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Cover Page Footnote
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Continuity and Disruption in European Networks of Print Production, 1550-1750

Matthew D. Lincoln *

Abstract
Computational analysis of the potential historical professional networks inferred from surviving print impressions offers novel insight into the evolution of early modern artistic printmaking in Europe. This analysis traces a longue durée print production history that examines the changing ways in which different regional printmaking communities interacted between 1550 and 1750, highlighting the powerful impact of demographic forces and calling into question narratives based on single key individuals or the emergence of specific national schools.

Data, code, and documentation for all figures in this paper are available online at: http://doi.org/10.5281/zenodo.1037568

Résumé

Données, codes, documentations et illustrations de cet article sont accessibles à l’adresse suivante : http://doi.org/10.5281/zenodo.1037568

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**Introduction**

There is no better means whereby the painter himself can make his renowned name known: Namely, that he sometimes, using time and diligence for this purpose, engraves one of his celebrated compositions of drawing in print: Because it can go through the whole world, coming into every art lovers’ hands, while paintings almost always remain in one place... ¹

...release your works freely into print, so that your name will sooner fly over the world. Albrecht Dürer and Lucas van Leyden, though wondrous painters, obtained their greatest fame from engraving.²

Regarding [prints’] effect: what fame is to the ear, theirs is to the eye. Painting has but one result, but engraving hundreds. Fame can tell the many wonders of painting in its absence; but engraving makes itself present everywhere; it flies the world over, as it sounds the echoing trumpet of renown.³

Late seventeenth- and early eighteenth-century Dutch art commentators Willem Goeree, Samuel van Hoogstraten, and Gérard de Lairesse uniformly agreed on the power of prints to transmit an artist’s images far and wide. Thanks to the relative ease of moving finished impressions, prints had been a mainstay of the international art market in Europe for more than a century and a half. At the renowned Frankfurt book fair, prominent book publishers even included special sections in their inventory lists devoted to artistic prints and engraved maps.⁴

The consumption of prints was clearly internationalized by the early 1500s. To what extent, however, was their production internationalized?

Starting from the focal point of the northern Netherlands, this paper will offer a novel perspective on the interconnection of print production communities within the larger early modern European world of printmaking. Research of artistic prints has turned its attention away from the traditional focal point of the individual creative achievements of the peintre-graveur in favor of understanding the material, logistical, and social circumstances of designing, plate-cutting, and publishing. Among others, Nadine Orenstein, Jan van der Stock, and Karen Bowen have demonstrated the importance of considering early modern artistic print production as a networked process dependent on coordination, both direct and indirect, between many parties.⁵ Given how fruitful this network paradigm has been over the past two decades for furthering our understanding of printmaking, it is worth more fully interrogating its methodological opportunities and implications.

Computational network analysis offers an alternative framework for examining networks, affording insight into the multiple scales and velocities of organizational changes among print designers, plate cutters, and publishers, both within and between regional communities. Comparing the timing and intensity of these changes to traditional narratives about the rise of, for example, the concentrated domestic Dutch printmaking community, reveals an alternative history of the emergence of the northern Netherlands as an artistic printmaking capital. More crucially, we can better gauge whether these changes in this production balance were determined by specific historical events, or, rather, subject to larger structural incentives coupled to *longue durée* population shifts across Europe over this period. Thus, rather than reifying ahistorical national labels assigned by modern art historians,
Dutch Internationalism / Dutch Regionalism

The early history of Netherlandish printmaking is tightly interwoven with international influences. Lucas van Leyden attracted international acclaim for his masterful handling of the burin. Among his admirers was no less than the Nuremberg master Albrecht Dürer, as well as the Italian Marcantonio Raimondi.⁶

Beyond these individual artistic connections, collaborative print production began to take on international dimensions with the rise of large print production houses and the professionalization of engraving in the mid-sixteenth century. Some Dutch printmakers had built thriving careers creating engravings for Italian painters in Venice and Rome, enjoying the fruits of northern Europeans’ reputation, promulgated by Giorgio Vasari, for printmaking prowess.⁷ For example, Cornelis Cort, in Rome from 1565-1578, found great success as a printmaker for major Italian painters such as Titian, Giulio Clovio, Girolamo Muziano, and Federico Zuccaro.⁸ In addition to German and Italian centers, the mid-sixteenth-century publishing house of Hieronymus Cock, Aux Quatre Vents, frequently contracted with Dutch engravers such as Philips Galle to produce plates to be published in Antwerp.⁹ The Haarlem master Hendrick Goltzius would continue this model of remote collaboration even after setting up his own independent studio in 1582. The well-known collaboration between Hendrick Goltzius and Bartholomeus Spranger, court painter to Rudolf II, illustrates how the design, cutting, and marketing of a print could easily take on an international scope.¹⁰ (Fig. 1)

But portions of this printmaking community also developed strong domestic connections as well. In the first decades of the seventeenth century, Haarlem printmakers Claesz Jansz Visscher, Esaais van de Velde I, Willem Buytewech, Hercules Segers, and Jan van de Velde II, began to produce their own versions of the local, rustic landscape view first popularized by Hieronymus Cock in Antwerp.¹¹ (Fig 2) All of these printmakers joined the Haarlem guild in 1612, forming a critical mass of pioneering talent. In the following decades, an increasing number of Dutch engraver-publishers such as Hendrick Hondius and Crispijn de Passe cultivated stocks of plates primarily produced by fellow Dutch artists.¹²

To what extent, however, can this handful of individuals be taken to stand for the overall balance of international vs. domestically-focused Dutch print production partnerships at different points in time? One can readily generate opposing plausible historical scenarios that would explain either increasing international connections by Dutch designers, plate cutters, and publishers—or, on the other hand, their increased domesticization.

On the one hand, the northern Netherlands entered a golden age of economic growth in the late sixteenth century thanks to their unmatched control of international sea trade around the world. Several waves of Dutch artists traveled south to study and paint in Italy, establishing an expatiate

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⁹ For example, during his early career in Haarlem between 1517-1570, Philips Galle engraved several prints to be published in Antwerp by Cock; Manfred Sellink, “Philips Galle (1537-1612): Engraver and Print Publisher in Haarlem and Antwerp” (PhD Diss., Vrije Universiteit, 1997).


¹² Orenstein, Hendrick Hondius, 47.
Figure 1. Hendrick Goltzius, after Bartholomeus Spranger, The Wedding Feast of Cupid and Psyche, 1587. Engraving, 43.5 cm. x 86.1 cm. Rijksmuseum, Amsterdam.

Figure 2. Esaias van de Velde, Fort with defenses at Tholen on the Schelde, 1615-1616. Etching, 8.3 x 16.9 cm. Rijksmuseum, Amsterdam.
community in Rome. Prominent Dutch and Flemish portraitists found many patrons in the English court, and printmakers from the Low Countries were in particular demand in London. Likewise, foreign publishers and print sellers may have found the thriving northern Netherlands a particularly attractive market. One might postulate, though, that domestic production would instead come to dominate Dutch printmaking. The political environment may not have been as conducive to the flow of prints across international borders as the previous scenario suggests. The start of the Dutch revolt against Spain in 1568 may have made it more difficult for artists in the Low Countries to conduct international business, from the early transmission of contracts and drawn designs to the large shipments of finished impressions required for a successful printmaking business. The flourishing economy supported a blossoming print industry in Amsterdam, in particular. With avenues to international collaboration curtailed, and an increasing amount of domestic supply and demand in centers like Haarlem and Amsterdam, Dutch printmakers and publishers may have been encouraged to make more domestic connections than ever before. Now, rather than having to turn to international partners to produce prints, Dutch artists, printmakers, and publishers could increasingly work with their own countrymen.

In the absence of a single intuitive and convincing historical answer, we can turn to network analysis to provide an alternate scale of evidence.

Operationalizing International Interaction

Computational network analysis is a discipline that attempts to formalize, or operationalize, the description of networks. When applied to historical subjects, network analysis can recast the way we describe the behaviors of individuals and groups, and alter the narratives we use to explain historical events. Over the past few decades, historians have begun to evaluate earlier, loosely-defined conceptions of networks against mathematical network models constructed from historic records. Most notably, John Padgett has worked with both Christopher Ansell and Paul McLean to research the impact of social networks’ effect on the history of Renaissance Florence.

While the concept of “network” may seem familiar to many art historians—whether networks of stylistic influence, of artist families and studios, or of patronage and collecting—computational network analysis demands precise definitions of who or what comprises the members of a network, and precisely what evidence is used to infer connections between those members. Adopting these strictures permits us to see the complex topological characteristics of the resulting network (e.g. how centralized or decentralized it is, the degree of interconnection between its constituent groups, and which members act as key brokers of connections between disparate communities) that are invisible from the ground-level perspective afforded when considering relationships one at a time. At the same time, understanding precisely

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13 On seventeenth-century Dutch artists’ interest in Italy, see Peter Schathorn, Drawn to Warmth: 17th-Century Dutch Artists in Italy (Amsterdam: Rijksmuseum, 2001); Laurie B. Harwood, Christopher Brown, and Anne Charlotte Steland, Inspired by Italy: Dutch Landscape Painting, 1600-1700 (London: Dulwich Picture Gallery, 2002). Moreover, as their prosperity increased, many Dutch authors, musicians, and artists sought to add internationalizing elements to their works as a way of asserting Dutch cultural legitimacy in the broader world of early modern Europe; see Alison McNeil Kettering, The Dutch Arcadia: Pastoral Art and Its Audience in the Golden Age (Totowa: Allianheld and Schram, 1983).


15 Ibid., 249.

16 A flourishing Dutch art market, both in Amsterdam as well as in smaller towns like Utrecht and Delft, appears to have supported a more decentralized print production network than had existed in the late sixteenth century. It is possible that this same decentralization may have spurred more domestic collaboration as well; Matthew D. Lincoln, “Social Network Centralization Dynamics in Print Production in the Low Countries, 1550-1750,” International Journal for Digital Art History 2 (2016): 134–57, doi:10.11588/dah.2016.2.253337.


what is included—and what is not—in source data is therefore essential when interpreting the results of any one quantitative network measurement.

Data: Forming Network(s)

The data for this study have been drawn from the collections of the British Museum in London (hereafter BM) and the Rijksmuseum in Amsterdam (hereafter RKM).20 (Table 1) Both of these collections feature broad and deep collections of European prints (and Dutch and Flemish prints in particular) from this period. Moreover, each museum has released meticulous curatorial data about these collections amenable to computational processing.

<table>
<thead>
<tr>
<th>Nationality</th>
<th>BM artists (prints)</th>
<th>RKM artists (prints)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch</td>
<td>682 (14,399)</td>
<td>730 (30,738)</td>
</tr>
<tr>
<td>English</td>
<td>730 (17,153)</td>
<td>456 (4,007)</td>
</tr>
<tr>
<td>Flemish</td>
<td>430 (14,306)</td>
<td>298 (15,820)</td>
</tr>
<tr>
<td>French</td>
<td>883 (16,420)</td>
<td>970 (14,745)</td>
</tr>
<tr>
<td>German</td>
<td>631 (8,325)</td>
<td>848 (7,208)</td>
</tr>
<tr>
<td>Italian</td>
<td>799 (14,429)</td>
<td>698 (8,662)</td>
</tr>
</tbody>
</table>

Table 1. Counts of artists (and prints) by nationality in the BM and RKM datasets.

Each print in the collection is treated as evidence of a professional relationship (whether direct or indirect) at a certain point in time. For example, the print in Figure 1 would be used to create a connection between Hendrick Goltzius and Bartholomeus Spranger during the year of 1587.21 Rather than producing a single network encompassing every constituent and connection from 200 years of print production, we can instead construct snapshots, or slices, of the network as it may have appeared in a given period of time based on the surviving evidence that we have. In this way, it is possible to chart the change in certain network-wide metrics over time. (Fig. 3)

Such a picture is inevitably flattening; it necessitates discarding a great deal of information. For example, the production network discussed here is precisely that, a production-focused network, rather than one that incorporates information about familial relationships, or financial relationships, or social relationships such as co-membership in a given parish or guild. This approach is, moreover, topological, rather than topographical: spatial information is not explicitly considered in this particular analysis. But, as with an X-radiograph of a painting, with the loss of some information comes the gain of information otherwise unseen. Careful focus on the patterns of print co-production will offer us a much broader structural context missing from other information-rich, but scale-poor, studies. Together, both perspectives are more valuable than either one seen alone.

Measurement: External/Internal Interaction

When, and to what extent, do actors who belong to one category make connections to each other, versus to actors in another? This is a common question in network analysis, and can be measured by using the group-external/group-internal index (hereafter referred to as the "EI index"). The EI index measures the balance between the number of connections actors made within a specified group (in this case, nationality) versus those they made to actors outside that group.22 (Fig. 4) This index can

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20 Data, code, and documentation for all figures in this paper are available online at http://doi.org/10.5281/zenodo.1037568
21 For an in-depth discussion of these data and the methodology for inferring production networks from object-based collections, see Lincoln, “Social Network Centralization Dynamics,” 138–41. As explained there, I will be keeping the BM and RKM datasets separate, running the same analysis in parallel and comparing the results from each. This will function as a check against the particular collecting histories of each institution. Where we see similar results from both institutions, we can be more confident that the results aren’t merely artifacts of one collection’s peculiar lineage. Where we see diverging results, we will need to be more conservative when interpreting it.
22 The EI index comprises the ratio of the difference between the number of a group’s external (ne) and internal (ni) links to the total number of links the group makes:

$$\epsilon = \frac{ne - ni}{ne + ni}$$

Originally proposed in David Krackhardt and Robert N. Stern, “Informal Networks and Organizational Crises: An Experimental Simulation,” Social Psychology Quarterly 51, no. 2 (June 1, 1988): 127–29; doi:10.2307/2786835; also see Hanneman and Riddle, Introduction to Social Network Methods, 128–32; for a research application of
Figure 3. Example time slices of print production networks. Artists are connected when they co-produced one or more objects during a given span of time.

Figure 4. A network with three groups of 20 nodes each. Group A is densely interconnected, so while its members do make some external connections, by in large they connect to each other. Therefore, that group has a negative EI index. Nodes in group B, on the other hand, make a slim majority of their connections externally, giving that group a positive index. Nodes in group C connect exclusively to each other, and so that group has the lowest possible EI index of -1.
work at several scales. It can be used to quantify an entire group’s propensity to connect with other groups (e.g. Dutch artists connecting to non-Dutch artists). A positive EI index indicates that nodes within that group made most of their connections to nodes belonging to other groups, while a negative EI index indicates those nodes made most of their connections internally. One can also measure the EI index of a single individual, comparing the number of connections they make to members of their own group, versus to those belonging to another.

It is crucial to reiterate that one must always approach with caution categorizations such as "artist nationalities" coded by modern-day researchers. Demarcating the borders of nationality in the early modern period is an inherently tricky problem, perhaps no more so than in the case of the Low Countries during the age of the Eighty Years War.23 The Dutch 1581 Act of Abjuration (in the wake of the Union of Utrecht two years prior) marks the official schism between the seventeen United Provinces in the northern Netherlands and the territories of the Spanish-controlled southern Netherlands. And while this break is a convenient historical landmark, it was soon followed by large waves of emigration from the south as Protestants and other non-Catholics fled religious persecution in Antwerp for the relatively more tolerant north. Many of these migrants were painters like Gillis van Coninxloo, Clara Peeters, and Roelandt Savery, who had an abiding impact on artistic development in the United Provinces.

Flemish printmakers also emigrated to the north, including Nicolaes de Bruyn and Jan van Londerseel, both of whom moved to Rotterdam.24 As noted earlier, Flemish landscapes were a crucial inspiration for the idiom of local Dutch countryside print series that were popularized by Haarlem printmakers in the 1610s.25 To split artists from these two countries can be an arbitrary division.26

On the other hand, such a distinction was important indeed for Dutch guild leaders who feared that the sudden influx of well-trained artisans from Antwerp at the turn of the century would flood the Dutch market. As a result, they planned regulations to protect native Dutch artists from this new competition.27 The division has also remained undeniably useful for art historians, and is reflected in the datasets used for this analysis.28

For the purposes of this analysis, I will use the present database classifications. But it is critical to understand that these classifications will be a factor to be tested in this analysis, rather than accepted as a foundational truth.29 The modern metadata about each artist in this network may assign the artist to a particular national/regional community. But how do the communities defined by these post-hoc labels compare to the relationships, and the communities that emerge from said relationships, inferred from the production evidence of the objects considered here? If these modern national classifications were, indeed, "correct" in describing communities of print production, i.e., if the "national school" framework of art history were one that fit well the actual production practices of prints in the early modern period, then we would

23 On the challenge of constructing the right national context for Netherlandish printmakers in particular, see Jan Piet FileeL Kok, "Early Netherlandish Prints in Amsterdam. Review: Tobias Pfeiffer-Helke, Mit Den Gezeiten: Briiche Druckgraphik Der Niederlande: Katalog Der Niederländischen Druckgraphik von Den Anfängen Bis Um 1540/50 in Der Sammlung Des Dresdener Kupferstick-Kabinettts." Print Quarterly 32, no. 3 (September 2015): 348.
27 Sluijter, "On Brabant Rubbish.
28 Both the BM and the RKM database differentiate between "Dutch"/"Noord-Nederlands" and "Flemish"/"Zuid-Nederlands" artists. While the RKM assigns only one nationality per artist, the BM allows artists to take multiple nationalities, though only six printmaking artists have been tagged as both "Dutch" and "Flemish": Nicolas de Bruyn, Daniel van den Bremden, Egbert van Vanderen, Gijbert van Veen, and Hans Bol. In cases where artists have been assigned multiple nationalities in the source data, they will be counted as both a domestic and an international when calculating the EI index, erring on the side of retaining as many potentially-pertinent links as possible, at the cost of slightly overstating the impact of multiply-classified individuals.
29 Both the RKM and BM begin to classify artists born in the Austrian Netherlands (post-1715) as "Belgian/Begisch"; however, there are only a small handful of such artists whose work falls into the 1550-1750 period examined here. For the purposes of this analysis, these few artists will be treated as Flemish.
expect to find persistently negative EI indices, indicating majority internal connections.

As we will see, these modern labels do not overlay comfortably over the topological communities in these production networks. However, by understanding when these production communities diverge from present-day classifications, we will gain a more fluid and dynamic understanding of how communities of practice interacted during this golden age of European printmaking.

Results: Catalysts and Sudden Shifts

Figure 5 plots the changing EI index for Dutch, Flemish, French, British, German, and Italian printmaking communities between 1550-1750, comparing the trends observed from both the BM and RKM datasets.

Both museum databases return roughly equivalent results for both the Dutch and Flemish printmaking communities. Dutch artists primarily connected to foreign collaborators up until the 1570s, when they shifted quickly to a roughly even split between domestic versus foreign connections. After this sudden shift, Dutch artists and printmakers continued to favor mostly domestic collaborators, hovering around an EI index of -0.5. In other words, after this major shift they tended to make at least 75% of their connections to fellow Dutchmen. The group of artists classed as Flemish presents a rough inverse of this pattern, making most of their connections internally in the sixteenth and early seventeenth centuries, before quickly shifting around 1675 to majority external connections.

Expanding our scope to look at other major European regions, the BM and RKM datasets present a more discordant picture of English, French, German, and Italian print production. Given the greater disparity between their trends, it is critical not to over-interpret small year-to-year shifts. This is especially true for the German results, in which BM and RKM datasets do not even share a unified trend towards increased external or internal connectivity. That said, some overall trends for other communities are still prominent. Though the absolute values in any given year for these datasets diverge, both BM and RKM curves show the French printmaking community turning relatively inwards between 1550 and 1750, and the Italian community starting in the early-to-mid-seventeenth century focused inwardly, shifting marginally towards more external connections by 1650, and then returning towards a somewhat inward orientation by 1750.

Another major discrepancy between the two datasets is seen in the EI index of the English printmaking community. Both curves turn from majority external to majority internal connections, however they do so at different years. Both datasets also suffer from a fair amount of missing or low information before 1625. That said, in this case the specific histories of the underlying data can inform our interpretation. The vast superiority of the BM’s holdings in English prints compared to that of the RKM (Table 1) suggests that, of these two curves, the trend observed from the BM data is likely more representative than that observed from the RKM, which has comparatively few holdings of early English prints.

These results support the hypothesis that Dutch printmaking indeed experienced a domestic "turn" not only in subject and style, but also in the infrastructure of print production itself. Two details are particularly surprising. It is noteworthy that this turn occurred in the 1570s, well before the commonly acknowledged burst of particularly "domestic" subjects in Haarlem in the 1610s. Even more surprising is how swiftly this landscape of print production changed. Within just a few years, Dutch artists moved from making over three-quarters of their connections to foreign sources to a roughly even split. We see a similarly precipitate turn in the Southern Netherlands in the mid-seventeenth century—but towards more international production, rather than more domestic.
Figure 5. The EI Index for Dutch, Flemish, French, British, German, and Italian printmaking communities between 1550-1750. At 1, all connections made by an actor are to actors outside their national group. At 0, they have an equal number of internal and external connections. At -1, all their connections are to actors within their national group. Note that in areas where the lines plateau or feature dramatic spikes (e.g., the English EI index before 1625; the German index as measured from the RKM data set before 1580) the underlying data sample may comprise only a few prints, and therefore ought to be interpreted with extreme caution.
Indeed, we can observe rapid shifts from majority external to majority internal printmaking collaboration in the French and English communities that are quite similar to the pattern seen in the northern Netherlands. Both the French and English communities also begin this period making most of their connections externally, but each underwent their own separate, inward shifts at 1620 and 1650, respectively.

In other words, no one single historical event appears to have catalyzed simultaneous shifts across these communities. However, before attempting to further interpret these trends, it is crucial to distinguish between those shifts that we might expect to see in any network of similar size and distribution of groups, versus those changes that are unexpected, and which might be attributable to some outside historical event.

**Simulating Production Networks**

Specific historical events like political changes or military conflicts surely affected patterns of production between printmakers and publishers from different countries. Yet they were short-term happenings that occurred within a landscape of equally-influential long-term incentives and population trends that may have been just as impactful, if not more so. In other words, the effects of one specific conflict or economic shift alone cannot tell the entire story of any given spike in these graphs.

Relatively simple network effects may offer a broader explanation for why the internal/external connecting ratios of each of these national communities changed in the dramatic ways that they did. In complex systems of all kinds, gradual changes such as generational population growth and decline can frequently manifest as punctuated shifts in the way that complex social networks organize. Thus, the gradual build-up of printmaking expertise in different regions may alone account for any one of these striking shifts, in which case it would be improper to speculate about a more temporally-bounded cause. To avoid this hazard, we want to differentiate which EI indices of these communities are to be expected in any community of that size relative to its neighbors, and which are unexpectedly high (favoring international connections) or low (favoring domestic).

To differentiate the expected from the exceptional, we first create a randomly generated network of the same size and makeup as that which we observe in our real museum data (Fig. 6a), but absent any international connections. To decide how to simulate the creation of international connections, we must consider the type of network that printmaking demanded. The industry required both expertise as well as social connections. Like many social networks, it favored the already-successful, and the already-well-connected. Aspiring printmakers from areas with smaller, less developed printmaking communities, on the other hand, would have had little choice but to reach out to foreign centers with more established printmaking infrastructure. Thus, a set of "international" edges are drawn by choosing source nodes at random and allowing them to connect to targets chosen based on a randomized distribution that favors already-well-connected nodes (Figure 6b)

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31 A classic discussion of this phenomenon is found in Duncan J. Watts, *Small Worlds: The Dynamics of Networks Between Order and Randomness* (Princeton: Princeton University Press, 1999), 53.


33 In the context of making connections within a network, a uniform distribution of ties means that all nodes in the network will have an equal chance of making or receiving a connection. On the other hand, a power-law probability distribution describes the distribution of some set of ranked occurrences in which small occurrences (e.g. people with only a few social links) are extremely common, whereas large instances (e.g. people with a huge number of social links) are extremely rare.

The model implemented here sets the connection chance, or fitness f, of node k such that: $f_k = k^{-\gamma}$ The exponent $\gamma$ 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 2.25 provides a close fit for almost every network shown here.
We can then measure the EI indices of each of these simulated regions and contrast those to the EI indices actually observed from those networks produced from the source museum data. Where the two measures converge, then we can say that the EI indices are no different than those of any other network with the same relative sizes of communities. Where they diverge, though, highlights exceptional periods where the model "breaks" because it cannot account for real historical events that may have disrupted the usual functioning of these networks. It is precisely when the model fails that we need to turn our attention from the longue durée to (again drawing on Braudel) histoire événementielle.

Simulation Results: Continuity Within Disruption

Figure 7 overlays the EI indices of these simulated networks on the results observed from the BM data, previously shown in figure 5. By and large, both trends overlap: the simulated networks return similar results to those found in the empirical results. Without knowledge of specific notable
individuals or landmark historical events, this simulation captured a great many of the major orientation shifts in these networks seen in Figure 5. In other words, it would be unreasonable to offer a more localized historical explanation for many of these sudden changes. The gradual shifting of populations can, indeed, produce unexpectedly dramatic shifts such as we see here.

However, there are several notable mismatches between the EI indices returned by these randomly generated networks, and those found in both the BM and RKM data. These are points at which this network simulation fails to predict the balance of domestic and international connections being made, either over- or under-projecting. Model failure, in this case, need not be an analytic roadblock. It can productively be rephrased as such: when are the relative sizes of each of these communities alone (the foundation of this model) not enough to explain the balance of network connections? In those timescales, what additional effects, such as shorter-term historical events, may have compounded, or counteracted, the universal network pressures to find well-connected collaborators?

Figure 7. Random graph EI indices compared to empirical EI indices. The black lines show the EI indices observed in the BM data, while the red ribbons show the range of results returned by simulated networks of the same size and overall connectivity. Some areas with diverging results are highlighted and annotated with concurrent historical events. For visual clarity, only the BM results are displayed here. However, highlighted areas mark significant divergences that appeared in simulations of both datasets. For a complete side-by-side comparison, see the supplementary figure available online at: http://doi.org/10.5281/zenodo.1037568.
For example, in the northern Netherlands between roughly 1650 and 1675, both the BM- and RKM-based networks return a lower EI index than are predicted by randomized networks of the same relative size. In other words, Dutch print producers were making a larger number of internal connections during this period than one would expect if merely considering their size relative to other communities. This disjoint suggests the influence of more short-lived events on the behavior of printmakers during that timespan. It is possible that the official end of the revolt in 1648 with the signing of the Treaty of Münster, and a burgeoning sense of national Dutch pride, may have been expressed in prints through more domestically-centered production. Conversely, in the southern Netherlands, a higher-than-predicted EI index (i.e. more international connections than found in a random network of the same size) around 1580-1610 coincides with the Spanish invasion of Antwerp and the accompanying exodus of Flemish artists, including printmakers. Such a result underlines the enduring effect that Flemish migration had on the art of this period.

One may also point (albeit with slightly less certainty, given the dissimilar results returned by the BM and RKM) to the possible influence of English and French monarchs’ artistic priorities on their countries’ printmaking communities. A higher-than-predicted number of international connections in the English printmaking community between 1625 and 1649 coincides with the reign of Charles I, who imported a wide range of both continental artworks and artists to London during his rule. In France during the reign of Louis XIV between 1643 and 1715, far more internal connections between French printmakers are found than predicted by the simulation. Several events during this period may have helped to fortify the already-burgeoning French printmaking community. In 1655, the Académie royale de peinture et sculpture began to admit printmakers, legitimizing the medium as a fine art rather than a mechanical craft and thus raising the social esteem and professional position of printmakers. The Sun King also issued a large number of print privileges during his reign, making the medium a more financially appealing specialty. Rather than the primary origins of a French printmaking community, these policy changes should be seen as partial (though important) contributors to larger demographic forces already at play.

Notably, for a period verging on one hundred years, the simulated network predicts more international collaboration by Italian print producers than we actually observe. What additional events may have caused such a prolonged divergence from the model? While only a supposition, it is possible that the prolonged lack of predicted international collaborations may have been due the plague of 1656 and the economic collapse that followed in its wake. The Italian peninsula would still be recovering from this disaster a century later, and it appears that the network of artistic print collaboration was not spared.

Considered as a whole, it seems little coincidence that the regional networks that were primarily inward-connecting or evenly connecting in the mid-sixteenth century (the southern Netherlands, Italy, and Germany) also had some of the longest-established printmaking traditions, dating back to the late fifteenth century. Already possessing well-developed printmaking infrastructure, those regions could host relatively self-sustaining networks of print producers.


37 Sue Welsh Reed and Alvin L. Clark, eds., French Prints from the Age of the Musketeers (Boston: Museum of Fine Arts, Boston, 1998), 18–19.


The pattern of early printmaking mastery in Italian and German regions, giving way in the later seventeenth and eighteenth centuries to consolidation in the Netherlands, France, and England, mirrors the general trends in European urban populations over this same period. (Fig. 8) The share of urban populations living in Italian and German cities decreased between 1500-1800, while the share living in Dutch, French, and English cities increased. The shifts observed in international interaction may have been driven less by particular disruptive historical moments or artistic movements and more by gradually building structural incentives powered by these changes in populations and the necessarily-collaborative nature of print production.

**The Exceptional Individual**

This long-term view of print production is a challenging one for traditional, individualist/nationalist perspectives on the history of artistic printmaking. At the scale of hundreds or thousands of artists working over two centuries, the broad contours of international print production appear to be predominantly determined more by demographic changes, rather than the impacts of specific artists or turning points.
in political or military history. And yet, the individual experience of international collaboration and exchange varied widely in this period. (Fig. 9) While space here is too limited to explore these examples fully, it is worth illuminating a very brief example of the individual patterns to be found within this macro-history.

Among Flemish print producers, while prominent engravers in the Galle, Wierix, and De Jode families tended to make most of their connections to Flemish collaborators, members of the Sadeler family consistently rank among the more internationally-focused Flemish print producers.41 Aegidius Sadeler maintained a roughly even split between collaboration with Flemish and artists and publishers versus foreign ones.42 Meanwhile, standing in contrast to the overall inward-focus of his fellow mid-seventeenth-century Dutch printmakers, such as Jonas Suyderhoef, the exceptionally international Cornelis Bloemaert

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41 Printmaking dynasties were a distinctive feature of Flemish printmaking organization; such multigenerational print businesses were far less dominant in the northern provinces; Lincoln, “Social Network Centralization Dynamics,” 149.

found great success working in Paris and later, Rome.\textsuperscript{43} (Fig. 10)

For all the international connections Bloemaert made, however, he relied heavily on fellow expatriates while abroad, albeit in a social capacity, rather than a direct professional one.\textsuperscript{44} This nuance is important to bear in mind when looking at quantitative results that suggest he did most of his work with foreigners. Bloemaert’s case demonstrates the importance of network connections that do not fall within the set of direct ties of artistic source, printmaker, and publisher captured by the datasets used for this study, and suggests promising avenues for future research.

\section*{Conclusion}

Art historians intuit connections between historic events and evidentiary anomalies, be they found in an archive, a collection, or a database. To build narrative from fragmentary evidence is, to be sure, a core skill in our discipline. In doing so, however,

\textsuperscript{43} On Bloemaert, see Filippo Baldinucci, \textit{Cominciamenti E Progresso Dell' Arte Dell’ Intagliare in Rame Colle Vite Di Molti de' Più Eccellenti Maestri Della Stessa Professione} (Florence, 1767), 131–38, http://hdl.handle.net/2027/gri.ark:/13960/t4gm9289m; G. J. Hoogewerff, \textit{De Bentvueghels} (’s Gravenhage: M. Nijhoff, 1952), 71; Marcel Roethlisberger and Marten Jan Bok, \textit{Abraham Bloemaert and His Sons: Paintings and Prints} (Doornspijk: Davaco, 1993), 513–26; the unexpected centrality of Suyderhoef to this production network is discussed in Lincoln, “Social Network Centralization Dynamics,” 150.

\textsuperscript{44} Bloemaert’s expatriate social network resonates with that of the Dutch etcher and mezzotinter Abraham Blooteling, who established a similar circle while working in London; Mary Bryan H. Curd, \textit{Flemish and Dutch Artists in Early Modern England: Collaboration and Competition, 1460-1680, Visual Culture in Early Modernity} (Burlington: Ashgate, 2010), 127–61.
we often miss the forest for the trees, unknowingly erasing continuities in our disruption-focused narratives. Even as print studies has turned towards a more holistic study of the social nature of collaborative printmaking, it still suffers from a myopic focus on individual actions and short-term events as primary agents in these histories.

This paper has shown that what appeared as dramatic, discontinuous changes in one register of these print production networks (the balance of domestic and international ties) can, by in large, be explained as the results of gradual, continuous changes in another (the relative populations of each community). Such an approach does not discount the importance of some critical events, as seen in the periodic failure of simulated networks to match observed results. That those disjunctions are exceptions, however, rather than the rule, should give us pause when formulating historical explanations. These results provide sorely-needed context for and corrective to histories of printmaking that continue to privilege national school origin stories and individual printmakers.

This study provokes further questions about what other longue durée historical factors, including physical geography itself, may have influenced the production and circulation of prints in this period. This approach also opens the door to many more nuanced questions that may be pursued with more detailed and complete data. For example, how do the shapes of these networks differ when considering one type of print versus another (e.g. engraved maps versus reproductions of paintings)? How and when do the visual or aesthetic networks between artists (relationships not explicitly encoded in museum metadata used here) differ from or align with these production networks?

This comparative computational approach also underlines the possibility of data-driven research to productively interrogate modern classification systems. Neither replicating national categories from these source data unthinkingly, nor discarding them as useless, this dynamic network analysis instead contrasted these assigned communities to the potential communities of production evidenced by the objects themselves. When these theoretical and empirical boundaries overlapped and when they diverged may differ radically from when those same national categories overlap or diverge from networks of another type, such as familial or religious ones. Far from reifying unsuitable categories, historical network analysis can better illuminate the plural nature of transnational art histories of the early modern world.46

45 A creative attempt at a geo-history of Dutch art is found in Elisabeth de Bièvre, Dutch Art and Urban Cultures, 1200–1700 (New Haven: Yale University Press, 2015).

46 This article is the result of a long and fruitful research project presented in a very early form at the 2015 Alliance of Digital Humanities Organizations annual conference in Sydney. It has benefitted immensely from comments by Arthur Wheelock, as well as the three anonymous reviewers. Research for this article was supported by fellowships from the University of Maryland, the Michelle Smith Collaboratory for Visual Culture, the Samuel H. Kress Foundation, and the Getty Foundation.