

A Network of Iconography: Tracing the Evolution of Iconography in History Paintings in the Dutch Golden Age

WEIXUAN LI

Weixuan Li is a PhD candidate at the University of Amsterdam and the Huygens Institute for the History of the Netherlands. Her dissertation focuses on the relationship between the urban fabric and artists' location choices within the city. Combining her training in digital methods at MIT and art history at the University of Amsterdam, she uses digital tools to analyse archival sources and aims to visualise the development of the art market from a spatial perspective.

Abstract

This article demonstrates how an expanding population of artists in the seventeenth-century Dutch Republic was connected artistically, and how such connections were translated into artistic innovations that fuelled the rapid flourishing of Dutch arts and the art market. It does so by conceptualising and visualising an art-historical network of iconography that, for the first time, connects artists not through social relations but through shared subject matters. Using network analysis, this study revisits the definition of product innovations used by the socio-economic art historian John Michael Montias. It further demonstrates that painters' choices of subject matter, styles, and qualities were often unrelated while artists' thematic connections had little to do with their social relations and the location of their residence. Rather, the choices of subject matter were subject to market forces and rooted deeply in an artist's ability, ambition, and marketing strategy. Lastly, this article visualises the artistic network implied in *Rembrandt's rivals* by Eric Jan Sluijter, which helps explain the breakaway success of the *Dismissal of Hagar* paintings.

Keywords: digital art history, network analysis, iconography, Rembrandt, art market

A Network of Iconography: Tracing the Evolution of Iconography in History Paintings in the Dutch Golden Age

WEIXUAN LI

From the late sixteenth century, the burgeoning population of painters in the Dutch Republic was responsible for producing an unprecedented quantity of painted material.¹ The many studies dedicated to estimating just how many painters there were in the seventeenth century have mostly relied on inventories, museum holdings, and demographic databases.² They have all reached a similar conclusion: the number of painters grew at astonishing speed in the first half of the seventeenth century but declined equally quickly after mid-century, although the exact turning point is still under debate. However, it remains unclear how the painters that fuelled the meteoric rise of Dutch arts and the art market were connected either socially or artistically.

To explain this rapid flourishing of both art and art market, scholars have followed two well-trodden paths. On the one hand, economic art historians have used market forces to account for the advent of new styles, techniques, and subject matters. John Michael Montias famously applied ‘process and product innovations’ to understand the link between economics and style.³ And yet, he did not specify what constitutes a new product or how the various features in paintings such as subject matter, painting technique, and quality relate to each other.⁴ On the other hand, art historians try to discern connections among artists and artworks but often within a limited scale.⁵ Although specialised studies on

1 The growth of the painter population is discussed in Montias, ‘Estimates’; Woude, ‘Volume and Value’; Rasterhoff, *Cultural Industries*, 193–195; Li, ‘Innovative Exuberance’.

2 Notable studies include Montias, ‘Estimates’; De Vries, ‘Art History’; Woude, ‘Volume and Value’; Montias, ‘Artists Named’; Bok, *Vraag en aanbod*; Bok, ‘Fluctuations in the Production of Portraits’; Rasterhoff, *Cultural Industries*; and Li, ‘Innovative Exuberance’.

3 Montias, ‘Cost and Value’; Montias, ‘Influence of Economic Factors on Style’.

4 Montias focused mainly on process innovation as a way to cut costs, but he did not specify what product innovation entailed. He mentioned that product innovations ‘generate either totally new products or products whose characteristics depart significantly from those known in the past’, but did not elaborate on what makes a painting ‘new’ or ‘departing from the past’. See Montias, ‘Cost and Value,’ 456; Montias, ‘Influence of Economic Factors on Style,’ 50–51.

5 They often focus on either a single artist or a small number of artists and their immediate circle. The historiography of the development of Netherlandish art is summarized in Sluijter, ‘New Approaches’.

particular artists, subjects, or genres abound, these studies struggle to offer a comprehensive explanation of why certain subject matters were more popular over the rest, perhaps as a result of their limited scope.⁶

In confronting the limitations of both approaches, scholars have begun to use social networks to unveil connections among artists, combining socio-economic and art historical methodologies. A few small, in-depth studies that reconstructed the social networks of individual artists have yielded convincing results.⁷ These studies, however, still take a descriptive approach and have yet to realise the analytical power offered by network analysis in extracting and visualising information.⁸ Recently, researchers have begun to develop methodological frameworks and have successfully embedded social network analysis on a larger scale within research on the art market.⁹

Art historians, however, tend to view any attempt to employ data-driven, quantitative analysis with scepticism, as it shifts the focus away from the works of art. In some sense, they are, of course, correct to do so, because discerning relational patterns from a massive social network would indeed steer attention away from artworks and the core art historical interests – the evolution of style, iconography, and artistic innovation.¹⁰ Art history, therefore, requires a new network concept that foregrounds artworks while still being amenable to network analytics. The recent exhibition *Vermeer and the Masters of Genre Painting*, held at the Louvre, the National Gallery of Ireland, and Washington's National Gallery of Art, explored this idea by considering a network of skills and influences among a few genre painters.¹¹ This study, however, still suffers from a lack of scale: it provides much information about specific artists but lacks a comprehensive vantage point that goes beyond the immediate social circles of a few painters.

This article seeks, therefore, to explicate artistic connections and their relations to artistic innovation at a larger scale. It does so by developing a novel network in which artists are connected, for the first time, *not* through their social relations but through their artistic ideas revealed in the subject matters of their works. As we shall see, this network of subject matters helps to reveal changes in artistic linkages through thematic choices, mirroring the market development. This article will then investigate whether artists' social relations, active locations, and style and quality of their works influenced the choice of subject matter. Lastly, this essay uses Rembrandt's circle and his rivals as a case study to showcase how this method can help to explicate implicit networks inscribed in art historical writings, and how the new insights explain the breakaway success of *Dismissal of Hagar* paintings, one of the most popularised scenes by Rembrandt and his circle. While

6 Exhibitions and studies on the visual connections within a genre are many, but to name a few: Sluijter, *De 'heydensche fabulen'*; Sutton, Vergara, and Adams, *Love Letters*; Kolfin, *The Young Gentry at Play*; Rosen, *Soldiers at Leisure*; Kwak, 'Proeft de kost'.

7 Kok, *Culturele ondernemers*.

8 Larson, 'A Network Approach'; Sun, 'Social Network behind an Architectural Style'.

9 A theoretical framework is discussed in Marx, 'Social Network Analysis for Art Historians'. For a brilliant application of this method, see Ginhoven, *Connecting Art Markets*, and for a more recent survey Lincoln, 'Network Thinking'.

10 A notable exception is Matthew Lincoln, who has explored an alternative use of social network in explaining artistic relations: Lincoln, 'Social Network Centralization Dynamics'; Lincoln, 'Continuity and Disruption'.

11 Waiboer, Wheelock Jr., and Ducos, *Vermeer and the Masters of Genre Painting*.

verifying existing knowledge using comprehensive digital sources, this study delves deeper into the evolution of market structure and revisits Montias's concept of 'process and product innovations'. Given its exploratory nature, this essay raises more questions than it can answer, but it is hoped that the methodology proposed here will provide inspiration for scholars wishing to bridge digital and conventional approaches.

Data on Subject Matters and Research Scope

The network of iconography draws a connection between two artists through mutual choices of subject matter (the term 'iconography' in this essay is used interchangeably with 'subject matter' to indicate the content of images as a whole, without interpreting possible meanings).¹² A link in this network between two painters is measured by the total number of overlaps in the subject matters found in their oeuvres. Constructing such a network generally requires a source that meets two criteria: first, it should offer a sizable pool of artworks attributed to a significant number of artists; and second, it should identify subject matter in artworks with standardised references, free from consistency issues and amenable to categorisation and comparison. These rather daunting prerequisites may have thwarted previous attempts to build a network of iconography, given that the image recognition technology is not yet mature enough to detect subjects of visual arts, were it not for the digitalised archives in the Netherlands Institute of Art History (RKD), which offers an opportunity to realise such a network, albeit within a limited scope.

The RKD Images database, the online version of the RKD's visual collections, presents a comprehensive digitised collection of Dutch art. It features broad and deep collections of photographs and reproductions of paintings by Dutch and Flemish artists, containing more than 100,000 unique paintings (including copies of known, attributed paintings), drawings, and sketches produced between 1550 and 1750.¹³ While the RKD collection has remarkably rich holdings, it cannot be regarded as perfectly representative of the full range of paintings produced in the seventeenth century. For example, it under-represents low-quality paintings as most did not survive.¹⁴ The RKD's own collection history may exacerbate this survival bias, as the collection originated in the personal photo archives of early twentieth-century art experts and collectors, which introduced a selection bias that favours high-quality works of famous seventeenth-century Dutch artists. That said, studying networks of artists and iconographies requires artistic originality and attribution. These two prerequisites rule out low-quality copies or cheap paintings without identified painters missing from RKD Images, meaning that a carefully crafted research focus can

¹² Erwin Panofsky has differentiated the description of an image's content (iconography) from the interpretation of the content's meaning (iconology): Panofsky, *Meaning in the Visual Arts*.

¹³ RKDimages contains 101,561 unique paintings, drawings, and sketches (including 55,718 unique paintings). Data was acquired via the RKD public API, <https://rkd.nl/nl/explore/images> (Accessed on 5 February 2018).

¹⁴ The low-quality paintings (*dosijnwerck*) had a much lower survival rate than those of Rembrandt, and are thus under-represented in the modern database. For the bottom layer of the art market, see Jager, *Mass Market*. Except for the few artists' oeuvres Jager laboured to assemble, most low-end artists' works were lost or remain unattributed.

alleviate – though not entirely eliminate – biases from the database. Despite some limitations, then, rKD Images, with its sheer volume, wide coverage, and diverse sources, is viewed as one of the most comprehensive repositories for surviving and/or identified Netherlandish paintings.

Besides images, the rKD releases curated data on its collection.¹⁵ It employs a hierarchical notation system known as Iconclass to describe subject matters and label works of art.¹⁶ A shared Iconclass tag denotes that paintings depict the same subject matter, thus drawing a thematic connection between these works of art. As such, rKD Images offers a unique opportunity to create a network of iconography at scale. Admittedly, this approach favours artworks falling into the broad category of history painting that depict moments in narrative stories in the Bible, mythology, history, and literature. These paintings are arguably the most researched and best documented in this database: they are the most thoroughly labelled with Iconclass tags and often have explicit references to scenes or stories, such as *Diana discovers Callisto's pregnancy* (92C35211). Other genres like landscape and still life are often bereft of Iconclass labels, as they do not have an apparent iconographic reference to scenes or stories. It is worth noting that the Iconclass labelling should not be confused with the keywords encoded in the same dataset. Iconclass often compresses complex scenes into a succinct code, like the *Adoration of the Shepherds* (73B25), whereas keywords are more descriptive, listing for example genres, scenes, and motifs.¹⁷ Furthermore, the Iconclass classification system with its standard vocabulary is used by museums and art institutions worldwide, thereby suffering less from uniformity and consistency issues than the keywords.¹⁸ It must also be noted that the genre of history painting underwent dramatic iconographical changes in the seventeenth century. Fig. 1 shows the number of new Iconclass codes introduced each year, suggesting that novel subject matters were concentrated in history paintings depicting scenes from the Old and New Testament (yellow and bright green) as well as from classical mythology (light blue).

To take full advantage of the richness of the dataset and bypass its inherent limitations, this essay will restrict itself to history paintings (including landscapes with small-figured histories), prints, drawings, and oil sketches concerning stories from the Bible, mythology, classical history, and literature by artists active in the Dutch Republic.¹⁹ This limited

¹⁵ The rKD houses various duplicated images from various sources under the same painting entry. Therefore, image duplication does not affect the quality of the rKD data.

¹⁶ See for the Iconclass system: <http://www.iconclass.nl> (Accessed on 5, February 2018).

¹⁷ For instance, Pieter Aertsen's *Adoration of the Shepherds* (1544, Amsterdam Museum) has the Iconclass code 73B25, and is tagged with keywords at various levels, such as *New Testament and Apocrypha*, *herdsman*, *birth*, and *bull*: <https://rkd.nl/explore/images/6991/> (Accessed on 5 February 2018).

¹⁸ Since the Iconclass system is maintained regularly, its vocabulary is less subject to the limitations of the certain dated terms. See the recent update in Section 32B: <http://www.iconclass.org/help/outline> (Accessed on 15 October 2021).

¹⁹ Allegory paintings, although falling into the broader genre of history, are excluded from this study because their iconographies can hardly suggest thematic connections among artists. For example, Ferdinand Bol's *Allegory of education* in the Rijksmuseum is labelled as *scholastic education*, *tuition* (49B), *historical persons*, 'portrait historié' (61B+2), and *cupids* (92D1916), all of which are not helpful to discern the shared iconographies between artists. Regarding prints, two major collections of Netherlandish prints are in the Rijksmuseum and the British Museum respectively, but their databases neither employ Iconclass nor can be easily linked to the rKD. Therefore, paintings and drawings are the main source of this article.

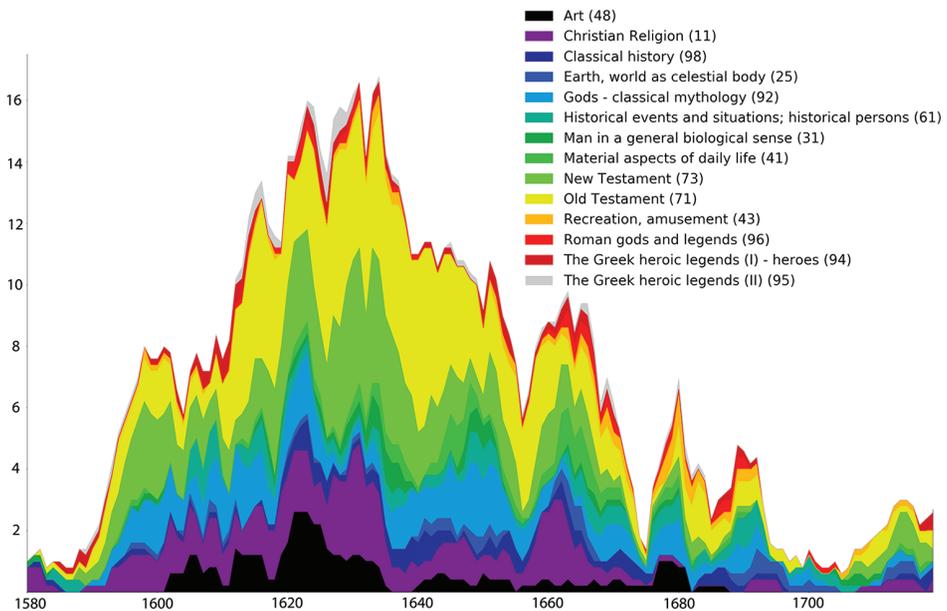


Fig. 1 Number of new Iconclass codes for paintings produced in the Dutch Republic, 1580-1720 (5-year average). New Iconclass codes are counted the first year they appeared in RKD Images.

scope guarantees the best coverage and high-quality Iconclass labelling in RKD Images. This research takes into account not only paintings but also drawings and oil sketches, because such preparatory sketches and studies also point to the awareness of an idea or a subject among artists, regardless of whether that idea was eventually executed in a painting or not. To guarantee the consistency of the Iconclass labelling, I manually processed the relevant labels to mitigate any possible flaws in the database.²⁰ I then linked RKD Images to the ECARTICO database to add biographical information about the artists, in order to understand if artists could have seen each other's work through their social connections or because they resided in the same city or neighbourhood.²¹ In particular, I used artists' active period and location as listed in ECARTICO to introduce a temporal dimension, tracing the evolution of popular subjects among generations of artists in the Dutch Republic. Admittedly, the dataset inevitably imposes a Dutch-centric view of artistic connections

²⁰ Iconclass is a hierarchical database: the number of digits of an Iconclass code often indicates the level within the hierarchy. For example, the *Adoration of the Shepherds* (73B25) consists of five levels: 7 (Bible) – 73 (New Testament) – 73B (birth and youth of Christ) – 73B2 (adoration of the Christ-child; Christ's birth) – 73B25 (adoration of the Christ-child by the shepherds; Mary and Joseph present). However, the number of digits or the level within the hierarchy does not necessarily indicate how specific a scene is in an art historical sense: the eight-digit *Diana discovers Callisto's pregnancy* (92C35211) and the seven-digit *Diana bathing with her nymphs* (92C3521) mark two distinctive scenes. Therefore, manual processing that applies art historical judgements is necessary to correct the possible biases in the RKD database.

²¹ ECARTICO provides a comprehensive collection of structured biographical data concerning painters and other agents involved in the 'cultural industries' of the Low Countries in the sixteenth and seventeenth centuries: <http://www.vondel.humanities.uva.nl/ecartico/> (Accessed on 5 February 2018).

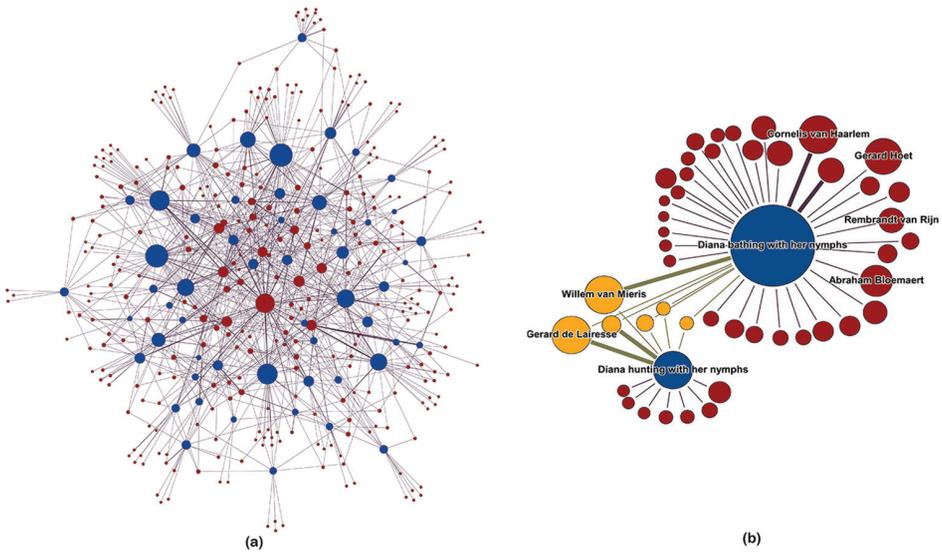


Fig. 2 a) Two-mode sample network of popular mythological themes (blue) and painters (red); b) detail of fig. 2a.

among Dutch painters and artworks, and overlooks the fact that painters sometimes drew inspiration from visual sources from abroad or from non-visual ones such as literature.²² The development of Dutch art was in fact more intertwined with the wider European art world than this article may suggest. It is hoped, however, that the methodology introduced in this essay can be applied to more comprehensive sources and datasets when these become available in the future.

Constructing a Network of Subject Matters

I took advantage of network theories and analytics programs such as Rstudio and Gephi to translate the vast visual database into clouds of connections, visualising a network of artistic ideas and iconographies. This section will briefly explain how the iconography network is developed conceptually, leaving technical measures to Appendix 1. The record of an attributed painting in RKD Images identifies a link between the painter and the subject matter (labelled with Iconclass). One painter can link to many subjects as he painted various scenes, and one subject matter can be tied to numerous painters who picked it up. Putting them together, I created a two-mode network with two types of nodes: artists and subject matters. Fig. 2a gives an example of such a two-mode network of artists (red) and subjects (blue), including around fifty scenes in mythology like *Venus and Adonis* and *Diana and Callisto*, both popular themes painted by many artists. Painters who created a variety of mythological scenes stand out with numerous connections (larger in size).

²² It is known that prints circulated throughout Europe. The discussion of Dutch art in relation to the international conventions is summarized in Sluijter, 'New Approaches,' 257-258. For an example of artists using literature in absence of a visual convention, see Seifert, *Pieter Lastman*, 69-82.

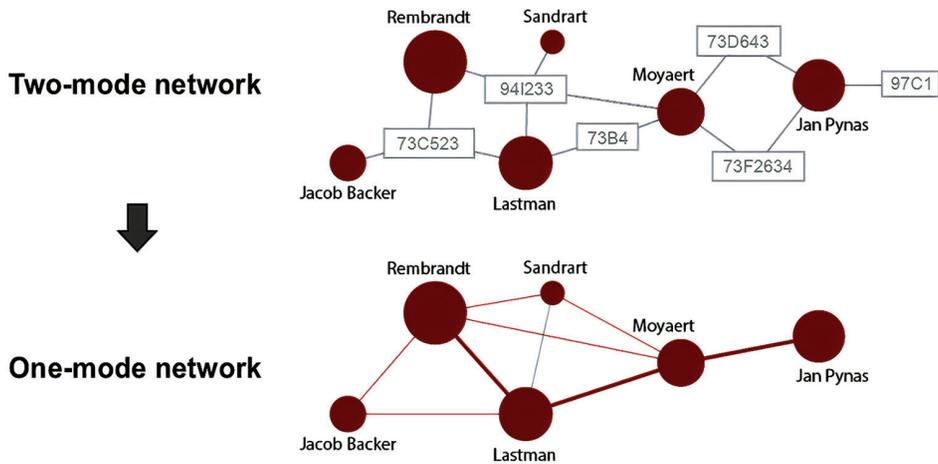


Fig. 3 Example of the projection of a two-mode network of artists (circle) and Iconclass (box) into a one-mode network of artists connected by Iconclass.

A closer look reveals how and why painters were connected artistically. Fig. 2b shows a surprisingly high degree of separation between the painters who painted *Diana bathing with her nymphs* and *Diana hunting with her nymphs*. Relatively few artists painted both subjects (highlighted in yellow), even though the two themes are closely related. The Dutch Republic seems to have had a long pictorial tradition of Diana's bathing scene, as we find artists ranging from Cornelis van Haarlem in the early seventeenth century to painters of the next generations, such as Rembrandt, and later Arnold Houbraken and Gerard Hoet. This phenomenon might be explained by the iconographical differences and the distinct painting skills required: *Diana bathing with her nymphs* presents many female nudes, whereas figures in *Diana hunting* are clothed; and painting bare skin presumably requires different knowledge and a different cultural, religious, and moral environment.²³

Although the two-mode network offers interesting insights, it does not demonstrate how artists were connected *directly* through shared subject matters. Nor can it be analysed by existing network theories, which are designed exclusively for one-mode networks that include either artists or subject matters, but not both.²⁴ To create such a one-mode network of artists, we must convert (or 'project', in network parlance) the two-mode network shown in fig. 2 by turning the shared subject matters into a conceptual link between two artists (fig. 3; see for more details Appendix 1). Likewise, a one-mode network of subject matters is generated by linking two subject matters by artists who depicted both. This conversion or 'projection' process eventually results in two one-mode networks: one of the

²³ The specific skills in rendering nude body had already been recognized by the contemporaries. Gerard de Lairese, for example, devoted two chapters to painting nude: Lairese, *Groot schilderboek*, 1, 35-42. The perception of female nude and the moral and erotic implications of the subjects are discussed in Sluijter, *Female Nude*, 143-163.

²⁴ For a discussion of one- and two-mode networks, see Graham, Milligan, and Weingart, *Exploring Big Historical Data*.

Tab. 1 Network metrics of the iconographic network of artists and subject matters by period.

Period	Network of artists			Network of subject matters		
	Painters	Links	Avg. link per painter	Iconclasses	Links	Avg. link per subject
1575-1610	31	80	5.61	35	89	5.09
1610-1650	97	462	9.53	75	237	6.32
1650-1700	66	182	5.52	57	380	14.58

Source: RKD Images and ECARTICO. Metrics were calculated by the algorithms in Gephi.

artists connected by mutual subject matters; and one of the subject matters linked via the artists who painted them. These two networks allow us to examine the artistic connections among artists through subject matters, and to observe changes in thematic fashion over time.

Evolution of Iconographical Connections Among History Painters

This section traces the changes over time in the network of iconography, grouping artists by the time they entered the market. To do so, I have relied on the three phases in the development of the Dutch art market as identified by Claartje Rasterhoff: a transition period from a traditional society to a modern economy between 1580 and 1610, followed by a rapid expansion over the next forty years, until the market reached a state of maturity after 1650.²⁵ The two networks of artists and subject matters link artists who entered the market during each of these three periods through at least two mutual subject matters in their oeuvre to avoid coincidences. Tab. 1 shows the structure of these two networks during different stages.

Tab. 1 shows that the network of artists tripled in size between 1610 and 1650, but shrunk significantly afterwards, which, given that it accords with existing scholarship, testifies to the validity and reliability of this method.²⁶ The number of links (which represent the connections among artists) increased fivefold between 1610 and 1650, signifying a structural change. The network of subject matters, too, witnessed a rapid growth in the variety of Iconclass codes from 1610 to 1650. Yet despite the great variety of subject matters explored and popularised by the artists during the second period, their successors relied on a much smaller pool of subjects, which were surprisingly more densely connected than in the preceding period. The fact that the network of artists and that of subject matters diverge in their network density and structure suggests a shift in the thematic choices of artists (see Appendix 1 for more network measures). In what follows, I will discuss the characteristics of the network of iconography within each of the three periods.

²⁵ Rasterhoff, *Cultural Industries*.

²⁶ This trend attests to the existing estimates of painter populations discussed by Rasterhoff as well as other studies mentioned in note 2.

Dawn of the Golden Age, 1575-1610

Fig. 4 visualises the iconographic networks of artists entering the market between 1575 and 1610. Mannerist giants like Cornelis Cornelisz. in Haarlem and Abraham Bloemaert in Utrecht occupy key positions in this network. They not only enjoy a close iconographic bond but also reach painters in relatively peripheral positions. This network of painters in the first period is highly centralised, as it is dominated by a few painters working in a similar style and depicting similar subject matters while residing in different cities.

The colours in fig. 4 mark the clusters of artists who are more likely to paint similar subject matters within the group as opposed to those outside of it. These colour-coded clusters represent the so-called modularity classes or modules in network analysis that detect densely connected clusters within a network (see Appendix 1). For instance, fig. 4 shows that the painters in blue shared more subject matters among themselves, and as such were separated from the red group, which was dominated by the aforementioned Mannerists. A closer look reveals that the blue cluster consists mainly of Amsterdam painters, led by Pieter Lastman and David Vinckboons. Unlike the Mannerists, these closely connected painters in blue worked in distinctive styles – no one will confuse Lastman's history

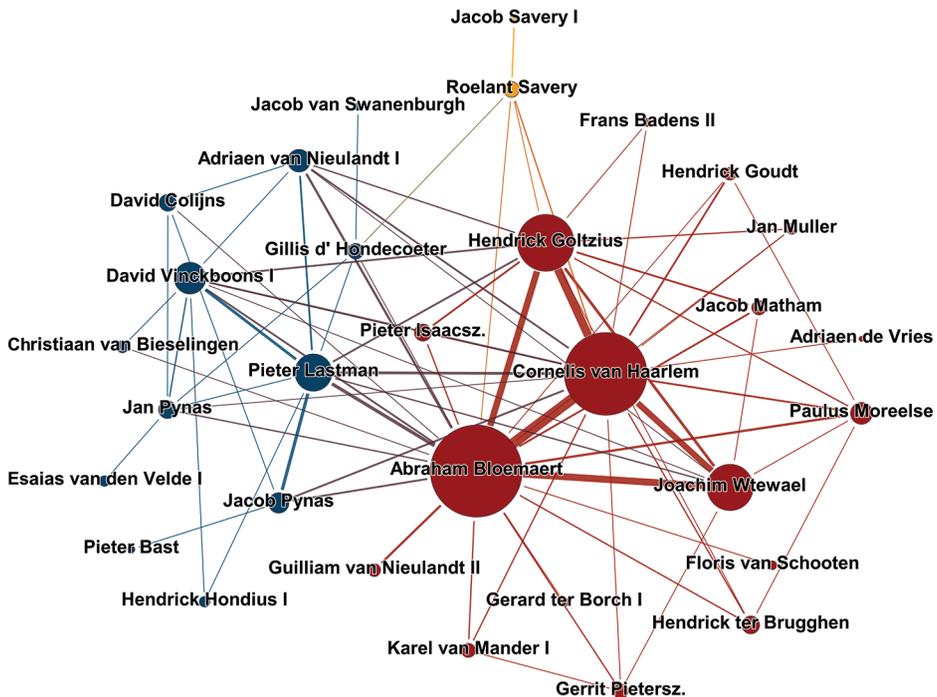


Fig. 4 Simplified network of artists active between 1575 and 1610, linked by at least two mutual subject matters. Nodes sized by weighted degrees and coloured by the modularity classes calculated in Gephi.

are to be found within the same cluster (marked in grey). This modular network structure heralds a transition from a conventional, small, and exclusive art world, in which artists were dependent on modest demand from the church or private patronage, to a commercial art market where paintings were sold as standardised commodities to a large group of ordinary citizens.²⁷

Rapid Development, 1610-1650

Fig. 6 displays a simplified network of artists between 1610 and 1650, which, when measured by the number of painters, tripled in size compared to the previous period. Previous scholarship has amply demonstrated the growth in the population of painters in this period.²⁸ However, scholars have not yet shown the structure of connections among these painters. Fig. 6 and tab. 1 illustrate that the number of links among artists increases almost sixfold (from 80 to 462), while the number of painters triples (from 31 to 97). In other words, this network's interconnectivity (as measured by the average links per painter) is almost twice as large as that of other time periods. Next to the well-known fact that more artists picked from a larger pool of subject matters, fig. 6 suggests that *each* artist covered more variety of subjects in *their own oeuvre* instead of specialising in selective subsets. This observation challenges the general impression of deepening specialisation among seventeenth-century Dutch artists.²⁹ Network analysis suggests that in fact the opposite took place at the subject level, adding weight to a new interpretation of specialisation that I have proposed elsewhere.³⁰

Furthermore, the network of 1610-1650 is the least centralised among the three periods, meaning that it does not have dominant individuals and that connections are spread more evenly among artists. Fig. 6 also shows that Rembrandt, supposedly the greatest master of the century, did not enjoy the same central position as Cornelis van Haarlem had in the previous period. Other individuals with a similar level of connections to Rembrandt include Leonard Bramer (known for his numerous designs) in Delft, Jacob de Wet in Haarlem, and Cornelis van Poelenburch in Utrecht. It means that popular subject matters were disseminated among artists working in different market segments and were diffused beyond the city walls. The question remains, however, whether these observed changes in the network are not merely artefacts of a larger network that we might find in *any network* of the same size. We can check our observations by comparing them

27 The political and economic events of the later sixteenth century that caused shifts in demand and changes on the supply side are discussed in Bok, 'The Rise of Amsterdam'; Bok, *Vraag en aanbod*, Montias, 'Cost and Value'.

28 Montias, 'Estimates'; De Vries, 'Art History'; Woude, 'Volume and Value'; Montias, 'Artists Named'; Bok, *Vraag en aanbod*; Bok, 'Fluctuations in the Production of Portraits'; Rasterhoff, *Cultural Industries*; and Li, 'Innovative Exuberance'.

29 Chong, 'The Market for Landscape'; Montias, 'Cost and Value'; Montias, 'Art Dealers'; Montias, 'Influence of Economic Factors on Style'.

30 Specialisation did not mean restricting one's oeuvre to few subjects. Rather, artists were anchored in their 'unique selling point' (such as horses for Philip Wouwerman) and graced sundry subjects with their speciality: Li, 'Spotting Specialists'.

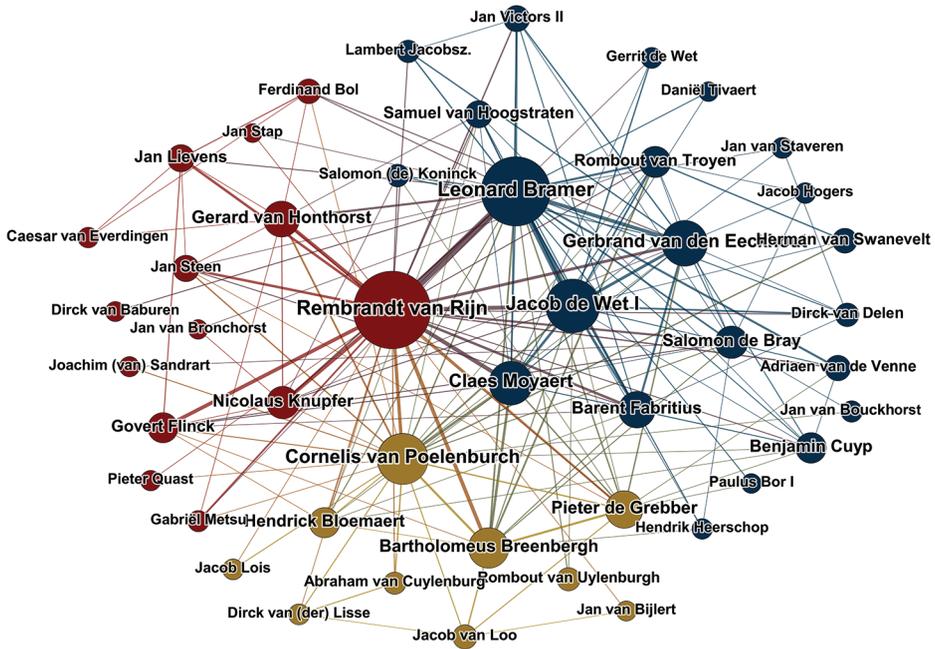


Fig. 6 Network of artists active between 1610 and 1650, linked by at least three mutual subject matters.

to randomly generated networks of the same size (Appendix II). The simulation results suggest that the network of 1610–1650 is in fact much denser and less centralised than typical, random networks of the same size. This means that the growth of the population of painters alone cannot fully explain the large number of connections relatively evenly spread among painters – clearly, a shift had taken place in how artists picked their subject matters.

What had brought about the structural change in the network of iconography between 1610 and 1650? I would argue that the rapid expansion of the art market forced painters out of their old career path, bringing about a shift in marketing strategy. It was their adaptation to this ‘new reality’ that eventually shaped the network. Of course, none of these reasonings is entirely new, as socio-economic art historians have shown that the art market developed into a complex and competitive arena in which many painters and art dealers vied for an equally large number of clients.³¹ A relatively free market facilitated the

³¹ Notable studies of Dutch art supply are: De Marchi, ‘Dutch Auctions and Lotteries’; Sluijter, ‘Over Brabantse voddem’; Bok, ‘The Rise of Amsterdam’; Bok, ‘Paintings for Sale’; Montias, *Art at Auction*; Raux, *Lotteries*. Paintings were found in houses of various social classes, as discussed in Fock, ‘Kunstbezit’; Wijsenbeek-Olthuis, ‘Boedelinventarissen’; Bok, *Vraag en aanbod*; Sluijter, ‘Paintings in Wealthy Interiors’. More recently, scholars have studied market mechanisms and social interaction to better understand the workings of the art market: Rasterhoff, *Cultural Industries*; Li, ‘Innovative Exuberance’. For art dealers, see Montias, ‘Art Dealers’; Bok, ‘“Paintings for Sale”’; Montias, ‘The Guild of St. Luke’; De Marchi and Van Miegroet, ‘Art, Value, and Market Practices’.

flow of information across cities and smoothed the spread of subject matter throughout market segments. All of these market forces account for the profusion of connections in fig. 6 and tab. 1. Jan Steen, for instance, who is best known for his chaotic domestic genre scenes, occasionally also painted history scenes, drawing thematic links to various masters outside his city of residence. Jan Steen and his clients had obviously kept a close eye on the market.³²

Economic art historians have suggested that painters were under market pressure to innovate and consequently introduced myriad new styles, techniques, and subject matters in this period.³³ However, the innovative burst in subject matters between 1610 and 1630 faded away decades before the market contracted (see fig. 1).³⁴ The art market seems to have continued to grow for another two decades despite the fact that the invention of new subject matters lagged behind.³⁵ This observation calls into question Montias's notion of 'product and process innovations'. Although Montias elaborated on various process innovations as ways of increasing painting productivity and reducing costs, he remained vague on innovations that generated 'new products', nor did he sufficiently explain how key features in paintings such as subject matter, painting technique, and quality contributed to the introduction of these 'new products' in the art market. This is precisely where a network approach can offer new insights.

The colour-coded clusters in fig. 6 suggest that artists' choices of subject matter, style, and quality were not connected. The Utrecht Caravaggist Gerard Honthorst had more subjects in common with Rembrandt than with his fellow Caravaggisti Dirck Baburen and Hendrick Bloemaert. Likewise, many painters in Rembrandt's circle, including Gerbrand van Eeckhout and Salomon Koninck, fall into a different group than the great master. The close thematic ties between artists working with different styles and qualities in fig. 6 suggest that the demand for subject matter trumped stylistic preference. It was likely the combination of subject matter, style, and quality that defined a new product in the art market, even when none of them was novel. These multiple variables generated a myriad of combinations that kept the public interested in its diversity for decades, even after the thematic inventions dwindled by the 1630s (fig. 1). This preference for diversity encouraged an interconnected yet decentralised diffusion of subject matters. For this reason, subject matters popularised by great masters were soon picked up by lesser painters, whose lower-quality works of the same subjects were still embraced by the market.³⁶ On the other hand, choosing the same subject matter means putting oneself in direct comparison to other masters. It explains why only Rembrandt's direct rivals and best pupils – Jan Lievens, Govert Flinck, and Ferdinand Bol – could afford to share many subject matters with Rembrandt (marked in red in fig. 6), while other painters who worked in a similar

32 Jan Steen's position as a history painter has recently been rediscovered in a recent exhibition: Suchtelen, Westermann, and Kloek, *Jan Steen's Histories*.

33 The pressure to innovate is best illustrated in Sluijter, 'Jan van Goyen als marktlieder'.

34 Economic historians have argued that market contraction occurred in the 1660s or 1670s, which put an end to the innovative, flourishing period of Dutch art: Vries, 'Art History'; Bok, *Vraag en aanbod*.

35 Landscape became the most produced genre in the Dutch Republic: Bok, "Paintings for Sale".

36 This phenomenon is discussed in Falkenburg, 'Onweer'.

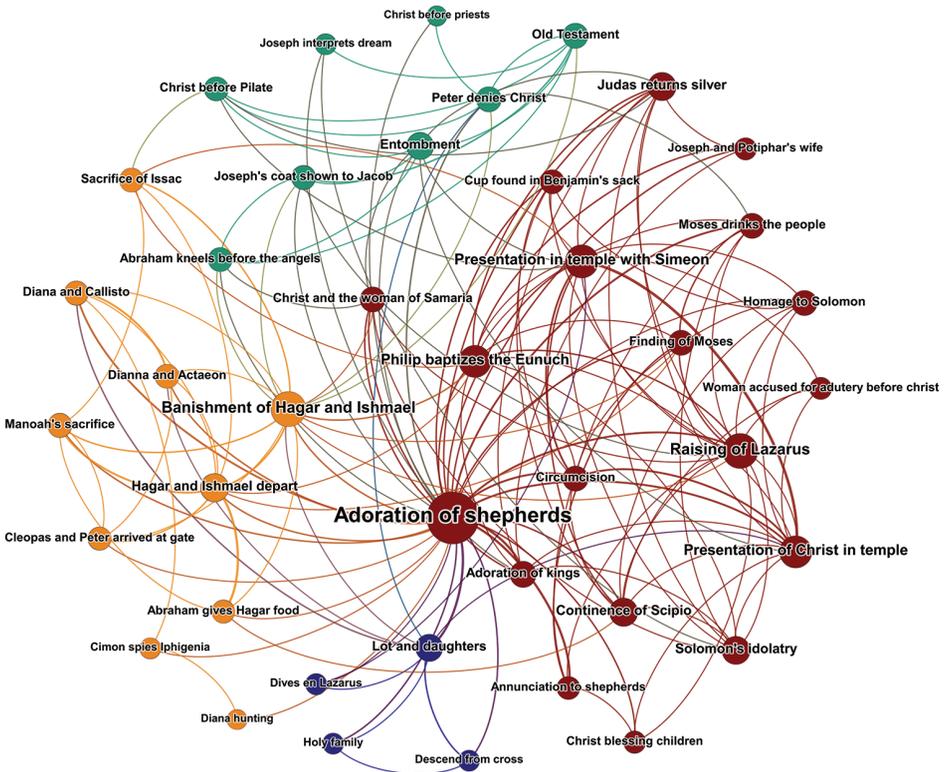


Fig. 7 Network of subject matters linked by at least three artists active between 1610 and 1650.

style to Rembrandt's, such as Salomon Koninck, avoided direct comparison by choosing different subjects (marked in blue).

In the network of subjects (fig. 7), mythological scenes – which dominated the subject network of the previous period – give way to the more conventional, even old-fashioned stories of the Old and New Testament, such as the *Adoration of the shepherds* and the *Raising of Lazarus*. Meanwhile, many new subjects formed their own cluster (marked yellow in fig. 7), including the *Dismissal of Hagar* and the *Sacrifice of Manoah*, which had been introduced by early innovators like Lastman and were subsequently popularised by successors like Rembrandt. However, except for a few outliers, most innovations in subject matters failed to gain momentum in the market, and painters still had to respect existing visual forms and traditional subjects if they were to appeal to buyers.

Mature Market, 1650-1700

Perhaps surprisingly, the centre of the network between 1650 and 1700 is occupied by many painters known as *fijnschilders* – Willem van Mieris in Leiden, Adriaen van der

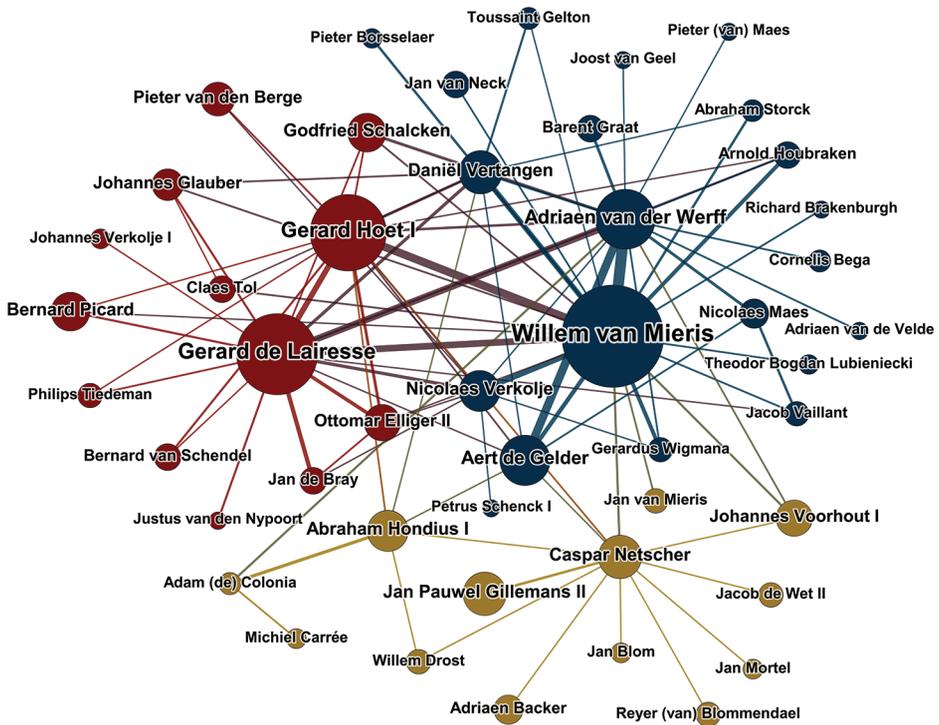


Fig. 8 Network of artists active between 1660 and 1700, linked by at least three mutual subject matters.

Werff in Rotterdam, and Caspar Netscher in The Hague – together with so-called Dutch Classicists like Gerard de Lairese and Gerard Hoet (fig. 8). Even so, they belong to different clusters (blue and red, respectively), which suggests that a relatively small number of shared subject matters could be executed both as small, refined paintings and as larger, relatively rough tableaus. The prominent position of *fijnschilders* and Dutch Classicists in the network of iconography thus attests to the bifurcation of history paintings during the last decades of the seventeenth century. On the one hand, Classicist painters like Lairese decorated palaces, public buildings, and mansions of the wealthy burghers, while on the other hand *fijnschilders* meticulously crafted small history pieces to enrich connoisseurs' collections. The popularity of both groups speaks directly to the new fashion favouring both alternative wall-hangings (ceiling and mural paintings) and highly-refined easel paintings for collectors, substantiating the 'aristocratization' (*veradelijking*) observed by art historians.³⁷

Furthermore, the strong ties among *fijnschilders* signal a change in competition and marketing strategy. Painters of the same style and quality no longer avoided using

³⁷ See for a detailed discussion about this new decoration trend Fock, 'Het interieur in de Republiek'; Mai, Paarlberg, and Weber, *De kroon op het werk*. For an overview, see Aono, 'Out of the Shadow of the Golden Age'.

Junko Aono has argued, affluent collectors valued these painters' works when they inherited and updated the pictorial tradition of the old masters.⁴⁰

In this period, the subject matters picked for paintings were increasingly drawn from mythology and the Old Testament. Painters seem to have abandoned the new inventions from the previous generation and resorted to the more traditional scenes like *Susana and the elders* and *Lot and his daughters*, constraining themselves to an even smaller collection of subjects. *Fijnschilders* and their patrons favoured the artistic execution over the subject matter, leaving little room and need for thematic innovation. The popularity of a limited number of subjects and the virtual absence of others in the network of subject matter attests to Eric Jan Sluijter's observation that the period saw a highly selective and restricted repertoire.⁴¹ As Marten Jan Bok has put it, 'creative freedom was an ideal rather than a reality'.⁴²

The Network of Iconography among Rembrandt's Rivals

The previous section broadly outlined how the structural change in the network of iconography reveals shifts in artistic choice, competition, and trending subject matters. This section takes a closer look at a group of well-researched painters in Amsterdam, using them as a case study to analyse how the network of iconography relates to the artistic 'influence' and connections identified in Eric Jan Sluijter's *Rembrandt's Rivals*.⁴³ In this seminal work, Sluijter examined the artistic competition as a conscious rivalry among artists, who both imitated and emulated each other in composition, manner (*handeling*), motif, and subject matter. In his analysis he draws connections between different painters, which implicitly weaves a network of artistic rivalry through influential relations. Fig. 10 visualises this rivalry network in *Rembrandt's Rivals*.

The node size represents a master's level of influence, measured by how many other artists picked up or 'borrowed' ideas from him. The thickness of the link between nodes represents the strength of such artistic 'borrowing', ranging from acquiring the source's style (such as the thick line between Rembrandt, Flinck, and Bol), to employing his compositions or motifs, and to there being merely the faintest of resemblances between the works (i.e., a thin line). The colour-coded clusters (modularity classes) in fig. 10 corroborate the grouping by style and manner as understood by art historians. But how does the iconographic network of artists relate to the rivalry network, and how do these two networks compare to the social network? To answer these questions, I have filtered out the artists featured in Sluijter's study and created an iconographic network among Rembrandt's rivals (fig. 11).

⁴⁰ Aono, *Confronting the Golden Age*.

⁴¹ Sluijter, *Seductress of Sight*, 15.

⁴² Bok, 'The Rise of Amsterdam', 202.

⁴³ I have put 'influence' between quotation marks because Sluijter has denounced the use of this nebulous term and has instead suggested the term 'artistic rivalry', which allows for different degrees of 'borrowing': Sluijter, *Rembrandt's Rivals*, 3-4.

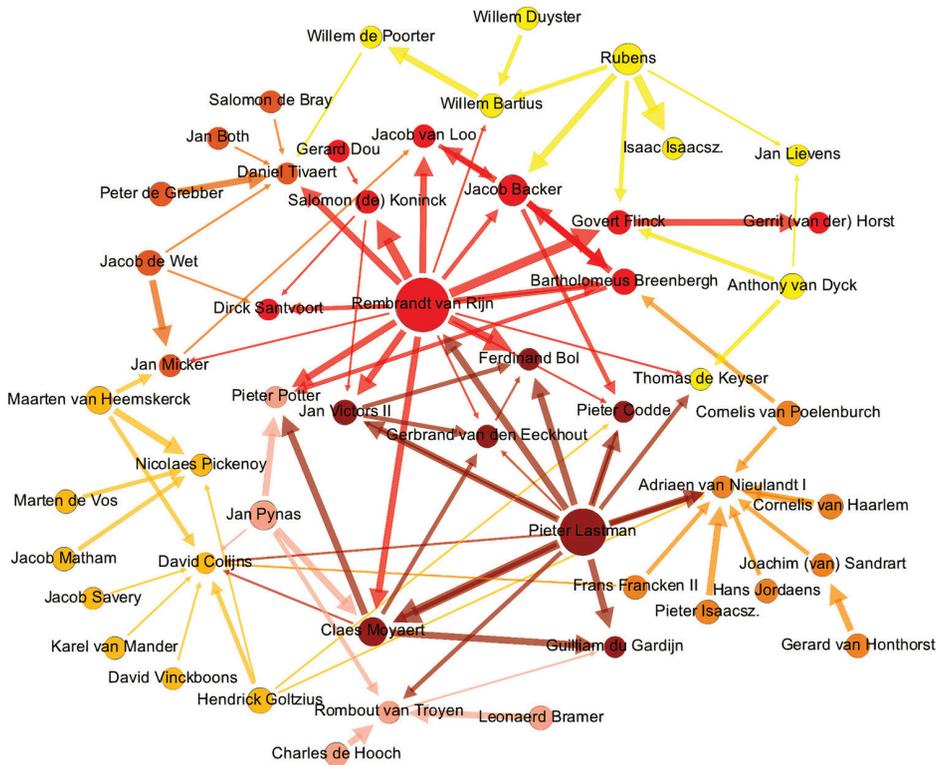


Fig. 10 Network of artistic rivalry derived from Sluijter, *Rembrandt's Rivals*. Nodes are coloured by the modularity classes.

Comparing the networks based on artistic rivalry and iconography, it is clear that the great masters who had a powerful stylistic impact (like Rembrandt or Lastman) also occupy prominent positions in the iconographic network. Nonetheless, the thematic network cannot distinguish innovators or trendsetters from their followers, as the latter – who kept a close eye on the innovators – could take on the same subjects. For this reason, the followers occupy more critical positions in the thematic network than they could in the rivalry network. Bartholomeus Breenbergh was one such astute follower, who stands out in fig. 11 for his numerous connections. Breenbergh, known for his Italianate landscapes with small figures, often inserted elements of Rembrandt's and Jacob Backer's works into his renowned landscapes, such as in the *Preaching of St. John the Baptist*.⁴⁴ In this way, Breenbergh relied on his 'unique selling point' while staying in tune with what was popular at the time. The difference in style and manner freed him from direct competition with the great masters. Duplications in subjects would have made Breenbergh's works more attractive to his clients.

44 Sluijter, *Rembrandt's Rivals*, 129-144.

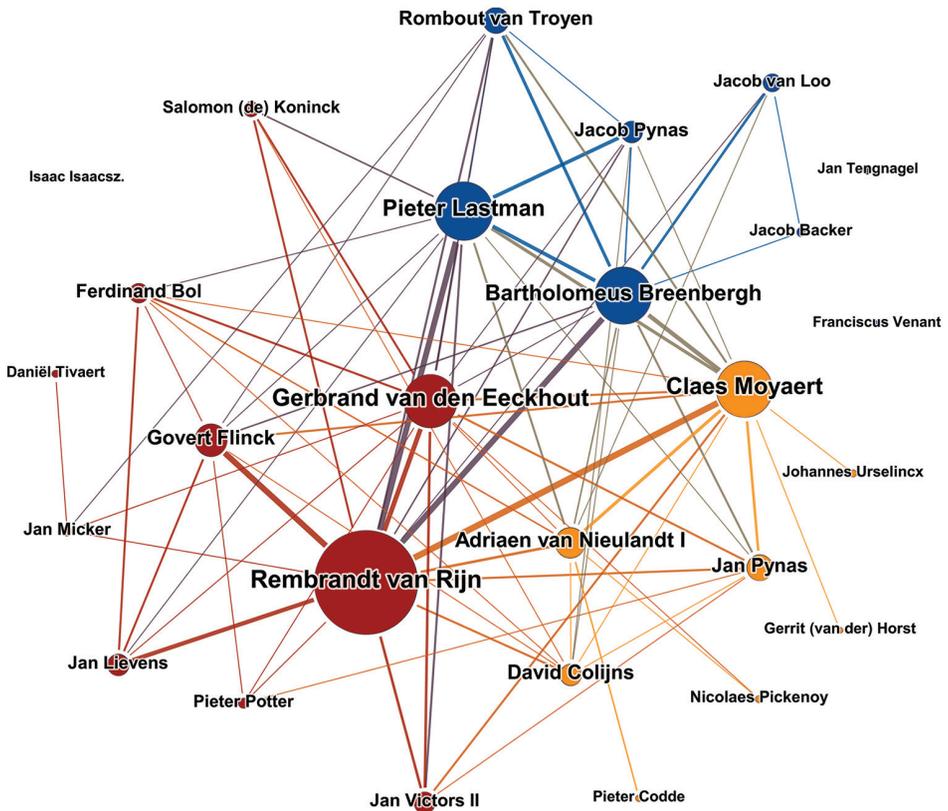


Fig. 11 Network of iconography among artists featured in *Sluijter, Rembrandt's rivals*, and linked by at least two mutual subject matters.

Sluijter suggests that many painters active in Amsterdam between 1630 and 1650 were oblivious to the new painting style introduced by Rembrandt and instead clung to well-established traditions and painting styles. The network of iconography reveals that it is not that they did not react to Rembrandt's innovations, but that they did so in a new way: painters rode the tide of popular subject matters introduced by Rembrandt and other innovators while sticking to their own style. Conventional painters like Adriaen van Nieulandt and David Colijns seem to have actively participated in the competition by picking up popular subjects, even though they did not adopt Rembrandt's new painting style.⁴⁵ In other words, even though artists produced topical and novel subject matters, they often did so in conventional styles. This observation underlines the fact that competition occurred

⁴⁵ Sluijter, *Rembrandt's Rivals*, 178. Adriaen van Nieulandt and Rembrandt were close neighbours for many years, and Van Nieulandt owned 'a book with 102 prints by Rembrandt', but there is no reflection of Rembrandt in Van Nieulandt's works.

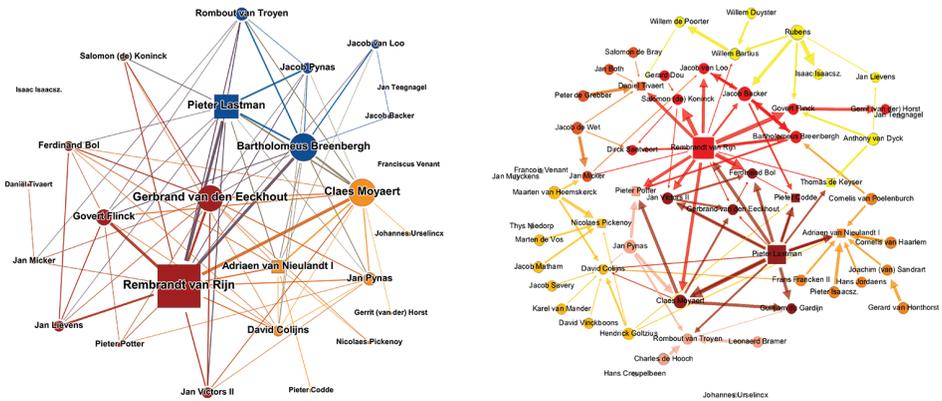


Fig. 12 Filtered network of figs. 10 and 11. The square nodes represent artists who lived in the Sint Antoniesbreestraat and the Jodenbreestraat.

not only in style, but also in subject matter. This was particularly suitable for a large and competitive art market like Amsterdam, which was capable of both accommodating and appreciating various styles depicting an identical (and often popular) story.

Fig. 12 visualises the painters who lived in Rembrandt's neighbourhood in squares, in order to see if spatial proximity was reflected in closer bonds in style or subject matter. However, both networks show little trace of artistic and thematic transmission facilitated by proximity. Perhaps counter-intuitively, the style and thematic connections between Rembrandt and Moyaert/Breenbergh, who never resided in the same neighbourhood, are much stronger than those between Rembrandt and Van Nieulandt, even though the latter lived across the street from Rembrandt for over a decade.⁴⁶ The choice of style and subjects was likely rooted more in one's ability, ambition, and marketing strategy than in location. It further suggests that artistic innovations flowed freely throughout Amsterdam and beyond, making residence and workshop location an insignificant factor for accessing information.

What about the social network? Many scholars have employed social networks to infer the transmission of ideas, yet the social network of Rembrandt's rivals (fig. 13) suggests no further diffusion of subject matters beyond those taught by masters to their pupils. Painters working in similar styles (such as Salomon Koninck and Rembrandt) or sharing many subject matters (Moyaert and Breenbergh) had somewhat distant social relations.⁴⁷ Therefore, social ties alone can hardly explain knowledge dissemination at scale.

What stories were favoured by painters in Amsterdam? The network of subject matter (fig. 14) shows that Amsterdammers endorsed more unconventional subject matters, many of which were introduced and popularised by Pieter Lastman in the early seventeenth century. The *Dismissal of Hagar* and the *Sacrifice of Manoaah* stand out as the most

⁴⁶ Locations of artists are listed in Dudok van Heel, *De jonge Rembrandt*, 78-79, fig. 34. See also Li, 'Deep-Mapping Painters' Locations'.

⁴⁷ The few connections are partially due to the lack of known, documented relationships.

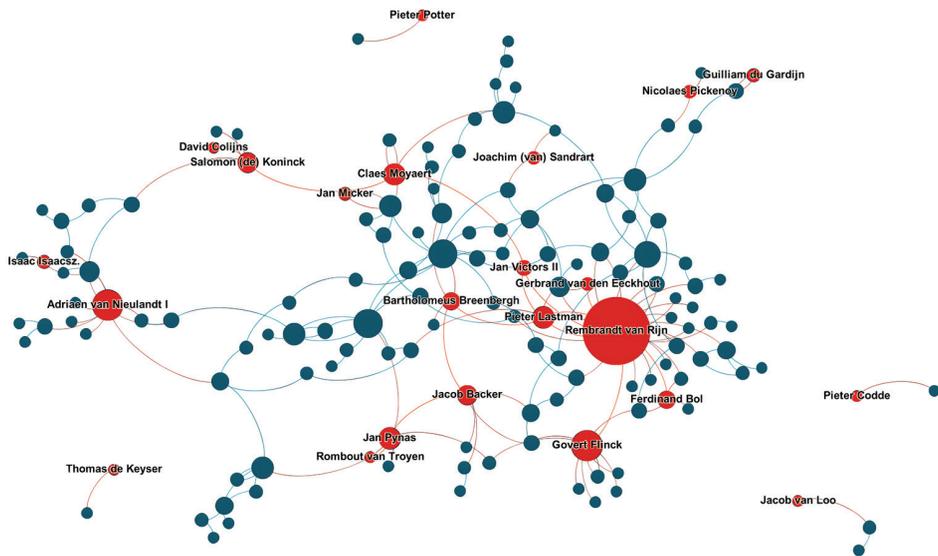


Fig. 13 Social network of Rembrandt's rivals (red) and intermediaries (blue).

popular scenes in fig. 14. These subjects had attracted painters ranging from Rembrandt to minor masters, such as Johannes Urselincx, who presented their own interpretation of the story in various styles and qualities.⁴⁸

Lastman's *Sacrifice of Manoah* seems to have triggered a wave of sacrifice scenes, echoing the popularity of such stories in the theatre at the time.⁴⁹ Numerous sacrifice scenes were depicted based on both heathen and sacred stories to fit into the sacrifice theme. Several painters picked up obscure stories like the *Sacrifice of Polyxena*, the *Sacrifice of Iphigenia*, and the *Sacrifice of Jephthah's daughter*, all of which share the iconography of a female victim confronting her fate at an altar.⁵⁰ However, very few examples of *Jephthah's daughter* are mentioned in inventories in the Montias database, and *Polyxena* or *Iphigenia* are missing altogether from the Getty Provenance Index – although there are many entries listed as a sacrifice scene without explicit references to a single story.⁵¹ Perhaps contemporaries were more concerned with the act of sacrifice than the individual girl in these instances: it was the dramatic, even brutal act of sacrifice that stood out in their eyes.

48 Lesser masters' Hagar paintings often placed the dull and stiff figures in simple pictorial planes lacking indications of space, movement, and emotions, bearing no resemblance of what Lastman and Rembrandt had introduced: Sluijter, *Rembrandt's Rivals*, 261-263, 319-322, 367-369.

49 Sluijter, *Rembrandt's Rivals*, 228.

50 See also Sluijter, *Rembrandt's Rivals*, 230-237, 250-252, 307-308.

51 Although the inventories were often drawn up by non-specialists who were cursory in their records, Reinier Falkenburg has convincingly argued that inventories can reflect genre notions used by contemporaries and the types of artworks that estate appraisers were able to recognize. The vocabulary they used to distinguish paintings echoed the painting types prevalent in the market, and whether a subject was commonly recognised or not: Falkenburg, 'Onweer', and more recently Li, 'Spotting Specialists'.

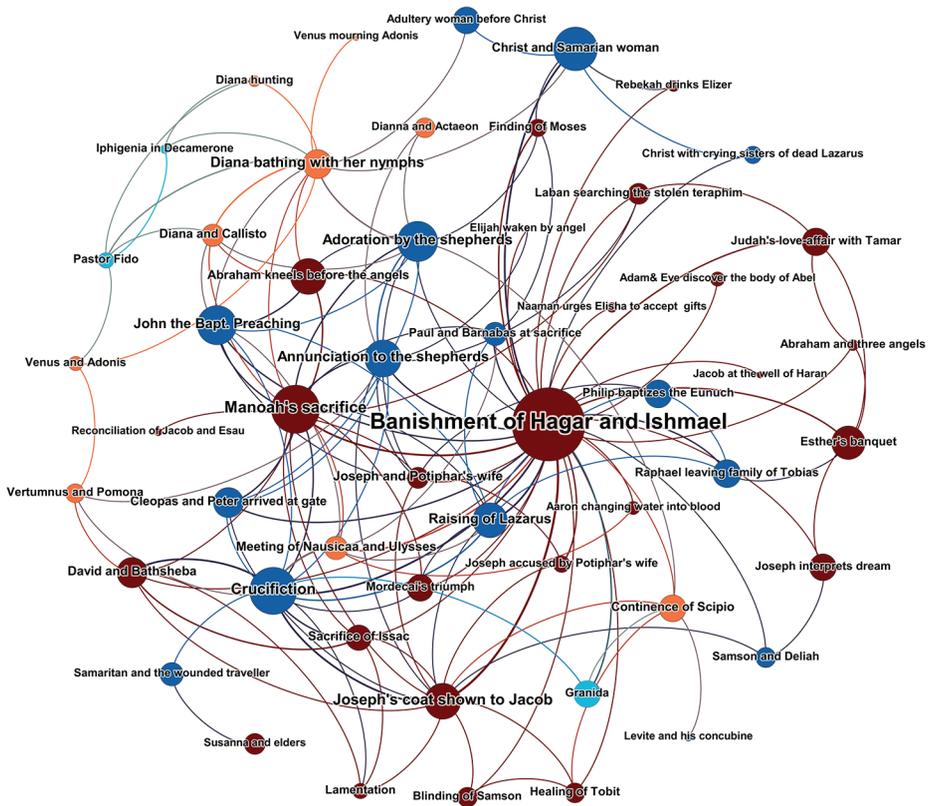


Fig. 14 Network of subject matters linked by at least three artists. Nodes sized by weighted degrees and coloured by subject category: Old Testament (dark red), New Testament (dark blue), mythology (orange), and literature (light blue).

The disparity between the networks of artistic rivalry and that of iconography further substantiates the earlier observation that for most painters, the choice of subject and style were unrelated. They fed the market with paintings depicting popular subjects in various styles, and perhaps used stylistic variance as a deliberate marketing strategy to differentiate themselves on the market, catering to different demands. This strategic differentiation is evident from the central location of several Hagar scenes of various qualities (fig. 15). After Lastman's work of 1612, the *Dismissal of Hagar* (fig. 16) seems to have swept the Dutch Republic. The production of this Hagar scene peaked between 1640 to 1660, even though demand for Old Testament subjects had declined after 1640 (fig. 1).⁵² Unlike the sacrifice scenes, the paintings of Hagar were well recognised by the market, as they regularly appeared in contemporary inventories. In Amsterdam, for

52 Bok, "Paintings for Sale".

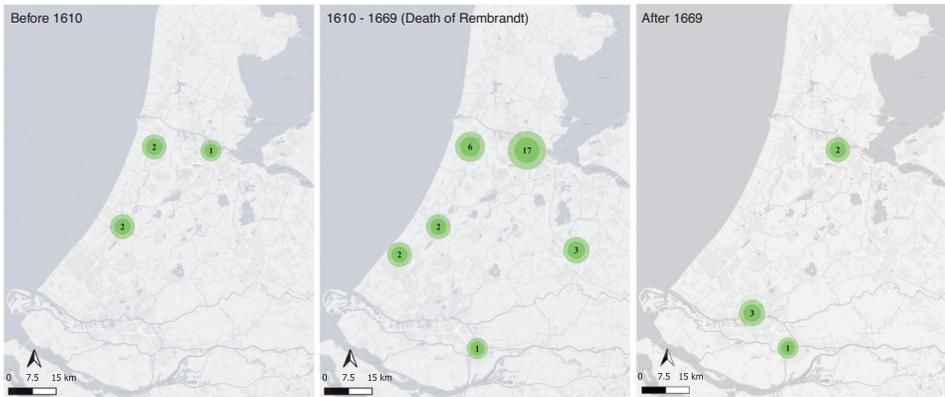


Fig. 15 Number of inventoried copies of the *Dismissal of Hagar*, before 1610 (a); after 1669 (b); and between 1610 and 1669, the year of Rembrandt's death (c).

instance, some forty-one Hagar-themed paintings were either inventoried or sold in auctions and shipped abroad.⁵³ Another sixteen hung in houses in Haarlem, and seven more in Dordrecht.⁵⁴

What made the *Dismissal of Hagar* so popular? Art historians have argued that the story is an expression of human emotions – jealousy, pride, loss, sorrow, and fear – that are all reflected in the twists and turns of the dismissal scene.⁵⁵ Jan Pynas even included a peacock (fig. 17), a traditional symbol of pride and arrogance in Dutch art and literature, to signify the cause of the banishment. ‘So pride comes before the fall’, as Jacob Cats wrote in his *Lamentation of Hagar*. Christine Sellin has argued for the didactic value of the Hagar story, as it was used in moralist pamphlets, literature, and sermons.⁵⁶ The congenial social environment and the catchy and emotive content of the story of Hagar could have created a general interest in the visual representation of the Hagar narrative from the market. That said, most of the literature and sermons that Sellin assembled in support of her argument did not appear until the early eighteenth century, long after the wave of Hagar paintings had subsided (fig. 15b). It seems that aspects of Dutch society other than the art market did not dictate artists’ choice of subject matter in this case. Nor could it explain why only the expulsion scene (Gen 21:14) gained momentum in visual arts, not the scenes discussed in moralistic writings, such as the her running away

⁵³ Several were identified as the expulsion scene, but most were labelled ‘Hagar/Agar,’ or ‘history of Hagar’. Given the lopsided popularity of the expulsion scene, we can assume that many unspecified Hagar scenes also referred to her dismissal. For the spread of Hagar painting abroad, see Noldus, ‘Dealing in Politics and Art’, 220.

⁵⁴ Surprisingly, no Hagar paintings are known from Utrecht houses. The only painting of Hagar in Utrecht was from a lottery list: Getty Provenance Index, Archival Inventory N-3977.

⁵⁵ Tümpel, *Oude Testament*. See also Bleyerveld, *Hoe bedriechlijk dat die vrouwen zijn*.

⁵⁶ Other than Jacob Cats’ *Houwelijk*, Sellin cited works of Petrus Dathenus published after 1620, Jan Goeree’s poem (published in 1712), and a sermon given by the Rotterdam minister Adrian Kattenburch in 1701: Sellin, *Fractured Families*, 11–67.



Fig. 16 Pieter Lastman, *The Dismissal of Hagar*, 1612, oil on panel, 49 x 71 cm, Hamburg, Hamburger Kunsthalle.

(Gen 16:7-12).⁵⁷ While it is true that the *Dismissal of Hagar* would not have been popular without a supportive social circle, these external forces alone cannot fully account for the Hagar phenomenon.

The missing factor, I would argue, lies in the artistic impulses. The vogue of Hagar paintings epitomised the instance when market interests and artistic pursuit crossed paths. The story caught the attention of influential masters such as Lastman and Rembrandt, who strove to depict the passions in their work.⁵⁸ The expulsion episode might have appealed to these artists for its suitability to study the relationship between strong emotions, subtle movement, and dramatic narrative, all of which fit their artistic pursuit and ambition.⁵⁹ Rembrandt is said to have assigned this subject to his pupils as a study, as most extant drawings of the expulsion scene come from Rembrandt's circle.⁶⁰ The diffusion of the *Dismissal of Hagar* can be seen as an interplay between artistic pursuits and market inter-

57 Sellin argues that the episode of Hagar running away was used by moralists such as Cats as a domestic homily to reinforce the virtues of humility and obedience in Christian households: Sellin, *Fractured Families*, 11-67. However, the plays of family and marriage life (such as *Het huwelyk van Orondates en Statira*) did not get recognized at the Schouwburg of Amsterdam until the 1670s, when the popularity of the Hagar story waned: ONSTAGE, <http://www.vondel.humanities.uva.nl/onstage/> (Accessed on 19 August 2021).

58 Sluijter, *Rembrandt's Rivals*, chap. 2.

59 Sluijter, *Rembrandt's Rivals*, 263.

60 Hamann, 'Hagars Abschied'.



Fig. 17 Jan Pynas, *The Dismissal of Hagar*, 1614, oil on panel, 78 x 106 cm, private collection.

ests: the artistic pursuit in depicting a complicated and emotionally charged scene was appreciated by the market and ignited the public's enthusiasm. The benefit of this fortuitous meeting of artistic and market interests spilt over to the lower end of the market and eventually allowed the *Dismissal of Hagar* to become a breakaway success.

Conclusion

This essay has revisited Montias's 'process and product innovations' and re-evaluated the artistic connections among Rembrandt's rivals by developing a novel network of iconography, which connects artists, for the first time, not through social relations but through shared subject matters. This new art-historical network examines history paintings in ways that traditional methods cannot and illustrates how scores of painters in the seventeenth century were connected artistically – and how such connections were translated into iconographical inventions. It further demonstrates that the choices of style and subject matter were often unrelated, and that thematic connections between painters often had little to do with their social relations or physical proximity. These findings suggest that painters did not need to know or see each other's work to pick up a certain subject. Conversely, the choice of subject matter was often influenced by market forces: artists at

all levels produced paintings of the same popular subjects, though executed in distinctive styles and qualities to increase diversity and maintain a competitive edge. As such, these findings help to understand what defines a new product in Montias's 'product and process innovation'. Nevertheless, market forces were not omnipotent. It also took painters' artistic pursuits in conjunction with market interests to allow a thematic innovation to sweep across the board, as did the *Dismissal of Hagar*. This approach also sheds new light on the structural shifts in the seventeenth-century art market and the ways in which painters adapted to changing patterns of demand and style.

Finally, it is worth stressing the exploratory nature of this study, as it raises more questions than it can answer. Questions regarding a possible correlation between the shift in market competition and the political, religious, and economic context of Dutch society, as well as the impact of foreign connections on networks of iconography, still remain unexplored. Due to the limitations of the data source, the findings presented in this article are necessarily limited in scope. Therefore, the main contribution of this study lies more in its methodological exploration than in its discoveries. It shows that the application of computational methodologies, if well thought out, can provide new interpretations through linking various datasets. Hopefully, the current digitisation process that promotes Linked Open Data will provide researchers with new information regarding the Dutch art market. Until then, this essay has hopefully demonstrated how (digital) art historians might approach the bridging of digital and conventional methodologies.

Appendix 1: Measuring the Network of Ideas

The two-mode network of artists and subject matters is transformed – or ‘projected’, in network parlance – into a one-mode network by converting one of the node types into a link between nodes of the other type.⁶¹ For every two-mode network, there are two one-mode equivalents. The two-mode, artist-subject network can be converted into 1) an artist-artist network, in which the link between two artists represents the number of subjects they both depicted; and 2) a subject-subject network, in which the link between two subjects represents the number of artists who painted both. The thickness of the links connecting artists or subjects indicates the strength of the connection, measured by the overlaps.

Network Size and Interconnectivity

Basic measures like network size (that is, the number of nodes) serve to gauge the population of history painters and the diversity of subject matters. Given the same number of nodes, more links/a higher average degree means that the network has a higher density or interconnectivity among the nodes. A highly interconnected network of artists suggests that painters picked subjects from more or less the same pool. The density, however, does not tell us about the size of this pool of subject matters. The same measure has to be applied to the network of subjects to complement the insights gained from the network of artists.

Tab. 1 Network metrics of the iconographic network of artists and subject matters by period.

Period	Network of artists			Network of subject matters		
	Avg. degree	Degree centrality	Modularity	Avg. degree	Degree centrality	Modularity
1575-1610	5.61	0.63	0.17	5.09	0.53	0.39
1610-1650	9.53	0.42	0.21	6.32	0.62	0.38
1650-1700	5.52	0.5	0.26	14.58	0.4	0.33

Source: RKD Images and ECARTICO. Metrics were calculated by the algorithms in Gephi.

Modularity

One of the aspects of a network that is particularly pertinent to art history is modularity, which measures the strength of the division of a network into modules. For the network of iconography discussed in this essay, the modularity identifies both clusters of artists who are more likely to paint similar subject matters and groups of subjects that occur within a painter’s oeuvre. For example, the subjects *Diana hunting* and *Diana bathing*

⁶¹ For theories about the conversion of a two-mode network into a one-mode network, see Watts, *Six Degrees*, 119-121; Hanneman and Riddle, *Introduction to Social Network Methods*; Knappett, *An Archaeology of Interaction*.

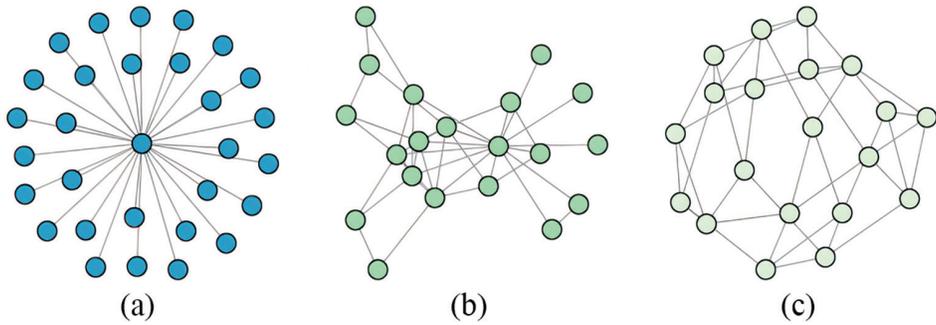


Fig. 1 Network centralisation examples. Source: Lincoln, 'Social Network Centralization Dynamics'.

discussed in this article are less likely to sit in the same cluster based on the modularity measure.

Centrality

Another important property of a network is centrality, which measures how evenly or unevenly links are distributed between its members. The centrality measures are designed for social network analysis and need to be carefully reframed when applied to the network of iconography. For instance, the 'betweenness centrality' measure, which evaluates the importance of a node as a bridge or broker between other nodes, does not work in a network of artists connected by subjects. That is because this network only considers direct connections: two painters either painted the same subject (connected) or not (not connected). On the other hand, degree centrality – measuring the number of connections to any given node – trumps other centrality measures, and best fits the network of iconography. Within a centralised network, a few key painters are well-connected and are responsible for almost all popular subjects, while the remaining painters took up a subset of the popular subjects introduced by the few influential or prolific painters. An extreme example of a centralised network is a so-called star network (fig. 1a), in which one key artist painted all the subjects, while everyone else picked only one theme. The other extreme is an entirely decentralised network in which the links are evenly distributed (fig. 1c), and no artist or subject occupies a dominant position. In reality, however, the network of iconography lay in between (fig. 1b): a few painters invented or popularised many subject matters while others followed and made contributions of their own.

Appendix 11: Random Network Simulation

To validate that the differences shown in network metrics over time are beyond natural network expansion, this research uses random networks to test against the results shown

Tab. 11a Random network simulation result using the same number of painters using *rstudio*.

Period	Painters	Actual links	Simulated links	Avg. degree	Centrality	Std. deviation centrality
1575-1610	31	80	87	5.61	0.59	0.09
1610-1650	97	462	285	5.88	0.73	0.08
1650-1700	66	182	192	5.82	0.67	0.09

Source: RKD Images and ECARTICO. Metrics were calculated by the algorithms in Gephi.

Tab. 11b Random network simulation result using the same number of Iconclass codes using *rstudio*.

Period	Iconclasses	Actual links	Simulated links	Avg. degree	Centrality	Std. deviation centrality
1575-1610	35	89	99	5.66	0.6	0.09
1610-1650	75	237	219	5.84	0.69	0.09
1650-1700	57	380	165	5.79	0.66	0.09

Source: RKD Images and ECARTICO. Metrics were calculated by the algorithms in Gephi.

in tabs. 1 and 1a. If the random network simulation shows a similar pattern, then the difference in network measurement can be fully explained by network expansion. It means no significant change in the network structure can be observed. If the results in tabs. 1 and 1a diverge from the simulation results, however, it means the networks experienced structural change due to historical circumstances that cannot be explained by the natural expansion of the network.

This research applies the Barabási-Albert model with a power-law probability distribution.⁶² The power law is observed in a wide variety of natural and man-made phenomena, which Matthew Lincoln applied for his study of the network of printmakers in Europe.⁶³ It describes the distribution of a set of ranked occurrences in which minor occurrences are prevalent, such as nodes with only a few links. In contrast, large instances (such as nodes with a considerable number of links) are sporadic. The model with power-law distribution sets the chance of connection, or fitness f , of node k , such that: $f_k = k^{-\gamma}$. The exponent γ determines the skew of the probability distribution. γ decides how attractive and well-connected individuals are to new entrants to the network, with a more significant skew denoting a stronger attraction. $\gamma = 2$ fits the network of artists well, and $\gamma = 1.9$ matches the network of the subject matter better. k (the number of nodes) is the same as the network size in tab. 1. Simulation results out of a thousand random networks are shown in the tables below.

Tabs. 11a and 11b show the simulated random network size, the number of nodes, and links. Between 1610 and 1650, the iconographic network of artists deviated dramatically

⁶² On the generation of random networks, and on the types of degree distributions that resemble real-world networks, see Barabási and Albert, 'Emergence of Scaling in Random Networks'. The programmatic implementation of this method in R is Csardi and Nepusz, 'The Igraph Software Package for Complex Network Research'.
⁶³ Lincoln, 'Social Network Centralization Dynamics'.

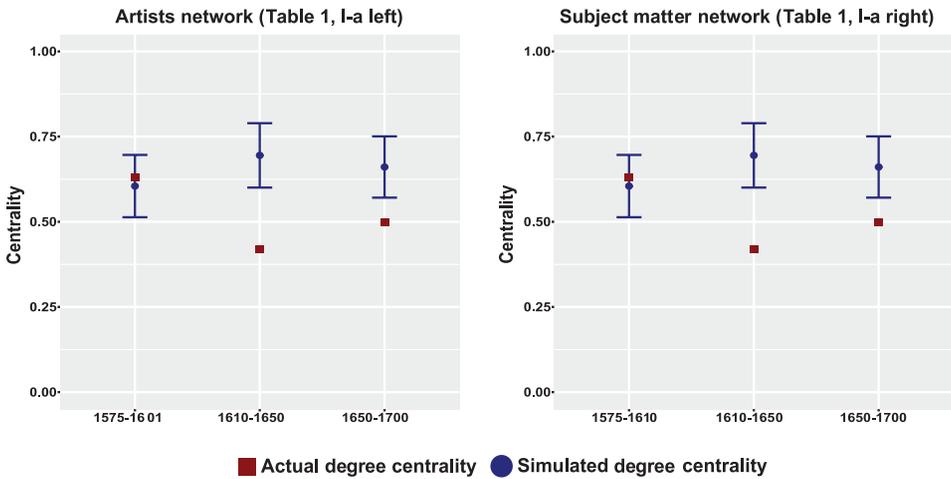


Fig. 11 Comparing degree centrality between the actual network and the simulated random network.

from the random network simulation, as the number of actual links between artists moved far beyond the natural network expansion. The same phenomenon occurred in the iconographic network of subject matter, but in the period 1650-1700. The degree centrality (fig. 11) further substantiates the exceptional period for artists active between 1610 and 1650 and the subject matter in the third, as the actual degree centrality values far outstrip the standard deviation range of the random simulation results. This means that the generation of artists who became active between 1610 and 1650 experienced a structural change in their thematic connections. Among the second generation, another shift occurred, as ‘creative repetition’ made the subject matter network denser and decentralised.

Bibliography

- Aono, Junko, *Confronting the Golden Age. Imitation and Innovation in Dutch Genre Painting 1680-1750* (Amsterdam, 2015).
- Aono, Junko, ‘Out of the Shadow of the Golden Age. Recent Scholarly Development Concerning Dutch Paintings of the Late Seventeenth and Early Eighteenth Centuries’, in Wayne Franits (eds.), *The Ashgate Research Companion to Dutch Art of the Seventeenth Century* (London and New York 2016) 286-301.
- Barabási, Albert-László, and Réka Albert, ‘Emergence of Scaling in Random Networks’, *Science* 286 (1999) 509-512.
- Bleyerveld, Yvonne, *Hoe bedriechlijk dat die vrouwen zijn. Vrouwenlijsten in de beeldende kunst in de Nederlanden circa 1350-1650* (Leiden 2000).
- Bok, Marten Jan, ‘Fluctuations in the Production of Portraits Made by Painters in the Northern Netherlands, 1550-1800’, in Simonetta Cavaciocchi (ed.), *Economia e Arte Secc. XIII-XVIII* (Prato 2002) 649-661.
- Bok, Marten Jan, ‘“Paintings for Sale”. New Marketing Techniques in the Dutch Art Market of the Golden Age’, in Jannet de Goede and Martine Gosselink (eds.), *At Home in the Golden Age* (Zwolle 2008) 9-29.

- Bok, Marten Jan, 'The Rise of Amsterdam as a Cultural Centre. The Market for Paintings, 1580-1680', in Patrick O'Brien, Derek Keene, Marjolein 't Hart, and Herman Van der Wee (eds.), *Urban Achievement in Early Modern Europe* (Cambridge 2001) 186-209.
- Bok, Marten Jan, *Vraag en aanbod op de Nederlandse kunstmarkt, 1580-1700*. PhD diss., Utrecht University, 1994.
- Chong, Alan, 'The Market for Landscape Painting in Seventeenth-Century Holland', in Peter C. Sutton and Albert Blankert (eds.), *Masters of 17th-Century Dutch Landscape Painting* (Boston 1987) 104-120.
- Csardi, Gabor, and Tamas Nepusz, 'The Igraph Software Package for Complex Network Research', *Inter-Journal, Complex Systems* 1695 (2006/5) 1-9.
- De Marchi, Neil, 'The Role of Dutch Auctions and Lotteries in Shaping the Art Market(s) of 17th Century Holland', *Journal of Economic Behavior & Organization* 28 (1995/2) 203-221.
- De Marchi, Neil, and Hans Van Miegroet, 'Art, Value, and Market Practices in the Netherlands in the Seventeenth Century', *The Art Bulletin* 76 (1994/3) 451-464.
- De Vries, Jan, 'Art History', in Jan de Vries and David Freedberg (eds.), *Art in History, History in Art. Studies in Seventeenth-Century Dutch Culture* (Santa Monica, CA 1991) 249-284.
- Dudok van Heel, Sebastien, *De jonge Rembrandt onder tijdgenoten. Godsdienst en schilderkunst in Leiden en Amsterdam* (Rotterdam 2006).
- Falkenburg, Reindert, 'Onweer bij Jan van Goyen. Artistieke wedijver en de markt voor het Hollandse landschap in de 17de eeuw', *Nederlands Kunsthistorisch Jaarboek* 48 (1997) 117-161.
- Fock, C. Willemijn, 'Het interieur in de Republiek 1670-1750. Een plaats voor schilderkunst?', in Ekkehard Mai, Sander Paarlberg, and Gregor J.M. Weber (eds.) *De kroon op het werk. Hollandse schilderkunst 1670-1750* (Keulen 2006) 63-84.
- Fock, C. Willemijn, 'Kunstbezit in Leiden in de 17de eeuw', in Th. H. Lunsingh Scheurleer, C. Willemijn Fock, and A.J. Van Dissel (eds.), *Het Rapenburg. Geschiedenis van een Leidse gracht*, 10 vols. (Leiden 1986-1992) V, 3-36.
- Ginhoven, Sandra van, *Connecting Art Markets. Guiliam Forchondt's Dealership in Antwerp (c.1632-78) and the Overseas Paintings Trade* (Leiden 2016).
- Graham, Shawn, Ian Milligan, and Scott Weingart, *Exploring Big Historical Data. The Historian's Macro-scope* (London 2015).
- Hannam, Richard, 'Hagars Abschied bei Rembrandt und im Rembrandt-Kreise', *Marburger Jahrbuch für Kunstwissenschaft* 8 (1936) 471-578, 578a.
- Hanneman, Robert, and Mark Riddle, *Introduction to Social Network Methods* (Riverside, CA 2005).
- Hecht, Peter, 'Dutch Seventeenth-Century Genre Painting. A Reassessment of Some Current Hypotheses', *Simiolus* 21 (1992/1/2) 85-95.
- Ho, Angela, *Creating Distinctions in Dutch Genre Painting. Repetition and Invention* (Amsterdam 2017).
- Jager, Angela, *The Mass Market for History Paintings in Seventeenth-Century Amsterdam. Production, Distribution, and Consumption* (Amsterdam 2020).
- Knappett, Carl, *An Archaeology of Interaction. Network Perspectives on Material Culture and Society* (Oxford 2011).
- Kok, Erna, *Culturele ondernemers in de Gouden Eeuw. De artistieke en sociaal-economische strategieën van Jacob Backer, Govert Flinck, Ferdinand Bol en Joachim von Sandrart*. PhD diss., University of Amsterdam, 2013.
- Kolfin, Elmer, *The Young Gentry at Play. Northern Netherlandish Scenes of Merry Companies 1610-1645* (Leiden 2005).
- Kwak, Zoran, 'Proeft de kost en kauwtse met uw oogen'. *Beeldtraditie, betekenis en functie van het Noord-Nederlandse keukentafereel (ca. 1590-1650)*. PhD diss., University of Amsterdam, 2014.
- Lairesse, Gerard de, *Het Groot Schilderboek*, 2 vols. (Amsterdam: Hendrick Desbordes 1712).
- Larson, Katherine, 'A Network Approach to Hellenistic Sculptural Production', *Journal of Mediterranean Archaeology* 26 (2013/2) 235-260.
- Li, Weixuan, *Artists and the Creative Urban Space. Deep-Mapping Painters' Locations in Golden Age Amsterdam*. PhD diss., University of Amsterdam, forthcoming.

- Li, Weixuan, 'Innovative Exuberance. Fluctuations in the Painting Production in the 17th-Century Netherlands', *Arts* 8 (2019/2:72).
- Li, Weixuan, 'Spotting Specialists. A Digital Approach to Contemporary Concepts of Genre and Specialisation', in Marije Osnabrugge (ed.), *Questioning Pictorial Genres in Dutch Seventeenth-Century Art* (Turnhout 2021) 43-71.
- Lincoln, Matthew, 'Social Network Centralization Dynamics in Print Production in the Low Countries, 1550-1750', *International Journal of Digital Art History* 2 (2016) 134-157.
- Lincoln, Matthew, 'Continuity and Disruption in European Networks of Print Production, 1550-1750', *Art@s Bulletin* 6 (2017/3).
- Lincoln, Matthew, 'Network Thinking and Network Analysis in the History of Art', in Kathryn Brown (ed.), *The Routledge Companion to Digital Humanities and Art History* (New York 2020).
- Mai, Ekkehard, Sander Paarlberg, and Gregor J.M. Weber, *De kroon op het werk. Hollandse schilderkunst 1670-1750* (Cologne 2006).
- Marx, Axel, 'Why Social Network Analysis Might Be Relevant for Art Historians. A Sociological Perspective', in Koenraad Brosens, Katlijne Van der Stighelen, and Leen Kelchtermans (eds.), *Family Ties. Art Production and Kinship Patterns in the Early Modern Low Countries* (Turnhout 2012) 25-42.
- Montias, John Michael, *Art at Auction in 17th Century Amsterdam* (Amsterdam 2002).
- Montias, John Michael, 'Art Dealers in the Seventeenth-Century Netherlands', *Simiolus* 18 (1988/4) 244-256.
- Montias, John Michael, 'Artists Named in Amsterdam Inventories, 1607-80', *Simiolus* 31 (2004/4) 322-347.
- Montias, John Michael, 'Cost and Value in Seventeenth-Century Dutch Art', *Art History* 10 (1987/4) 455-66.
- Montias, John Michael, 'Estimates of the Number of Dutch Master-Painters, Their Earnings and Their Output in 1650', *Leidschrift* 6 (1990/3) 59-74.
- Montias, John Michael, 'The Guild of St. Luke in 17th-Century Delft and the Economic Status of Artists and Artisans', *Simiolus* 9 (1977/2) 93-105.
- Montias, John Michael, 'The Influence of Economic Factors on Style', *De Zeventiende Eeuw* 6 (1990) 49-57.
- Noldus, Badeloch, 'Dealing in Politics and Art. Agents between Amsterdam, Stockholm and Copenhagen', *Scandinavian Journal of History* 28 (2003/3-4) 215-225.
- Panofsky, Erwin, *Meaning in the Visual Arts. Papers in and on Art History* (Garden City, NY 1955).
- Rasterhoff, Claartje, *Painting and Publishing as Cultural Industries. The Fabric of Creativity in the Dutch Republic, 1580-1800* (Amsterdam 2017).
- Raux, Sophie, *Lotteries, Art Markets, and Visual Culture in the Low Countries, 15th-17th Centuries* (Leiden 2018).
- Rosen, Jochai, *Soldiers at Leisure. The Guardroom Scene in Dutch Genre Paintings of the Golden Age* (Amsterdam 2010).
- Seifert, Christian Tico, *Pieter Lastman. Studien zu Leben und Werk. Mit einem kritischen Verzeichnis der Werke mit Themen aus der Antiken Mythologie und Historie* (Petersberg 2011).
- Sellin, Christine Petra, *Fractured Families and Rebel Maidservants. The Biblical Hagar in Seventeenth-Century Dutch Art and Literature* (London 2006).
- Sluijter, Eric Jan, 'All Striving to Adorne Their Houses with Costly Peeces'. Two Case Studies of Paintings in Wealthy Interiors', in Mariët Westermann (ed.), *Art and Home. Dutch Interiors in the Age of Rembrandt* (Zwolle 2001) 102-127.
- Sluijter, Eric Jan, *De 'heydensche fabulen' in de schilderkunst van de Gouden Eeuw. Schilderijen metverhalende onderwerpen uit de klassieke mythologie in de noordelijke Nederlanden, circa 1590-1670* (Leiden 2000).
- Sluijter, Eric Jan, 'Jan van Goyen als marktlieder, virtuoos en vernieuwer', in Christiaan Vogelaar (ed.), *Jan van Goyen* (Zwolle 1996) 8-59.
- Sluijter, Eric Jan, 'New Approaches in Art History and the Changing Image of Seventeenth-Century Dutch Art between 1960 and 1990', in Frans Grijzenhout and Henk van Veen (eds.), *The Golden Age of Dutch Painting in Historical Perspective* (Cambridge 1999) 247-276.

- Sluijter, Eric Jan, 'Over Brabantse vodden, economische concurrentie, artistieke wedijver en de groei van de markt voor schilderijen in de eerste decennia van de zeventiende eeuw', *Netherlands Yearbook for History of Art/Nederlands Kunsthistorisch Jaarboek* 50 (1999/1) 113-144.
- Sluijter, Eric Jan, *Rembrandt and the Female Nude* (Amsterdam 2006).
- Sluijter, Eric Jan, *Rembrandt's Rivals. History Painting in Amsterdam 1630-1650* (Amsterdam 2015).
- Sluijter, Eric Jan, *Seductress of Sight. Studies in Dutch Art of the Golden Age* (Zwolle 2000).
- Suchtelen, Ariane van, Mariet Westermann, and Wouter Th. Kloek, *Jan Steen's Histories* (Zwolle 2018).
- Sun, Yanan. 'The Social Network behind an Architectural Style over Space and Time', in Maria Boştenaru Dan and Cerasella Crăciun (eds.), *Space and Time Visualisation* (New York 2016) 79-96.
- Sutton, Peter, Lisa Vergara, and Ann Jensen Adams, *Love Letters. Dutch Genre Paintings in the Age of Vermeer* (London 2003).
- Tümpel, Christian, *Het Oude Testament in de Schilderkunst van de Gouden Eeuw* (Zwolle 1991).
- Waiboer, Adriaen, Arthur Wheelock Jr., and Blaise Ducos (eds.), *Vermeer and the Masters of Genre Painting. Inspiration and Rivalry* (New Haven, CT 2017).
- Watts, Duncan, *Six Degrees. The Science of a Connected Age* (New York and London 2004).
- Wijsenbeek-Olthuis, Thera, 'Boedelinventarissen', *Broncommentaren* 2 (1995) 1-75.
- Woude, Ad van der, 'The Volume and Value of Paintings in Holland at the Time of the Dutch Republic', in Jan de Vries and David Freedberg (eds.), *Art in History, History in Art. Studies in Seventeenth-Century Dutch Culture* (Santa Monica, CA 1991) 284-329.