. The Metropolitan Museum of Art, The Elisha Whittelsey Collection, The Elisha Whittelsey Fund, 1949.

# Social Network Centralization Dynamics in Print Production in the Low Countries, 1550-1750

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**Abstract:** The development of a professionalized, highly centralized printmaking industry in northern Europe during the mid-sixteenth century has been argued to be the inevitable result of prints' efficacy at reproducing images, and thus encouraging mass production. However, it is unclear whether such a centralized structure was truly inevitable, and if it persisted through the seventeenth century. This paper uses network analysis to infer these historical print production networks from two large databases of existing prints in order to characterize whether and how centralization of printmaking networks changed over the course of this period, and how these changes may have influenced individual printmakers.

**Keywords:** printmaking, network analysis

## Introduction

The development of a professionalized printmaking industry in northern Europe during the mid-sixteenth century has been singled out as a turning point in the history of early modern reproductive prints. In their landmark overview of European printmaking, *The Renaissance Print*, David Landau and Peter Parshall trace two parallel trends in artistic print production in sixteenth-century Europe: individual, highly innovative printmakers who acted as their own printers and distributors; and, on the other hand, an emerging class of professionalized publishers who coordinated the print production pipeline.<sup>1</sup> By the mid-sixteenth cen-

tury, "industrialized" houses such as that of Hieronymus Cock in Antwerp and Antonio Lafréri in Rome began to dominate the artistic print landscape. Landau and Parshall posited that the practical considerations of printmaking inevitably led to this kind of centralized production. To make one's business out of selling relatively cheap images, one had to operate at scale. Publishers needed a wide-ranging network of buyers, yes, but also of talented platecutters, suppliers of paper, plates, and presses, as well as artistic collaborators for creating designs for single prints, series, or large book illustration projects. (Activities illustrated by Jan van der Straet in Figure 1) Modern firms separated the roles of *inventor* and *sculptor* as a way to increase the efficiency and scale of

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production. Large, highly-centralized firms could take full advantage of these affordances of scale. A print publisher who was able to position himself in the core of the larger web of the print market by accumulating enough artistic, material, and social capital would have rosy prospects, indeed.

But does this theory hold for the seventeenth-century century? Current overviews of seventeenth-century print production in the Low Countries offer conflicting assessments.<sup>2</sup> This paper takes a quantitative approach to the question of centralization by applying formal network analysis methods to study databases of existing artistic prints from this period, looking at both network-wide centralization as well as the changing positions of

individual printmakers and publishers. The results suggest how the simple incentives of a professionalized production market could result in unexpectedly complex repercussions.

## Why centralization mattered

A key structural property of any network is its network centralization, a measure of how evenly or unevenly ties are distributed between its members. In a centralized network, a few key individuals occupy powerful and flexible broker positions. Actors in these positions are able to

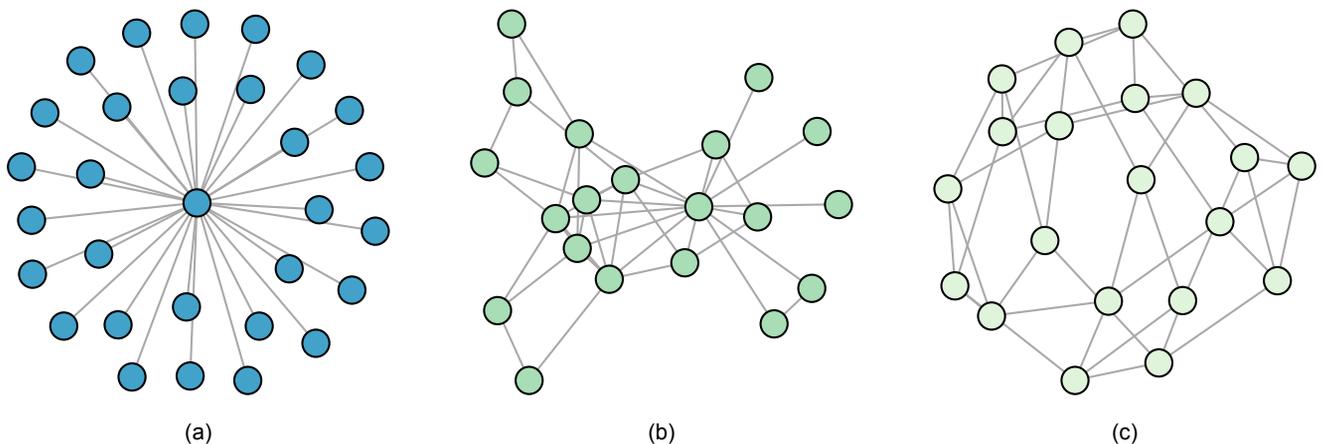


Figure 2. Network centralization examples. (a) is a highly-centralized “star” graph, where one actor receives all the connections. (b) is a relatively centralized graph, where a few nodes receive most of the connections. (c) is a relatively decentralized graph, where most nodes have the same number of connections.

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initiate contact with a wide range of individuals they already know, and are granted easy access *through* those immediate contacts to the rest of the network. (Figure 2(a) and 2(b)) Centralized networks are not equal networks, however. The average individual in that same network is unlikely to know multiple well-connected actors, meaning that their access to the rest of the network is mediated and easily cut off by those few highly-central individuals. Conversely, in a more decentralized network (Figure 2(c)), where connections are spread more evenly, a given individual has a better chance of knowing more than one well-connected actor, reducing his or her distance to the rest of the network and making it easier to forge new and diverse connections.

This characteristic of networks is directly relevant to the making of artistic prints. On the one hand, the medium of printing demanded a set of artistic and technical skills, not to mention a set of social connections and financial capital, that presented a barrier to new entrants into the printmaking world. A printmaker could only get so far based on their individual talent with the block knife, burin, etching needle, or mezzotint rocker. Printmakers also needed social capital in the form of connections to publishers who could pay them for their plates, and to artists with artworks or designs whose reproductions were marketable. Publishers gained a competitive advantage by having a large pool of contacts, both with artists as well as with distributors and

buyers in domestic markets and at the international book fairs<sup>3</sup> Designers likewise relied on printmakers and publishers to promote and disseminate their artworks All these requirements may have made it more likely that a few centrally-connected individuals would continually increase their number of contacts in a rich-get-richer pattern of increasing centralization.

On the other hand, several factors at both the individual as well as the societal level may have instead encouraged a less centralized printmaking network. A nascent printmaking community with a relatively small population of printmakers and publishers might well have had just a few relatively skilled, experienced, and professionally-established individuals occupying very central positions. But such a structure could be transient. As the number of printmakers increased, those experienced, highly-central players would necessarily take on apprentices and commission less-experienced collaborators. Knowledge is not a fixed quantity; as printmaking opportunities expanded, more and more of those less experienced artists could have learned the technical skills necessary to succeed in the medium. Likewise, a greater number of knowledgeable publishers would be able to create their own local connections without relying on the established knowledge and social connections of a printmaking “elite”. As a result, what began as a highly-centralized network could, over time, evolve into a much more distributed one.

A burgeoning Dutch economy in the first half of the seventeenth century may have contributed to this decentralization by supporting print markets in smaller Dutch towns, thus enabling a more decentralized network of print producers with a wider geographic spread. Michael Montias has shown how economic prosperity in the early decades of the seventeenth century may have promoted a burst in painting activity between 1630 and 1650 in Delft, a market that was relatively decentralized, with little institutional patronage compared to other contemporary artistic centers.<sup>4</sup> Might the same effect have changed the production pattern of prints as well?

On paper, these contradictory incentives are both plausible; indeed, they both may have been operating in parallel between 1550 and 1750. Can we determine, though, which incentive (if either) won out? Using the empirical evidence offered by the British Museum and Rijksmuseum print databases, I will show how the balance of these centralizing and decentralizing incentives may have played out over the seventeenth century.

## Data on artistic prints

The rich collections of Dutch and Flemish prints in the British Museum (hereafter BM) and the Rijks-

museum (hereafter RKM) present an excellent opportunity to bring quantitative methods to bear on data concerning prints. It must be noted that while these institutions have especially rich holdings, particularly in Dutch prints, no one print collection can be said to be perfectly “representative” of the full range of actual connections between printmakers in the sixteenth and seventeenth century. For example, while these databases have rich information on *constprenten*, or fine art prints, engraved illustrations for books will likely be undercounted. Missing almost entirely from these data are information about the lowest end of print production in illustrated broadsides, playing cards, calendars, and cheap devotional prints.<sup>5</sup> Therefore, the claims of this study will be restricted to the production of fine art prints. Each of these museums also has its own unique collecting history. This distortion can be mitigated, however, by comparing two distinct sources of data about the same phenomenon.<sup>6</sup> By running the same analysis on both datasets, it will be possible to easily compare the results offered by both sources. Where similar results are returned by both the BM and RKM datasets, we can at least reject the claim that the results are *solely* artifacts of collecting preferences specific to each museum.

Second to the source-specific biases of each dataset is the larger question of historical distortion inevitably shared by *both* institutions. This study will have to contend with the same unknown unknowns that plague any historical investigation. Because of

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paper impressions' fragility, prints likely have a very uneven survival rate, and it would be unwise to take modern day collections as a proxy for the absolute sizes of editions and print runs in the sixteenth and seventeenth centuries.<sup>7</sup> That said, the reproducibility of prints does grant one advantage. Peter Parshall has endorsed the idea that, if the exact sizes of *print runs* are not accurately represented in modern day print collections, we can nevertheless understand a great deal about overall *patterns* of production because the survival rate of a given print that has been reproduced several times is much greater than that of other non-reproducible artifacts. In 1998, Parshall suggested that the voluminous evidence of today's museum print rooms, could be invaluable for research if only it could be aggregated and analyzed fluently.<sup>8</sup> We now have that capability.

Both the BM and the RKM have published the cataloged information for their collections as structured digital data.<sup>9</sup> These data include object-level descriptions such as creators and their various roles, title, date, medium, dimensions, and subject matter. For printed artworks, each database details (when known) the artists who produced the original design for the print, the printmaker who cut the woodblock or plate, and, when applicable, the publisher who printed and distributed the artwork. The BM database describes 14,821 print impressions dated between 1550 and 1750 by Dutch or Flemish artists,

while the RKM database contains 19,980 of the same. These numbers represent records that have been assigned dates, and which also have at least two identified creators.<sup>10</sup> Each database also contains biographical information on the creators associated with these prints, including life dates and classifications by nationality.

## Inferring print production networks

From these individual artwork records, it is possible to construct a digital model of a network that represented the inferred social connections between these artists. In this network, artists (the nodes of the graph) are connected when they are associated with the production of a print in one of three general roles: *designer* (either as an active participant, or simply "made after"), *printmaker*, and/or *publisher*.<sup>11</sup> A single print may thus provide a basis for connecting designer, engraver, and publisher nodes at a particular point in time. Dozens or hundreds of prints support the construction of a larger network. The network will be projected like so:

1. Create small sections, or time-slices, of the production network as it may have existed at different points in time.
2. From these time-slices, calculate the centralization of the network as a whole.

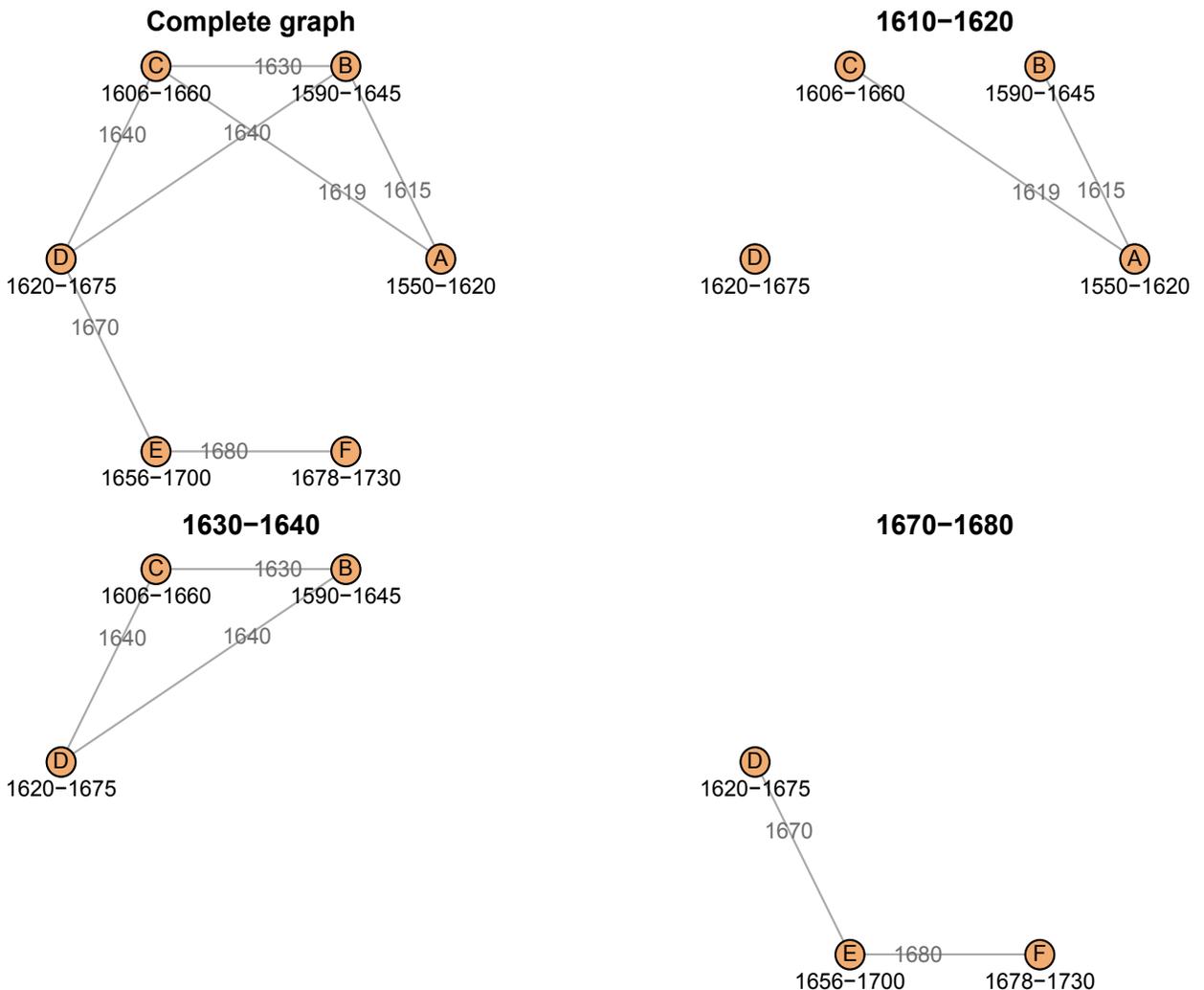
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3. For each individual within each of these time-slices, calculate various metrics for that given individual at that point in time.

Rather than construct a large network looking at every print in the BM and RKM databases at the same

time, I will use a rolling window approach to construct many “slices” of the network as it existed at different points in time. (Figure 3) For example, a slice of the network between 1640 and 1650 would include all artists who were alive at some point during that ten year interval.<sup>12</sup> These artists will

Figure 3. Visualizing the method for creating time slices of the historical print production network. Each node in the graph is an artist, engraver, or publisher, and links are formed when two artists both worked on the same print.



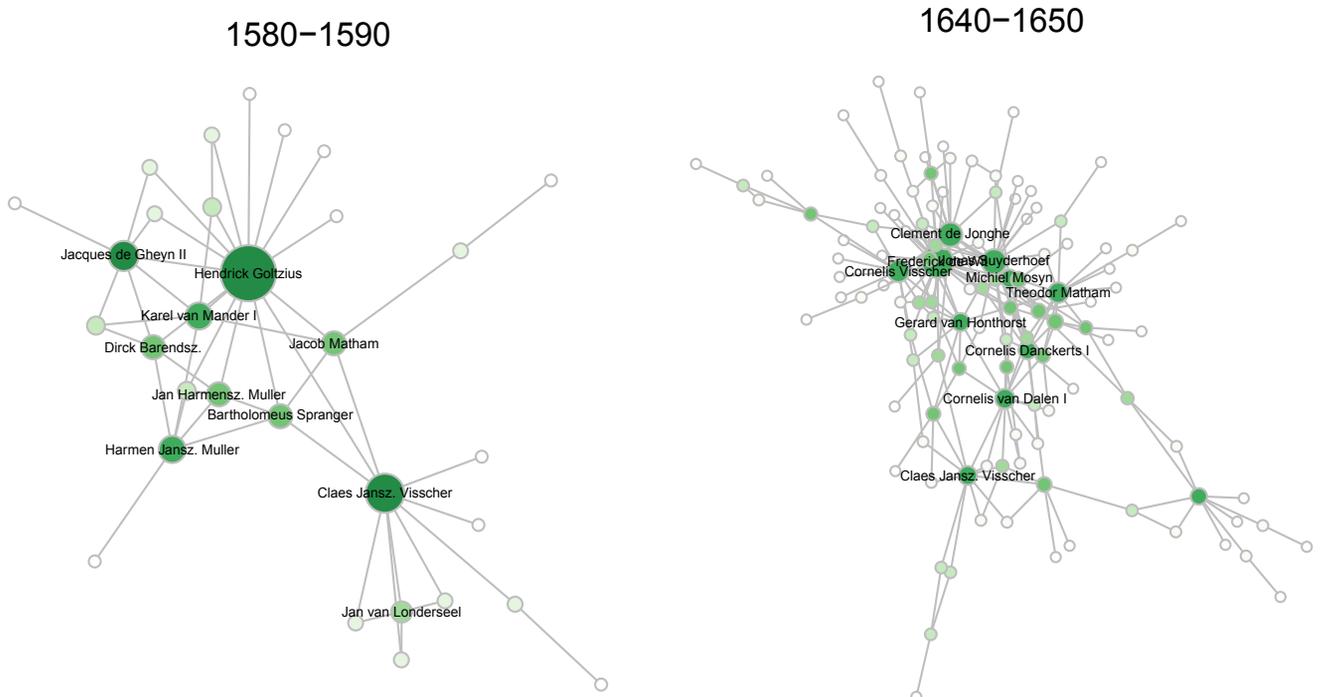
only be connected by edges derived from what prints were being produced during that same 1640–1650 interval.<sup>13</sup> (Figure 4) The resulting network will be unweighted and undirected.<sup>14</sup>

Having created national sub-networks from each time slice, we can compute their graph centralization scores.<sup>15</sup> The higher score, the more centralized a graph is; the lower the score, the more distributed it is. It is also possible to characterize centralization at the scale of the individual. An individual node's degree centrality characterizes how many different connections it has to other members of the network.<sup>16</sup>

## Results: A mixed message

Figure 5 displays the changing network centralization score for the Dutch and Flemish communities of print producers between 1550–1750, contrasting that metric with the numbers of nodes and edges in each network over the same period. Results from both the BM and RKM datasets are overlaid. While there are several local differences between the BM and RKM results, they are generally consistent with each other, providing some measure of confidence that the result we are seeing is partially

Figure 4. Visualizations of the core components of two Dutch network time slices.



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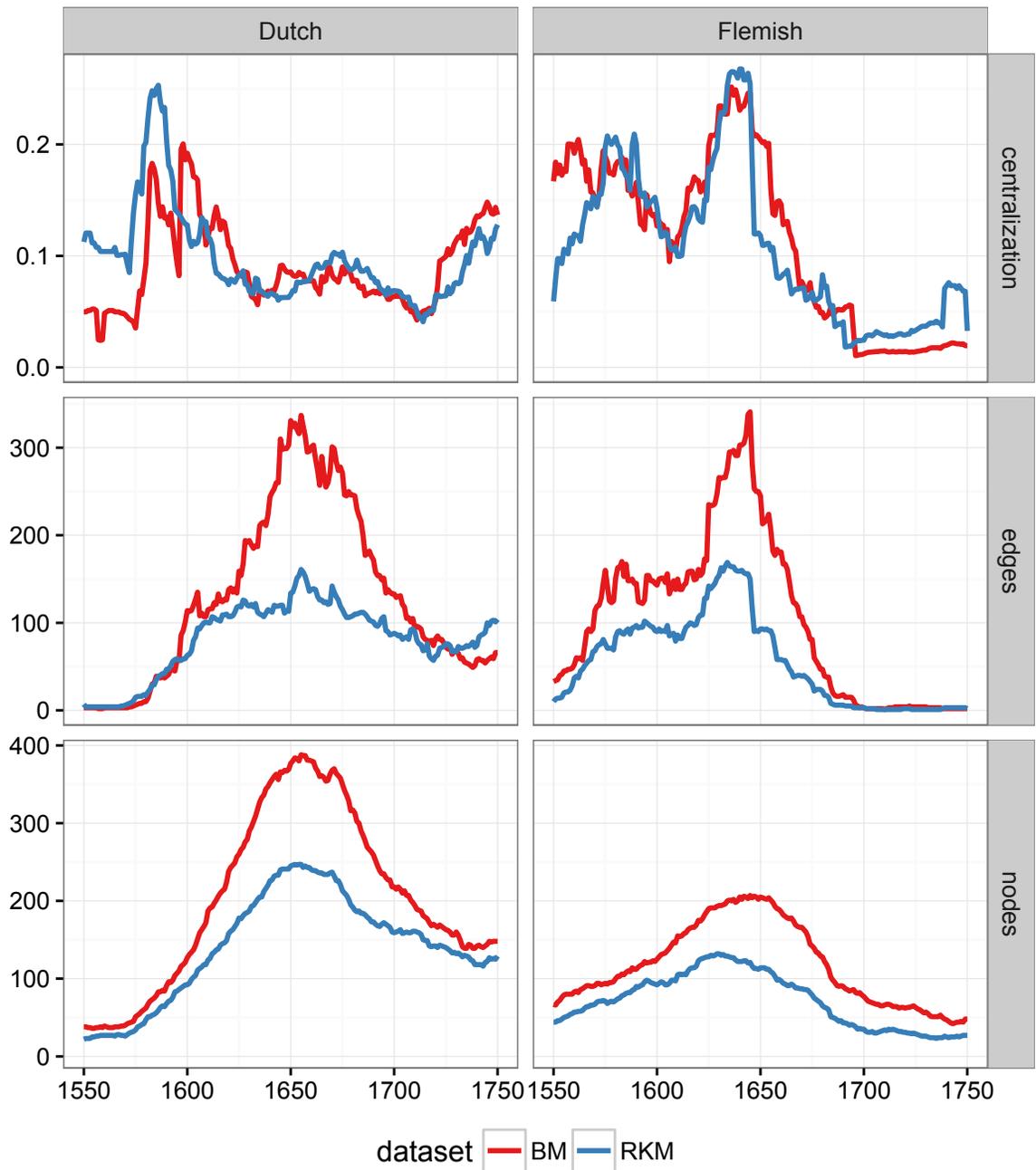


Figure 5. Comparison of the changing centralization of the Dutch and Flemish print production network between 1550–1750 with the changing number of actors and the changing number of edges connecting them over the same period.

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representative of actual historical trends, and not solely an artifact of the individual collecting practices of either the BM and RKM.

A gradual rise and fall in the number of active printmakers is observed over the sixteenth and seventeenth centuries. However, the networks of both Dutch and Flemish printmakers fluctuated sharply between relative centralization and decentralization during the same period. In the northern Netherlands, centralization was generally low through most of the sixteenth-century, spiking rapidly around 1575, with another spike at 1600, before falling quickly down to earlier levels by about 1650. With small variations, the Dutch network centralization remained at relatively consistent levels from then until about 1720, when it once again quickly increased.

The southern Netherlands, by comparison, exhibited a much higher level of centralization in the mid-sixteenth century than did the Dutch. In 1550, the Flemish network also had more participants than did the Dutch. However, the population of Flemish printmakers increased only gradually through 1650, the number of active Dutch printmakers surpassing them in 1600. By 1650, the number of Flemish printmakers began to decline. Despite the smaller number of active printmakers, the print production of the southern Netherlands easily rivaled that of the north, experiencing an especially sharp increase between

1625 and 1645. Flemish centralization gradually declined until shortly after 1600, when that network experienced its own sharp spike in centralization at the same time as it saw a dramatic increase in the number of prints being made by Flemish artists. This spike was short-lived, however, and by 1650 the Flemish print production underwent relatively quick decentralization as soon as this brief printmaking boom wore off, dropping to very low levels by 1675 as it diminished greatly in size and activity.

Both the Dutch and Flemish results suggest that both the centralizing and decentralizing incentives posited above *did* have their effect in the sixteenth and seventeenth centuries, but that the incentives towards *decentralization* won out—at least in the long run. This would seem to confirm Landau and Parshall's claim that the highly-centralized model that Hieronymus Cock constructed in Antwerp was an immense success in its own time. But these initial results also undermine the notion that printmaking would inevitably necessitate highly centralized production in the following centuries. If printmaking, as a medium, encouraged high centralization at the local level, with printmaker-publishers amassing a wide range of contacts, why did this not result in persistently high centralization at the regional level? What is more, these results also suggest the surprising speed with which these structural shifts could occur. The gradual changes seen in the network population would indeed appear to

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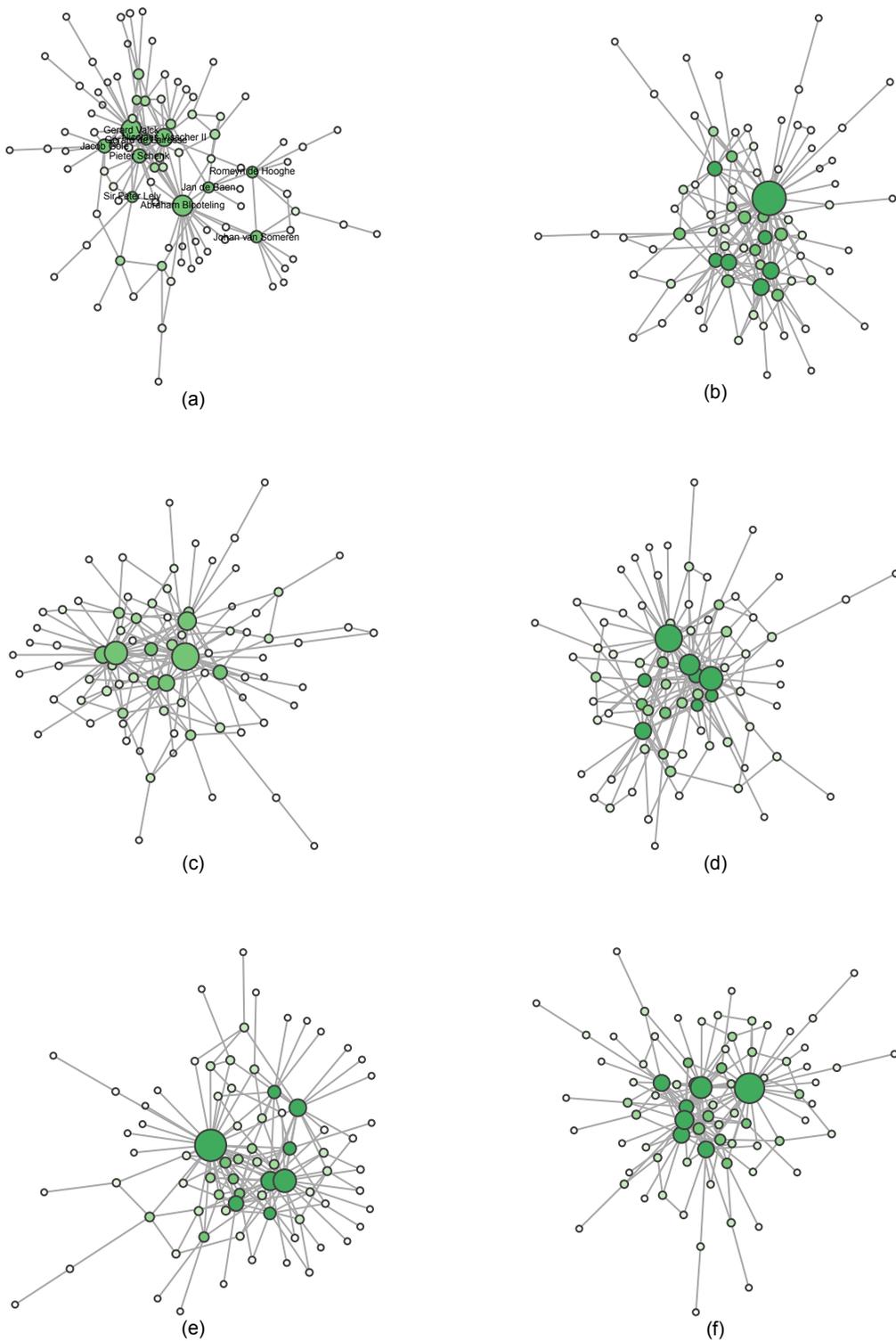


Figure 6. A visualization of random graph generation. (a) is the network generated from the BM data between 1640–1650. (b-f) are five randomly generated networks with the same number of nodes and edges as (a).

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mask more dynamic upheavals in actual network concentration. The change in centralization, on the other hand, was far more abrupt.

Unaccustomed to thinking of our subject matter in terms of unpredictable systems, art historians may be surprised to find such rapid structural changes in networks involving hundreds of artists, printmakers, and publishers. This type of “phase change” behavior, where marginal changes in one set of characteristics catalyze a much more dramatic change in another measurement, are common characteristics of complex systems like social networks.<sup>17</sup> This raises the question: which of these changes might signify the influence of some outside event or other fundamental change in the ways in which these designers, printmakers, and publishers connected to each other? (e.g. were certain publishers or printmakers able to attract far more students or collaborators than we might expect given the size of that network?) And which changes are just the kinds of levels we might find in *any network* of the same size that follows a similar, rich-get-richer pattern of connection?<sup>18</sup>

We can do this by running the same centrality measurement on a random network of the same size as each network time slice (that is, with the same number of nodes and the same number of edges) derived from the BM or RKM data. Links between any two nodes in this graph are generated based on a power law probability distribution. It

produces a graph such that a handful of nodes have a very large number of connections, and the majority of nodes make very few connections.<sup>19</sup> This distribution of edges creates a network similar to the kind that we have observed in the print production networks: a rich-get-richer scenario, where a few actors make and receive the majority of connections. Because random graph generation is stochastic, the same simulation run twice with the same inputs will produce slightly different outputs. (Figure 6 (b-f)) Run many times, a randomized simulation will tend to produce values that fall within a certain range, with many iterations producing values close to some average, and a few iterations producing outliers.

Figure 7 compares the centralization values returned by these random graph models to those found for the Dutch and Flemish communities in both the BM and RKM datasets. The shaded bands indicate the range occupied by 90% of the most central values produced by random graph sampling (thus excluding the most extreme outliers). The black trend line represents the actual centralization value measured from the data at each year. These bands indicate how centralized random networks of the same size tend to be.

Both the BM and RKM datasets are largely congruent. Moreover, we find that many of the sudden changes in Dutch and Flemish centralization through the sixteenth and seventeenth centuries are surprisingly consistent

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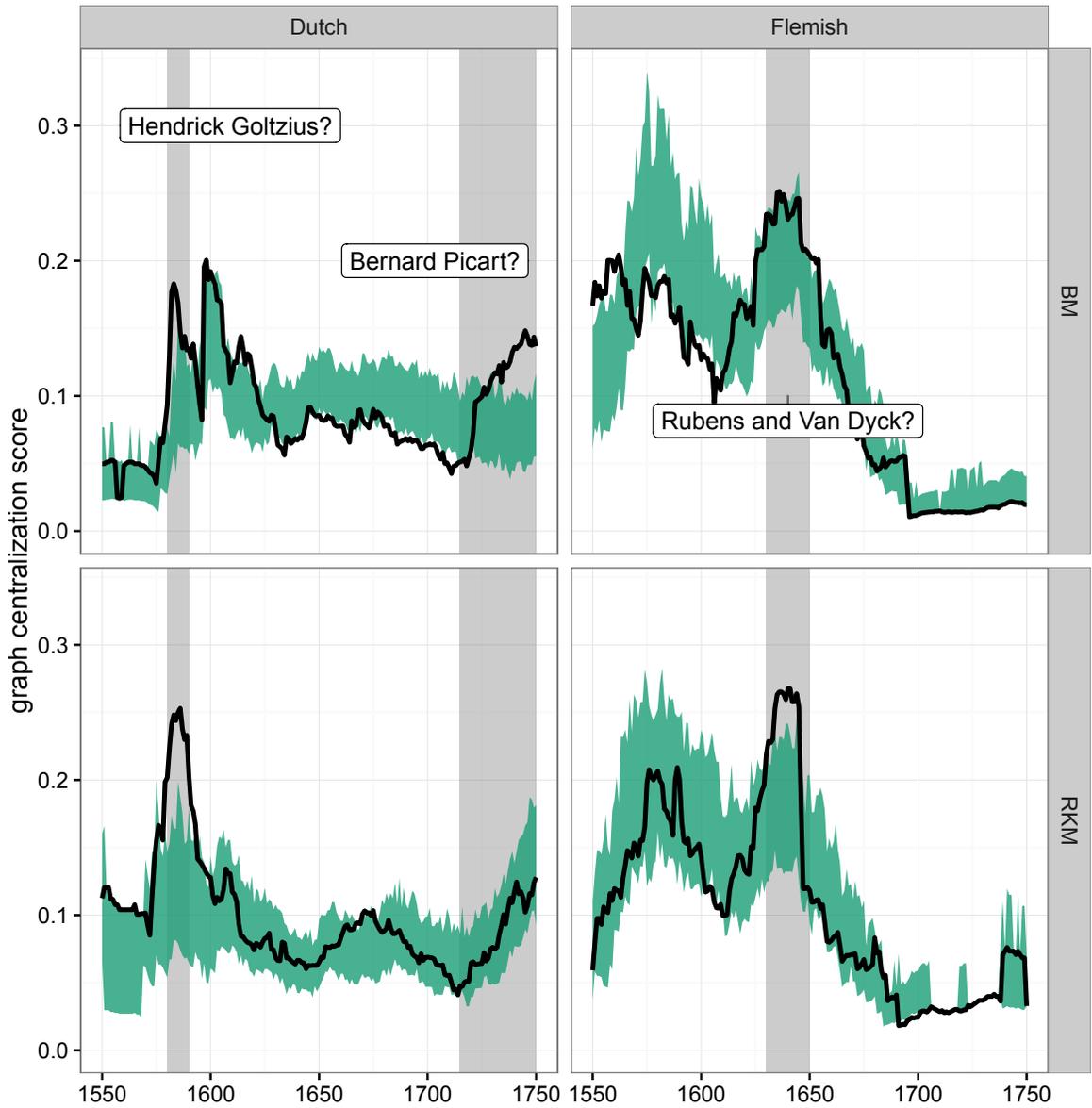


Figure 7. Comparing observed centralization results with centralization returned by random graph sampling.

with the results returned by random graph sampling. Even as observed levels of centralization shifted dramatically over this period, the basic attractiveness of well-connected individuals (the exponent of the power law probability distribution) remained essentially constant between 1550–1700. In other words, for all the apparent fluctuations in the printmaking networks in the northern and southern Netherlands, the simple incentive for printmakers to seek out well-connected collaborators appears to have been nearly constant through the end of the seventeenth century. This constant, coupled with the gradual changes in the sizes of these networks, could result in surprisingly sudden shifts in network structure.

Not every year of empirical data lines up with the random graph results, however. Not all these changes, in other words, were due to the shifting size of these communities alone. The first deviation, which appears in both the BM and RKM results, occurs in the Dutch network around 1580, with a spike in centralization that does not occur in the random graphs with the same number of nodes and edges. Another major aberration occurs in the BM results (though not the RKM model), where, around 1720, the model underpredicts the jump in centralization experienced by the Dutch network. In the Flemish network, a large spike is observed around 1640 that exceeds the centralization shown by random graph sampling.

## Case studies in centrality

Having calculated the overall level of centralization in the Dutch and Flemish print production networks above, it is useful to disaggregate these larger networks and look at the changing positions of the individual artists within them. Figure 8 shows the most central members of the Dutch print production network at different points in time.<sup>20</sup> Many of the most central artists in each of these years are well-known names, such as Hendrick Goltzius, Claes Jansz Visscher, Hendrick Hondius, and Frederick de Wit. However, other highly central artists are relatively unknown, such as Abraham Blooteling and Jonas Suyderhoef.

Hendrick Goltzius made an enduring contribution to engraving styles and techniques, as well as to the overall artistic standing of prints, in the Netherlands and beyond in the seventeenth century—this much has never been in dispute.<sup>21</sup> But more than that, these results suggest that his firm also had a dramatic impact on the future structure of the Dutch printmaking network—an impact due in large part to the timing of Goltzius' career. Goltzius' well-deserved reputation as a masterful printmaker attracted apprentice engravers from many different cities in the northern and southern Netherlands. This attractive power was truly exceptional; it is the rise of Goltzius and his studio

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that likely explain that remarkable surge in centralization seen around 1580 that well exceeded levels seen in randomized networks of the same size. When Goltzius opened his firm in 1582, there were no Dutch competitors as centrally-placed as he was, with connections not only to his own group of Dutch printmakers, but also to foreign publishers and commissions. Any aspiring printmaker or publisher looking for a partner in the northern

Netherlands would have had few choices as attractive as Goltzius' Haarlem studio at that time.

The highly centralized “star power” that had attracted so many aspiring engravers to apprentice with Goltzius in the last decades of the 1600s likely primed the network for its speedy decentralization in the following decades. The following generation of printmakers had enough built up

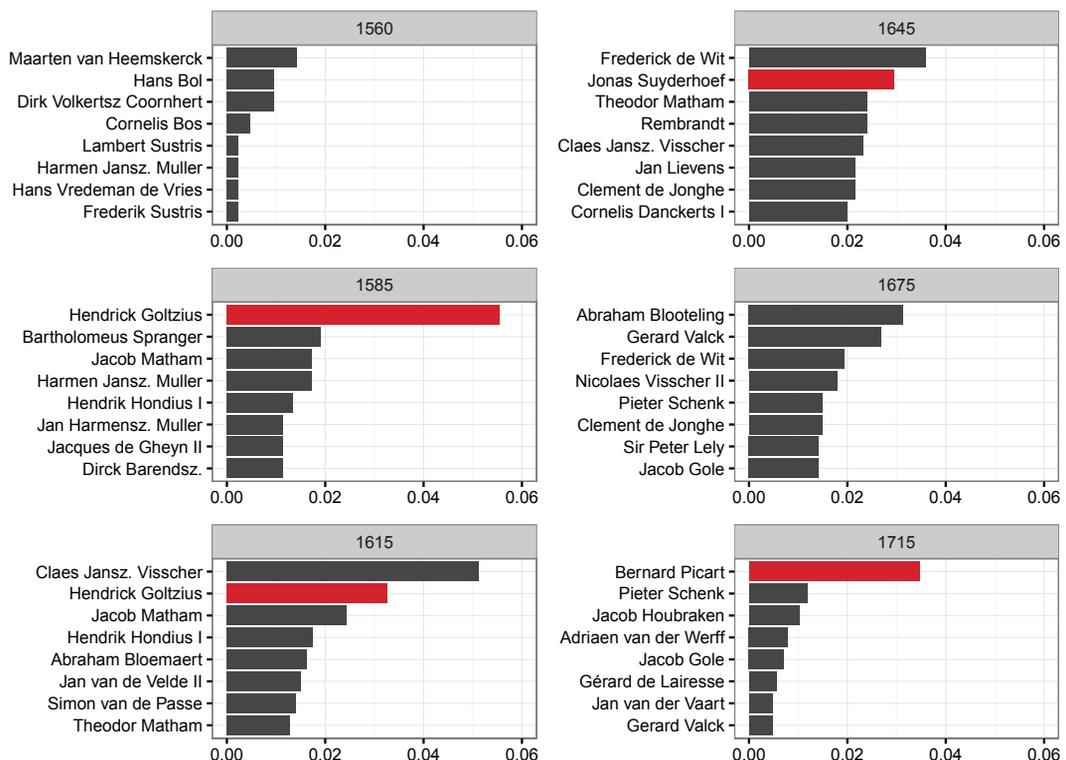


Figure 8. The top most central members of the Dutch printmaking network in the years 1560, 1585, 1615, 1645, 1675, and 1715, ranked by their degree centrality, with some notable examples highlighted. (BM Dataset)

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artistic and technical knowledge to allow the print network to spread out, increasing the number of relatively competitive printmakers and thus decentralizing the overall network. For example, in 1640, Jacob Matham's son, Theodor (1605/6–1656) had risen to become the most well-connected member of the Dutch network, working in Amsterdam and specializing in engraving large figural scenes.<sup>22</sup> However, even as Matham, or

members of the Visscher family, would assume powerful positions brokering ties between a large array of other artists, printmakers, and publishers, they would have more well-placed competition than Goltzius ever did. For the remainder of the century, no single individual would occupy as privileged a position in the Dutch network of printmakers as Goltzius did in the 1580s.

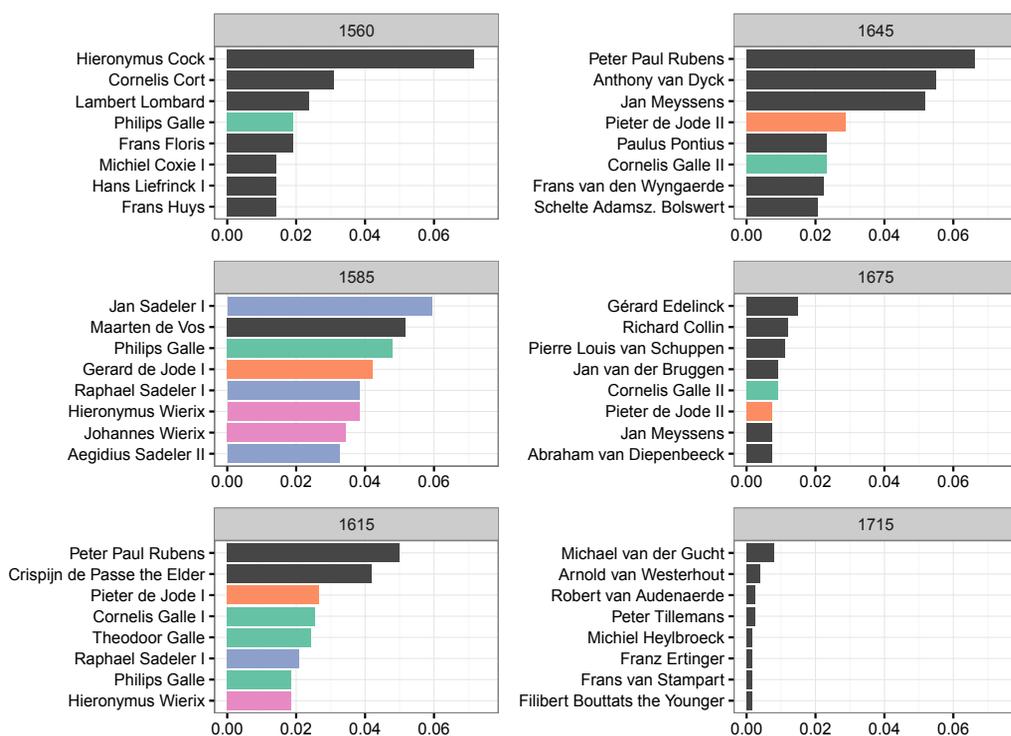


Figure 9. The top ten most central members of the Flemish printmaking network in the years 1560, 1585, 1615, 1645, 1675, and 1715, ranked by their degree centrality. Members of family dynasties are highlighted. (BM dataset).

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The other exceptional spike in Dutch centralization occurs in the early eighteenth century, where the French-born Bernard Picart dominated the print trade in Amsterdam soon after moving there in 1711 at the age of 38. Picart was a prolific printmaker himself, and would establish his own publishing house for producing both fine art prints as well as book illustrations. Picart trained many Dutch engravers in a formally-regulated academy, the *Amsterdamse tekenschool*, emulating his own training the French academic manner.<sup>23</sup> This centralized school—unique to the Dutch print production world up to that point—may account for the fact that the Dutch printmaking network began to centralize far more than would be expected from its size alone in this period.<sup>24</sup>

It is unsurprising to find names like Goltzius or Picart at the top of the Dutch centralization charts. Far less known is the printmaker Jonas Suyderhoef, who ranks as one of the central hubs of Dutch printmaking in 1640. Jonas Suyderhoef was born in Haarlem to Andreas Pietersz Suyderhoef, secretary to the Dutch Ambassador to Constantinople.<sup>25</sup> He was an active member of the Guild of St. Luke, and would become dean in 1678. Suyderhoef used a combination of engraving and etching to produce prints after a remarkably wide range of artists, from formal portraits by Frans Hals, Rembrandt van Rijn, Anthony van Dyck, and Pieter Dubordieu, to history paintings by Rubens, to peasant scenes by Adriaen van Ostade,

and Italianate landscapes by Jan Both. What is more, Suyderhoef worked with an impressively broad range of publishers, not only in his hometown of Haarlem, but also in Amsterdam and Leiden.

At first glance, it is easy to understand why Suyderhoef has been overlooked in literature on Dutch printmaking. Because his only known works are reproductions, he has never received the kind of close attention given to engravers from the same period who made original works as well as reproductions, such as Hendrick Hondius. Moreover, Suyderhoef's prints are often workmanlike in character. In other words, Suyderhoef had little to contribute to the aesthetic achievements of Dutch printmaking. That said, there was clearly a broad market for prints of this quality, and it is for that reason that his career deserves some attention. Suyderhoef appears to have fulfilled a demand for freelance engravers who were able to produce reasonably good engravings after almost any artist or genre, and who were willing to work with a wide array of publishers. Unlike Goltzius or Hondius, Suyderhoef does not appear to have ever tried to establish his own publishing business. Perhaps this was because there was already too much established competition among publishers in Haarlem by the 1630s when Suyderhoef would have begun producing prints for the market. Conversely, the rising number of active publishers, both in Haarlem and in other Dutch cities, may have made it possible

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for Suyderhoef to make a comfortable living as a freelance engraver alone. In the decentralized network that existed in the mid-seventeenth century northern Netherlands, it may have made professional sense not to work exclusively with a single publisher, given the wide array of reasonably well-connected publishers that were available as clients.

Like the Dutch, the Flemish print production network underwent sudden structural fluctuations during the seventeenth century. As can be seen in Figure 5, these fluctuations did not occur in tandem. Disaggregating these network-wide statistics in order to examine individuals within this network sheds light on this difference. (Figure 9) Much as Goltzius did in the Dutch network of 1585, Hieronymus Cock unsurprisingly dominated the Flemish network of 1550. The other top-ranking participants in that year were either Cock's artistic sources (Lambert Lombard, Frans Floris, Pieter Bruegel the Elder, Michiel Coxie) or engravers with whom he contracted (Cornelis Cort, Philips Galle).<sup>26</sup> By 1585, the Flemish network had transitioned from a unipolar one with Cock at the center, to a multi-centric network with a large array of engraver/publishers who had worked for either Cock or Plantin early in their careers, but then transitioned into publishing works by themselves and after others. These included Jan and Rapahel Sadeler, Philips Galle (a former student of Cock's), Hieronymus and Johannes Wierix, and Gerard de Jode. Like the

transition underwent by the Dutch network around 1610, the Flemish network trended towards a more decentralized structure as the overall skill level of its inhabitants increased. While one or two well-connected hub individuals might have maintained their dominance for a few decades, the small number of new printmakers that they enabled soon were influential enough to become hubs in their own right—albeit smaller in scale, and with more competition.

Yet something occurred in the south that did not happen in the North. The print production network suddenly *re-centralized*. Starting around 1625, the gradual decline in Flemish centralization reversed sharply, if briefly, to become more centralized than ever before for about two decades—a surge that was far greater than expected for a similar network of that size. (Figure 7) Sitting at the heart of this re-centered Flemish network were Rubens and Van Dyck, both of whom had a long, sustained engagement with printmakers, and whose studios generated huge demand for reproductive prints.<sup>27</sup> During this period of greatest network concentration, the number of prints being made surged with no accompanying increase in the number of actual participants in the network. While Flemish printmakers and publishers were producing more prints than their northern counterparts at this time, note they did so with little more than half the number of participants in the network. At the same time that the

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United Provinces were experiencing an economic boom that attracted many artists, the southern Netherlands' economy was still suffering from the effects of Spanish invasion at the end of the sixteenth century.<sup>28</sup> The closure of the Scheldt river and the exodus of prosperous Protestant merchants had led to economic stagnation in Antwerp. Though shining stars like Rubens and Van Dyck, not to mention engravers like Aegidius Sadeler, could still attract international commissions, Antwerp itself was not an attractor for young artistic talent, by in large. In a small network with few new entrants, a handful of influential individuals could still maintain the kinds of highly centralized positions that were no longer available in the more distributed northern provinces. This focused and demanding environment would have favored highly professionalized printmakers who were able to produce prints consistently and prolifically. This may explain the predominance of printmaking *families* among the list of central Flemish print producers like the Weirixes, the De Jodes the Galles, or the Sadelers. They all established businesses that were able to produce massive, multi-generational stocks of plates. With few newcomers in the seventeenth century tempted to try their luck at starting an engraving or publishing practice in Antwerp, already established firms were easily sustained over multiple generations.

More so than any of their counterparts in the northern Netherlands, these Flemish printmaking families

were able to establish long-lived dynasties that dominated Antwerp print publishing for more than a century. Without the persistent influx of new talent and competition into Antwerp, these established Flemish families could easily maintain their businesses by passing down artistic knowledge, social connections, and (perhaps most importantly), large inventories of plates that provided a stable foundation for young heirs to the business.

## Conclusion: Simple rules for a complex system

In one sense, this analysis has confirmed Parshall and Landau's core argument: that the highly centralized form of print production originated by Hieronymus Cock, Antonio Lafréri, and other sixteenth-century publishers would govern printmaking well into the future. This system of professionalized publication would tend to favor well-connected individuals able to marshal commissions, clients, and labor from a wide spectrum of the market. However, network analysis has also revealed that the ramifications of this simple rule could be unexpectedly complex. With a handful of exceptions where combinations of economic circumstances and extraordinary individuals like Hendrick Goltzius, Bernard Picart, or Peter Paul Rubens caused unique spikes in centralization, many of the apparently major changes

in Dutch and Flemish printmaking centralization were simply manifestations of the gradual rise and fall in the number of active printmakers over this period. A network-based approach to studying print production has also highlighted otherwise neglected artists like Jonas Suyderhoef, who may have played a far more important role in disseminating images through reproduction than has previously been acknowledged. This approach offers a crucial context for future studies of individual printmakers, while also demonstrating how network analysis can illuminate dimensions and scales of historical events that are otherwise difficult for art historians to conceptualize.



### Supplementary Material

To this article supplementary material can be found at HeiDATA Dataverse Network <https://heidata.uni-heidelberg.de/dvn/dv/dahjournal>

Data, analysis, and visualization code (R-package)  
Supplementary methodology details

## Notes

1 David Landau and Peter W. Parshall, *The Renaissance Print, 1470-1550* (New Haven: Yale University Press, 1994), 260–283.

2 Riggs and Silver generally find support for continuing professionalization and central-

ization; Timothy Riggs and Larry Silver, *Graven Images: The Rise of Professional Printmakers in Antwerp and Haarlem, 1540-1640* (Chicago: Mary & Leigh Block Gallery, Northwestern University, 1993); however Orenstein has noted an increasing number of smaller print publishing houses flourishing in the Netherlands around mid-century: Nadine M. Orenstein, “The Shift from Antwerp: The Diversification of Print Publishers in the United Provinces Around 1600,” *Block Points: The Annual Journal and Report of the Mary and Leigh Block Gallery* 5 (1995): 43–63; Nadine M. Orenstein, “Marketing Prints to the Dutch Republic: Novelty and the Print Publisher,” *Journal of Medieval & Early Modern Studies* 28, no. 1 (1998): 141.

3 See for example, the strategies of Christopher Plantin; Karen L. Bowen, *Christopher Plantin and Engraved Book Illustrations in Sixteenth-Century Europe* (Cambridge: Cambridge University Press, 2008), 22–25, 54–55.

4 John Michael Montias, *Artists and Artisans in Delft: A Socio-Economic Study of the Seventeenth Century* (Princeton: Princeton University Press, 1982), ch. 7.

5 Even in the sixteenth century these products were usually not preserved; Jan van der Stock, *Printing Images in Antwerp: The Introduction of Printmaking in a City: Fifteenth Century to 1585*, *Studies in Prints and Printmaking* 2 (Rotterdam: Sound & Vision Interactive, 1998), 179–180.

6 For an effective demonstration of this technique, see Jan De Vries, “Art History,” in *Art in History, History in Art: Studies in Seventeenth-Century Dutch Culture*, ed. David Freedberg and Jan De Vries (Santa Monica: Getty Center for the History of Art & the Humanities, 1991), 259–260.

7 Future work may involve applying statistical models of survivability to thinking about the loss of prints, possibly based on surviving archival evidence about the sizes of original print runs; see, for example, Karen L. Bowen and Dirk Imhof, “18,257 Impressions from a Plate,” *Print Quarterly* 22, no. 3 (September 2005): 265–79.

8 Peter W. Parshall, “Prints as Objects of Consumption in Early Modern Europe,” *Journal of Medieval & Early Modern Studies* 28, no. 1 (Winter 1998): 21.

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9 On the BM Linked Open Data initiative, see Dominic Oldman et al., “Realizing Lessons of the Last 20 Years: A Manifesto for Data Provisioning and Aggregation Services for the Digital Humanities (A Position Paper),” *D-Lib Magazine* 20, no. 7/8 (July 2014), doi:10.1045/july2014-oldman. What documentation is available for the RKM data may be found at <http://rijksmuseum.github.io/>.

10 For the handling of unknown creators, see supplementary material.

11 These three roles encompass 97% of the artistic ties as described by the BM for the set of prints under consideration, and 77% of all ties described by the RKM. A more detailed discussion of the various types of production roles can be found in the supplementary material.

12 The interval of ten years is somewhat arbitrary. I have selected it because it strikes a good balance between granularity and generality, and also falls within the rough art historical convention of using “circa” to mean five years. See the supplementary material for a discussion of including only alive vs. deceased artists in the network.

13 Both the BM and RKM databases specify a `start_date` and `end_date` for artworks. Most artworks have only one date of production associated with them; in these cases, `start_date` and `end_date` are equal.

14 On directed versus undirected networks and network weighting, see supplementary material.

15 Freeman defines graph centrality by summing the difference of each individual nodes’ degree centrality to that of the most-central node, normalized based on the size of the network: Linton C. Freeman, “Centrality in Social Networks: Conceptual Clarification,” *Social Networks* 1, no. 3 (1978): 226, doi:10.1016/0378-8733(78)90021-7-237.

16 There are several other more subtle methods for measuring centralization, such as betweenness, closeness, or eigenvector centrality. The simple measure of degree centrality is useful for this particular question because we are interested in looking at the basic numbers of collaborators that these network participants had, rather than more complex

2nd-degree or nth-degree relationships whose meaning in this co-production network is more ambiguous.

17 Duncan J. Watts, *Small Worlds: The Dynamics of Networks Between Order and Randomness* (Princeton: Princeton Univ. Press, 1999), 53.

18 Such patterns are often found in cultural networks, as seen in Maximilian Schich et al., “A Network Framework of Cultural History,” *Science* 345, no. 6196 (January 8, 2014): 558–62, doi:10.1126/science.1240064.

19 The model implemented here sets the connection chance, or fitness, of node such that: The exponent determines the skew of the probability distribution. In this context, the skew governs precisely how attractive well-connected individuals are to new entrants to the network, with a larger skew denoting a stronger attraction. A  $\gamma$  of 1 provides a close fit for almost every network shown here. On this model for generating random networks, see Albert-László Barabási and Réka Albert, “Emergence of Scaling in Random Networks,” *Science* 286, no. 5439 (October 15, 1999): 511, doi:10.1126/science.286.5439.509, and the R implementation in G. Csardi and T. Nepusz, “The Igraph Software Package for Complex Network Research,” *InterJournal Complex Systems* (2006): 1695, <http://igraph.org>.

20 This sampling of years is somewhat arbitrary, but does provide a relatively even overview of the time period under consideration.

21 On the Goltzius studio, see Jan Piet Filedt Kok, “Hendrick Goltzius: Engraver, Designer, and Publisher 1582-1600,” *Nederlands Kunsthistorisch Jaarboek* 42-43 (1991): 159–218; Huigen Leeftang, *Hendrick Goltzius 1558-1617: Drawings, Prints, and Paintings* (Amsterdam: Rijksmuseum, 2003), ch. 4.

22 Léna Widerkehr, “Jacob Matham Goltzj Privignus: Jacob Matham Graveur et Ses Rapports Avec Hendrick Goltzius,” *Nederlands Kunsthistorisch Jaarboek* 42-43 (1991–1992): 219–60.

23 Nelke Barthelings, “Bernard Picart, a French Engraver in the Dutch Republic,” in *Les échanges Artistiques Entre Les Anciens Pays-Bas et La France, 1482-1814*, ed. Gaëtane Maës and Jan Blanc (Turnhout, Belgium: Brepols, 2010), 49.

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24 Future work is required to confirm this suggestion, particularly given that the BM and RKM databases return conflicting results for the early eighteenth century.

25 Johann Wussin, *Jonas Suyderhoef, son œuvre gravé, classé et décrit*, trans. Henri Hymans (Brussels: Labroue et Mertens, 1862), 11–12; F. W. H. Hollstein, *Dutch and Flemish Etchings, Engravings, and Woodcuts, ca. 1450–1700* (Amsterdam: M. Hertzberger, 1949–2001), 28:201–260.

26 Joris van Grieken, Ger Luijten, and Jan van der Stock, *Hieronymus Cock: The Renaissance in Print* (New Haven: Yale University Press, 2013), 30–36.

27 Nico van Hout and Paul Huvenne, *Copyright*

*Rubens: Rubens en de grafiek* (Gand: Ludion, 2004); Ann Diels, *The Shadow of Rubens: Print Publishing in 17th-Century Antwerp: Prints by the History Painters Abraham Van Diepenbeeck, Cornelis Schut and Erasmus Quellinus II*, trans. Michael Hoyle and Irene Schaudies (Turnhout: Royal Library of Belgium, 2009).

28 On the downturn's effects on the Flemish art market, see Claartje Rasterhoff and Filip Vermeylen, "The Zeeland Connection: The Art Trade Between the Northern and Southern Netherlands During the Seventeenth Century," in *Moving Pictures: Intra-European Trade in Images, 16th–18th Centuries*, ed. Neil De Marchi and Sophie Raux (Turnhout: Brepols, 2014), 123–50.

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