Creating Networks of Skill: Technology Transfer and the Glass Industry of Venice

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Introduction

Venetian glass has long been admired for its quality workmanship, diverse forms, and visual appeal. Even today, the visitor to Venice is struck by the colourful vases and beads in shop windows, the elegance of luxury glass pieces on display in Piazza di San Marco, and the steady stream of tourist boats headed to the island of Murano where the craft of glassmaking has been concentrated since the XIIIth century.

In XVIth and XVIIth century Europe, Venetian glassmaking was a relatively "high-tech" industry in comparison to other local crafts. Along with ship-building and textile production, glassmaking in Venice was one of the few European manufacturing activities that can be referred to as "industrial" in the modern sense[1]. Characteristics of industrial production includes relatively large capital investments, factory-style production, and a clearly defined division of labour. To this list of "industrial-like" features, I would add a modicum of state support, a high degree of standardization in terms of products and manufacturing procedures, a larger-than-average-sized production unit, and a large market for the goods produced, both in terms of customers and geographic area. All of

[1] R. Rapp, *Industry and Economic Decline in XVIIth Century Venice*, (Harvard University Press, Cambridge, 1976), pp. 6-7.

these attributes can be were present in Venice's Renaissance-era glass industry[2]. In addition, there are three basic features characterizing a "new" approach to ceramic production in XVIII[th] century France and England - the distinction between preliminary and production work, use of tools and technology to allow for faster production, and the employment of experimental methods to create innovation[3]. These basic characteristics were all present to some degree in the glass workshops of Venice 200 years earlier.

Studies of the Venetian glass industry have typically been written from the perspective of the collector. Accordingly, the emphasis has traditionally been on the glass objects themselves. Much of the connoisseur-oriented literature concerning Venetian glass has focused on issues of provenance - "where did it come from?" and "how did it get there?". The interest of curators and collectors in this topic has produced a great amount of information concerning the distribution of Venetian glass as a commodity. While not readily acknowledged in scholarly treatments, there are actually *two* aspects of distribution to consider. The first, obviously, is the selling and trading of the actual glass objects. The second aspect is the distribution and dissemination of the skills and knowledge associated with making Venetian glass. In this case, the nature of the commodities - labour skill and knowledge - is much less tangible than the physical objects themselves. Yet it was every bit a "product" that was distributed and purchased. While distribution of glass or

[2] W. P. McCray, *The Culture and Technology of Glass in Renaissance Venice* (Ph.D. dissertation, University of Arizona, 1996). Good general discussions on the history of Venice's glass industry can be found in Rosa Barovier, *Il Vetro Veneziano* (Electa, Milan: 1982) and Astone Gasparetto, *Il Vetro di Murano* (Neri Pozza, Venice: 1958). For a more detailed treatment that draws heavily upon archival material, see Luigi Zecchin's collected works in *Vetro e Vetrai di Murano*, vol. 1 (1987), vol. 2 (1989), and vol. 3 (1990) (Arsenale Editrice, Venice). Zecchin's work is based primarily on his 30-year investigation into Venetian archival material concerning the glass industry, a formidable undertaking considering the necessity of having to read documents handwritten in Venetian dialect. All modern scholars who study Venetian glass owe a great debt to Zecchin for his exhaustive and detailed work in this area.

[3] S. Reber, "The Uses of Science in XVIII[th] Century Ceramic Production," in *The Changing Roles of Ceramics in Society: 26,000 B.P. to the Present*, ed. W.D. Kingery (American Ceramic Society, Columbus, 1990), pp. 279-282.

the knowledge required to make it resulted in essentially the same outcome - the acquisition of Venetian glass - the two pathways were very different in process and nature. The focus of this paper will be on the latter form of distribution - the spread of skills and knowledge associated with glassmaking.

Venetian glassmaking technology spread in the XVIth and XVIIth centuries to other emerging centres of production in Europe such as Florence, Amsterdam, and London. This transfer of technology occurred via two primary mechanisms. The first, and more direct means, was the migration of Muranese craftsmen who took with them the trade practices associated with making Venetian-style (*façon de Venise*) glass. A second and more subtle means of technology transfer took place through the written word in the form of recipe books and technological treatises. The combined, synergistic effect of these two mechanisms allowed for other regions of Europe to create or improve their own local glass industries and offer effective competition to Venice's glass industry. In this manner, "networks of skill" were created along which the technology associated with successful glassmaking travelled.

Glassmaking in Renaissance Venice

The craft of glassmaking in Venice has a long tradition even before the Renaissance period[4]. Documentary and archaeological evidence shows that the craft was practised in the Venetian lagoon by AD 982. By the end of the XIIIth century, a wide variety of glass products was produced, a glassmakers' guild had formed and the industry had been transferred to the island community of Murano where it exists today.

Numerous reasons have been suggested for the concentration of the craft on this small island in the Venetian lagoon. It reduced the risk of fires in the larger city of Venice from the wood-stoked glass

[4] Zecchin (no. 2 above (1987)), pp. 5-45.

furnaces. The relocation of the industry also concentrated the industry into a smaller and more controllable locale. The situating of the industry on Murano adhered to general policy enacted by the Venetian government of creating an early form of "industrial parks"[5]. Numerous Venetian industries were concentrated in particular areas of the city - examples include the ship-building industry in the Castello district, the craft of lace-making at Burano, and the location of jewellers and other business activities in the Rialto district. The Venetian state most likely encouraged a phenomenon that would have occurred gradually anyway - the nucleation and growth of an industry in a favourable and distinct setting. The situating of the glass craft in Murano has particular relevance to the story told here. The glassmakers were now in a location where they could be better monitored by the state and guild authorities.

The glassmakers of Renaissance Venice produced an extraordinary variety of glass products such as mirrors, beads, common/utilitarian vessels, windows, glass for enamels, and so on. A relatively sudden revitalization in the Venetian glass industry occurred in the mid-XVth-century with the production of fine luxury glass directed at the upper and middle classes of Renaissance society. In response to perceived consumer demand, a variety of technological changes took place in the glass industry including: increased raw material consumption, growth of the industry in terms of the number of employees and shops in operation, and the sudden appearance of new and more complex glass compositions and designs requiring a greater overall

[5] W. P. McCray, (no. 2 above). It is interesting to note the occurrence of a similar phenomenon in the mid-XXth century Italian tile industry. See M. Porter, *The Competitive Advantage of Nations* (The Free Press, New York, 1990). This took place primarily through a process of nucleation and growth. One successful tile company led to the creation of another; these successful business enterprises soon formed the basis of a much larger industrial network involving raw materials suppliers, product distributors, specialized consulting firms and so forth. The establishment of both Renaissance Venetian glass production and modern Italian tile manufacture are examples of what Brian Arthur has described as patterns of positive feedbacks and increasing returns; see Brian Arthur, "Positive feedbacks in the economy," *Scientific American*, 2 (1990), pp. 92-99.

technical sophistication to produce[6]. The resurgence of the glass industry in the 1450's was sparked initially by the innovation of a new glass composition called *cristallo* whose appearance evoked the visual qualities of much rarer and more expensive naturally occurring rock crystal[7].

At the broadest scale, the resurgence in the glass industry was clearly linked to the overall economic fortunes of the city. In the mid-XVth century, Venice was the centre of a world-economy[8]. The city's economic power and far-reaching trade connections created the milieu for the expansion of industries such as glassmaking. The structure and distribution of wealth in Renaissance Italy allowed more persons to buy moderately priced luxury goods[9]. Furthermore, attitudes in Renaissance society had changed so that it was now socially accepted, and indeed expected, to participate in the consumption of luxury goods such as glass and majolica[10].

The renewed life of Venice's glass industry, c. 1450, was a unique development in the history of the craft. For centuries, the primary innovations in glassmaking had occurred in places such as Syria and Egypt. Beginning in the XVth century, the glassmakers of Venice, in response to changing patterns of demand and consumption, developed new glass designs and novel compositions. These were desired and imitated throughout Europe and the Near East[11]. It marked an important event when a European glass industry broke

[6] Evidence for this resurgence can be seen, for example, in the greater number of shops in operation after the mid-XVth century. There was also increased consumption of raw materials as evidenced by the yearly shop records translated and published by Zecchin in his collected works. Specific evidence for the greater consumption of soda ash by the glass industry may also be found in Eli Ashtor and Guidobaldo Cevidalli , "Levantine alkali ashes and European industries," *The Journal of European Economic History* 12, no. 2 (1983), pp. 475-522.

[7] M. Verità, "L'invenzione del cristallo muranese," *Rivista della Stazione Sperimentale del Vetro* , no. ½ (1985), pp. 17-29.

[8] F. Braudel, *The Perspective of the World,* (Harper and Row, New York: 1979).

[9] Richard Goldthwaite, "The economy of Renaissance Italy: The pre-conditions for luxury consumption," *I Tatti Studies* 2 (1987).

[10] W. D. Kingery and M. Aronson, "On the technology of Renaissance majolica glazes," *Bollettino del Museo Internazionale delle Ceramiche in Faenza* 5 (1990): pp. 226-235.

away from Near Eastern influences and established an independent regional technological and artistic tradition.

Venice would initially seem an unlikely candidate to usher in a new era in glassmaking. This stems from the fact that the city had none of the basic raw materials necessary for glass production - no readily available wood for stoking furnaces and no high-quality sources of either sand and fluxing agents. All of these materials, along with colouring agents and the very clay used to build the glass furnaces themselves, had to be imported into the city[12]. Instead, the success of Venice's glass industry rested on three essential components: the social and economic context of the craft; the capability of Venice's glassmakers to manufacture sophisticated glass compositions using available raw materials; and their technical ability to work these into pleasing and desired forms. These latter two components of the industry's success would be in demand throughout Europe in the XVIth and XVIIth century as glass technology was transferred from Venice.

Clearly a consumer market for the diverse products of the glass industry was necessary. The market for glass was both domestic and overseas[13]. Furthermore, the city of Venice, through its trade policies and guild regulations, created an environment and infrastructure in which glassmaking, along with other domestic crafts, was stimulated and protected. This can be seen quite clearly, for example, in Venice's policy towards the importing and exporting of raw materials used in the glassmaking process. From as early as 1285, there were rules stating that these materials were not to be taken out of the city[14]. A pattern emerged of Venice importing relatively inexpensive raw

[11] Goldthwaite (no. 9 above).

[12] The materials and construction of Venice's glass furnaces are described in W. Patrick McCray, *The Technology of Glass Furnaces in Renaissance Venice*, ed. P. Rice and W. D. Kingery (American Ceramic Society, Columbus, 1996).

[13] G. Corti, "L'industria del vetro di Murano alla fine del secolo XVI" in una relazione al granduca di Toscana," *Studi Veneziani* 13 (1971), pp. 649-654.

[14] See Zecchin (no. 2 above (1987)), p. 7 as well as D.Jacoby, "Raw materials for the glass industries of Venice and the Terraferma about 1370 to 1460," *The Journal of Glass Studies* 35 (1993), pp. 65-90.

materials and exporting finished goods to be sold at a substantial profit. At the same time, other centres of glass production (i.e. competition) were denied access to the same necessary raw materials due to Venice's aggressive trade policies[15].

At the level of actual craft production, the viability and success of the glass industry rested on the technical skill and knowledge of the *maestri* and *padrone* who worked the glass into objects and who owned and managed the workshops. Glass, like most ceramic products, is fashioned from relatively cheap and readily available raw materials. In Venice, these included sand from the Ticino River near Milan and a sodium-based ash imported from the Near East and added to lower the melting point of the former[16]. As a material, glass is unique in terms of its ability to be worked and shaped into a variety of forms replete with a host of different visual effects. Some of these designs were in imitation of other forms or materials while others were unique to glass. This multifaceted ability of glass is derived from the unique response of glass to high temperatures and the variety of colours as well as the visual effects that the material can have. Glass, in its clarity, design possibilities, and colour (or lack thereof, especially when made of *cristallo* glass) offered the Renaissance consumer a unique and special tangible quality. The consumption of Renaissance Venetian glass also afforded the Renaissance consumer an opportunity to own objects reflecting high standards of artisan skill, cleverness, and craftsmanship. This was especially true in the XVIth and XVIIth century when objects made of glass became even more elaborate and fanciful.

A second aspect of the glassmakers' skill and knowledge lies in their ability to make consistently successful glass compositions with the available raw materials. This is especially relevant considering that these raw materials were quite variable with respect to quality and chemical makeup. This forced the glassmakers to be both creative and attentive to the process at hand. Indeed, an artisan's

[15] Ashtor and Cevidalli (no. 6 above).
[16] See Jacoby (no. 14 above).

skills combined differing proportions of several components - dexterity, judgment, planning, and resourcefulness[17]. Superior workmanship, such as that evidenced in Venice, is the result of the artisan understanding the properties of the materials with which he is working. A central part of this skill is the ability to successfully create objects in the face of incomplete information and understanding.

It is not coincidental that a new and more specialized labour occupation - the *conciatore* - developed in the Renaissance-era glasshouse at the same time that the glass industry was preparing for an economic revitalization. First mentioned as a specific job category in 1444, this person was responsible for mixing the raw materials in the proper ratios which were then melted to form glass[18]. The *conciatore* also maintained a vigilant eye on the glass batch as it was heated, melted, and homogenized while making necessary additions of materials such as fluxes, decolourants, and colourants. While they did not actually work the glass, a skilled and knowledgeable *conciatore* was as important to the successful production of complicated glass compositions and forms as the *maestri* were. Glassmaking, above all, was a group-oriented craft requiring the skills and knowledge of several persons in order to competently practise it.

The respect the Muranese glassmakers received, in terms of their technical skill and their knowledge to make a variety of different glass compositions, can be seen in praise for the industry given by Vannocio Biringuccio in 1540:

> "The best glasswork that is made in our time and that which is of greater beauty, more varied colouring, and more admirable skill than that of any other place is made at Murano. In addition to colouring them all possible tints, they also make them very clear and transparent like true and natural crystal, and ornament them with painting and other very fine enamels. Thus it seems to me that all the metals must

[17] R. Gordon and P. Malone, *The Texture of Industry*, (Cambridge Press, New York, 1994), pp. 38-39.
[18] Zecchin (no. 2 above (1987), p. 48.

> give way to glass in beauty...From this body are the very fine enamels, coloured and so beautiful...they are also used to counterfeit emeralds, diamonds, rubies, and all other gems of any colour...Thus, in short, to anyone considering it well, all the effects of glass are marvellous."[19]

As discussed previously, the glass workshops of Venice exhibited several attributes more commonly associated with the "industrial" style of the XVIIIth and XIXth centuries. However, they still possessed one characteristic that harked back to earlier modes of production - the presence of guilds. Unlike guild systems in other Italian cities such as Florence, Venetian guilds wielded no direct political power. Rather they served the dual function of administering state policy and as craft associations[20]. Documentary evidence of a glassmakers' guild in Venice can be found as early as 1224 and the first edition of the guild rules (the *Capitolare*) were assembled by 1271. The *Capitolare* does not present much information related to the technical aspects of glassmaking or its products but, rather, is more concerned with the organization and discipline of the guild and its members. The problem of glass workers migrating outside of Venice and taking their skills with them is seen from the very first edition of the *Capitolare*[21]. This collection of rules states that workers practising the craft outside of Venice were subject to fines and banishment. Workers also took an oath not to practise the craft outside of the city. Over time, the glassmakers' guild, acting as an instrument of Venetian government policy, would make the punishment for emigration much more severe. By the mid-XVth centuries, this included fines of up to 100 *lire* and 3 months in prison[22]. The nagging problem of workers emigrating from Venice surfaces constantly in archival sources about

[19] C. Smith and M. T. Gnudi, *The Pirotechnica of Vannocio Biringuccio,* (Institute of Mining and Metallurgical Engineers, New York, 1942).
[20] R. MacKenney, *Tradesmen and Traders: The World of Guild in Venice and Europe* (Barnes and Noble, Towa, NJ, 1987), pp. 1-43.
[21] See Zecchin (no. 2 above (1989), pp. 8-13.
[22] *Ibid.*, p. 33.

glass workers from the pre-Renaissance up to the fall of the Venetian Republic in the late XVIII[th] century. It was, as we shall see, a key mechanism in the transfer of glassmaking technology to other parts of Europe.

Before the late XV[th] century, government control over the glass guild and industry had been exercised through the *Giustizieri Vecchio* and, later, the *Provveditori Comuni*[23]. However, after the innovation of *cristallo* and the revitalization of Venice's luxury glass industry, glass manufacture began to fall increasingly under the supervision of the Council of Ten and its three heads, the *Capi*. Continued involvement of the Council of Ten in the glass industry can be found throughout the XVI[th] century. One of the areas in which the Council was the most involved was the selling of glass. The Council of Ten also intervened in other glass matters such as the problem of workers leaving Murano (1547, 1597), administration (1587), and charity for glass workers during the annual vacation period (1555). Numerous other dates and decrees relevant to the Council's involvement in glass activities can be cited. However, the message remains the same. In the decades following the invention of *cristallo*, and particularly in the XVI[th] century, the Council of Ten assumed a direct and prominent role in determining policies relevant to the glass industry.

Reasons for this increased interest are unclear. Glass production was not of central economic importance to Venice in terms of either annual revenue or percentage of the labour force employed. This distinction was reserved for the city's textile and ship-building industries, along with revenue brought in by trade[24]. One explanation was the desire of the rulers of Venice to keep the glass industry competitive in order to have a balanced and diverse economy. In addition, the glass industry was a tourist attraction, much as it is today. Numerous Renaissance-era diaries of pilgrims, princes, and other persons attest to this. Therefore, the prestige

[23] *Ibid.* pp. 28-29.

[24] McCray (no. 2 above), pp. 328-331; also see Rapp (no. 1), p. 100 and pp. 140-141.

glassmaking brought to the Renaissance Venice must be considered as well.

While not a crucial component of Renaissance Venice's economy, sales of glass products made in Venice were still quite substantial. Information on this subject can be found in the writings of Lorenzo Usimbardi to Ferdinand I de'Medici in the 1592 *Memoria di Vetrerie che si cava di Venezia*[25]. Usimbardi was the granducal secretary for the Medici and resided in Venice. Ferdinand was interested in new commercial ventures that would bring revenue to Florence, such as restoring the glass furnaces set up by the Medici in Pisa earlier in the century. Ferdinand de'Medici asked for information about the quantity, quality, and prices of glass produced at Murano - in short, a market analysis. The figures given by Usimbardi for the amount of glass sold show that some 182,000 ducats of glass were made and sold that year. Much of this glass (~ 70%) was destined for markets outside of Italy while only 22% remained in the Veneto. Venetian glass was exported all over the known world including Spain, England, Turkey, Egypt, Portugal, and the Spanish colonies. Usimbardi also notes in his report that the glass industry of Venice was in a state of decline at the end of the XVIth century with only 24 furnaces in operation when a few years prior there were almost twice this number.

Usimbardi's comment to Ferdinand de'Medici on the state of the Venetian glass industry in 1592 reflects continuing trends in the industry. In the XVIIth century, there was an overall and relative decline of Venice's industries in which the glass industry unhappily participated. Over time, as more and more Venetian glassmakers migrated to other parts of Europe, their production technology and tacit knowledge were taken outside of Venice. This transfer of information was aided and amplified by the publication and dissemination of technological treatises which gave specific directions for the practice of glassmaking. Many of these foreign industries, set up with either Venetian workers and/or using

[25] Corti (no. 13 above).

Venetian techniques achieved their success with what the Venetians described as unfair practices[26]. The general pattern was to introduce products - clothes, soap, and glassware, all former Venetian specialties - into Levantine or European markets at bargain prices. The production of *façon de Venise* glass was part of this overall pattern. Made in the Venetian style, this glass was produced outside of Venice and exported all over Europe[27].

During the XVII[th] century, the English, using techniques derived from Venetian sources, developed lead crystal and diminished the demand for Venetian *cristallo*. The Bohemian glass industry refined its potash-chalk composition and also offered competition in the production of "colourless" glass[28]. The Venetian glass industry was forced to scramble and develop new glasses that could rival the foreign compositions[29].

Mechanisms of Technology Transfer

The glassmakers of Murano continued to turn out innovative and high quality vessel glass for both the foreign and domestic market in the XVII[th] century. Yet the industry, like many of those in Venice, experienced a relative decline in this period partly because of foreign competition. A Venetian priest, Father Coronelli, in his *Isolario dell'Atlante Veneto* (1696) discussed the state of the craft at the end of the XVII[th] century. He noted that only about half of

[26] Rapp (no. 1 above), p. 155; also see D. Sella, "The Rise and Fall of the Venetian Woollen Industry," in *Crisis and Change in the Venetian Economy*, ed. Brian Pullan (Metheun and Co., London, 1968), pp. 106-126.

[27] Rapp (no. 1 above), p. 155.

[28] D. Watts, "Why George Ravenscroft introduced lead oxide into crystal glass," *Glass Technology* 31, no. 5 (1990), pp. 202-212; K. Hettes, "Venetian trends in Bohemian glassmaking," *The Journal of Glass Studies* 5, no. 39-53 (1963); C. MacLeod, "Accident or design? George Ravenscroft's patent and the introduction of lead-crystal glass," *Technology and Culture* 28, no. 4 (1987), pp. 776-803.

[29] C. Moretti and T. Toninato, "Cristallo e vetro di piombo da ricettari del '500, '600', '700," *Rivista della Stazione Sperimentale del Vetro* , no. ½ (1987), pp. 31-40. Also see A. Klima's "Glassmaking Industry and Trade in Bohemia in the XVII[th] and XVIII[th] Centuries," *Journal of European Economic History*, 13, no. 3, (1984), pp. 499-520.

the 50 furnaces working a few decades prior were still in operation[30]. By this time, competing industries had been established all over Europe. Countries and cities such as England, Bohemia, Amsterdam, and Florence now had glass works capable of making passable glass in the Venetian style and no longer needed to import it from Venice. At the same time, these regions were developing their own artistic and technological styles independent of Venice. Effective foreign competition and technology transfer were made possible primarily through the dual mechanisms of worker relocation and the increased availability of glassmaking knowledge in the form of recipe books and technological treatises.

Migrating glassmakers: *L'espatrio dell'arte*

The departure of glassworkers from Venice, taking their skills with them, was a perennial problem in the industry from its earliest days. The first *Capitolare* (the guild rules) of 1271 contained regulations concerning workers who chose to leave the city[31]. Yet, for the most part, the Venetian state does not appear to have been overly concerned with this problem until the mid-XVth century and the renewed production of luxury glass. These products were sold at a higher cost and profit than other more utilitarian objects. At this time, fines and penalties became harsher and even included short prison sentences. Often it was the glassmakers themselves who petitioned the government for harsher penalties against their colleagues.

Part of the reason for this endemic problem of worker migration lies in the guild rules themselves. One of the traditions of the Venetian glass industry from its inception was an annual vacation period each autumn. Initially, this period was from the middle of August until the middle of January but by the XVth

[30] Zecchin, (no. 2 above (1989)), pp 290-294.
[31] Zecchin (no. 2 above (1987)), p. 13.

century this had been shortened to only about 3 months on average[32]. There were three reasons for this annual vacation period.

One of these reasons was technical. Glass furnaces, in operation almost continuously during the working season, needed to be repaired and rebuilt at periodic intervals. From an organizational perspective, the vacation period gave shop owners the opportunity to hire new workers and allowed workers to switch employers. Another reason for the annual recess was financial. Glass made in the prior working season was sold during this period and the glassmakers and the guild associated with selling the glass (the *stazioneri*) could avoid saturating the market[33]. The annual vacation period resulted in a substantial period of time when the Muranese glass workers had a reduced or non-existent income[34]. Clearly, this annual recess created a situation in which glassmakers were easily tempted to leave Venice and take their skills elsewhere. Workers who left the city to work temporarily at another city's glass houses during the recess period, only to return home a few months later, certainly created minor problems for Venice's glass industry. However, the workers who emigrated permanently from the city to other locales in Europe represented the most serious threat to the Muranese industry. They remained outside the Veneto indefinitely and established glass factories which gave long-term competition to Venice.

Two distinctly different types of glassmaking enterprises resulted from the relocation of Venetian workers and their accompanying skills. The first were large-scale glassmaking factories producing glass for a profit. An example of one of these will be discussed later. These industries were established in cities such as London, Antwerp, and Amsterdam in the XVIth and XVIIth centuries. A second type of enterprise was the formation of smaller-scale

[32] Zecchin (no. 2 above (1989), pp. 34-35.
[33] Ibid., p. 9.
[34] Ibid., p. 44.

workshops run at least partially as a hobby or personal interest by their patron. A very good example of this phenomenon was the establishment of a small glasshouse under the patronage of Archduke Ferdinand in 1563. It was located near his palace of Ambras at Innsbruck and was manned by a small force of workmen, several of whom were from Venice.

Several other small-scale and patron-supported glasshouses were established in the late XVIth century in German-speaking areas[35]. Closer to home, Bortolo d'Alvise, owner of a glass shop in Murano, was lured to Florence in 1569 by Cosimo I de'Medici. There he established a small glass shop that was in operation for at least 10 years and made predominantly luxury glass under the patronage of the Medici family[36]. Workers who risked fines and punishment to make glass in Florence were rewarded with wages that were considerably higher than those received at home or in comparison to what skilled masters in other Florentine trades earned[37].

In comparison to the larger-scale operations initiated and staffed by Venetians in cities such as London and Amsterdam, the smaller shops were essentially objects of prestige and amusement for their wealthy patrons. As such, they did not represent a serious threat to the long-term prosperity of the Venetian glass industry The interest of persons such as Archduke Ferdinand and the Medici must be viewed against the background of the general curiosity for arts such as glassmaking which was in vogue at this time[38]. Prestige was associated with understanding and participating in a complicated and sophisticated craft such as glassmaking. Several members of the Medici family, for example, maintained a strong interest in many sophisticated Renaissance technologies as

[35] Examples include workshops in Munich, Kassel, Vienna, and Nuremberg, among others.

[36] D. Heikamp, *Studien zur Medicieschen Glaskunst*, (Florence, 1986).

[37] R. Goldthwaite, *The Building of Renaissance Florence; An Economic and Social History*, (Johns Hopkins Press, Baltimore, 1980), pp 320-321.

[38] W. Eamon, *Science and the Secrets of Nature* (Princeton, Princeton University Press, 1994)., p. 141 and p. 226.

porcelain making and glass production, as well as alchemy[39]. The commodity of knowledge in relation to craft production such as glassmaking may be interpreted as a form of "intellectual property"[40]. The knowledge and understanding to practise complex and sophisticated craft activities were intangible yet desirable commodities with clear commercial value. The skills of Muranese glassmakers represent a form of communal property which had been refined and developed for the benefit of the city and for the glassmaking community as a whole. This perception of community knowledge contributed to the development of early patents, especially in cities such as Venice[41]. For example, numerous concessions and protective decrees were awarded to glassmakers who developed new and innovative glass compositions and decorative techniques[42]. The efforts of the Venetian state and glassmakers' guild to restrict the migration of glassmakers via the threat of fines and prison sentences certainly suggests that their skills and abilities were both desirable and guarded domestically. At the same time, because their products were in demand, Venetian glassworkers were consistently tempted to leave Venice and take their skills with them.

Glassmaking in Print

The migration of skilled and knowledgeable Venetian workers to other parts of Europe was only one mechanism through which glass technology was transferred. The publication and dissemination of information related to glassmaking was a second, less direct means for this transfer.

The first record of a recipe book for glassmaking in Venetian

[39] *Ibid.*, p. 270. Also see P. Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era,* (Harper and Row, New York, 1970), pp. 1-61.

[40] P. Long, "Invention, authorship, "intellectual property", and the origin of patents," *Technology and Culture* 31, no. 4 (1991), pp. 846-884.

[41] *Ibid.*, p. 875.

[42] Barovier (no. 2 above) and Zecchin (no. 2 above (1987)), p. 303.

historical sources occurs in 1446[43]. Recipes, as part of European glassmaking practice, have a long history that pre-dates the appearance of Renaissance texts, however. Examples include the *Mappae Clavicula*, the *Speculum Majus*, and other medieval writings[44]. With the exception of Theophilus' excellent *On Divers Arts* (c. 1122), most of the pre-Renaissance writings which mention glass fall into two categories. Some are oriented towards philosophical speculations on the nature of glass as compared to other materials. Others treatises exist as collections of recipes, often very alchemical in nature, which are of little practical use. In many cases, the texts are merely compendia of all types of recipes with little indication that the author had tried them or was even a glassmaker. In contrast, the writings on glass made during the XVth - XVIIth centuries began to vary from these patterns.

The best practical writings on glassmaking from the Renaissance era are those in which the author had direct experience with the subject. These may be considered in opposition to earlier medieval writings mentioned above where the author was merely copying down recipes for the sake of collecting them and with little or no knowledge of whether they actually worked. The emphasis on experience on the part of recipe authors coincides with trends towards experimentation, testing, and empirical observation that would all become part of the scientific method. In contrast to earlier philosophical treatises, recipes for glass such as those of Antonio Neri and the Darduin family, discussed below, do not theorize on the nature of glass as a material. Instead, clear instructions are presented along with attempts to explain observed phenomenon rationally. Medieval and Renaissance artisans may thus be seen as "...the true scientists of the period, and if they lacked the flash of genius to produce a consistent theoretical framework, it must be remembered that even genius could do nothing without the reserve of established

[43] Zecchin (no. 2 above (1990)), p. 34.
[44] J. Stillman, *The Story of Alchemy and Early Chemistry*, (Dover, New York, 1960), pp. 184-299.

fact"[45]. Such recipes may be interpreted as the forerunner of later attempts to codify, explain, and standardize knowledge and include increasingly rigorous experimental methods. Examples of this may be found later in XVIIIth century European ceramic production (French porcelain and Wedgwood wares specifically)[46]. The roots of such patterns can thus be traced to the recording of Venetian and Italian glassmaking knowledge decades earlier.

The "practical" type of writing provided the best and most direct instructions to a person wishing to make glass. These books would have been the most influential, in terms of printed material, in facilitating the transfer and spread of technical knowledge. Even within this category, however, there is considerable variability with respect to the social and technical background of the authors and their intended audience. Therefore, I wish to consider the impact of two of the more practical collections of recipes for glassmaking. One is an example of a glass recipe book kept in private hands while the other was printed and made available to the public.

The Darduin book is an excellent example of a collection of glass recipes assembled by a glassmaking family[47]. It was written over a very long period of time with the earliest recipes dating from the XVIth century and the later ones from the early XVIIIth century. The authors were practising professional glassmakers in Venice whose livelihood depended on their ability to make successfully a wide variety of different types of glass. As a result, their collection represents knowledge derived from decades of practical experience. The value of this experience is noted at one point in the text as Giovanni Darduin states that "in everything, experience is more necessary than science"[48].

[45] C. S. Smith and M. T. Gnudi, *The pirotechnica of Vannocio Biringuccio,* (Institute of Mining and Metallurgical Engineers, New York, 1942), p. xv.
[46] Reber, (no. 3 above).
[47] L.Zecchin, *Il Ricettario Darduin,* (Venice, Arsenale Editrice, 1986).
[48] *Ibid.*, p. 174.

The Darduin book was never meant for publication and was instead aimed at a small, private audience. The authors were artisans and the book is written in Venetian dialect. The book, according to the one of the writers (Giovanni Darduin) was designed to "gather all the secrets concerning enamels drawn from the books....of my beloved father [who died in 1599]...in separate lists of colours...so that if one wishes to make one kind of enamel, one can find it...". The purpose of the book, besides organizing the family recipes, was to serve as a working shop manual. Therefore, the material is presented in clear technical terms with the exact raw materials and amounts specified. The authors have also included their own personal observations on the utility of certain recipes with notations such as "I do not place any trust in this one" present in some places. In many senses, therefore, the recipe collection of the Darduin family may be viewed as a tool used in the Venetian glasshouse, in much the same manner as a furnace or blowpipe. It was also a way for the glassmakers to collect and transfer technological information among family members or within the workshop. In contrast to the next type of recipe book discussed, collections such as this, because of their primarily private nature, did not directly distribute glassmaking knowledge outside of Venice.

Antonio Neri's 1612 treatise, *L'Arte Vetraria*, is also an example of the practical/empirical (as opposed to speculative/philosophical) type of technological treatise[49]. It was however oriented towards a different audience and written for a different purpose. Where the Darduin recipe book was a private collection of practical information for use in the family business, Neri's book was deliberately intended for publication. The Forword to the treatise, which Neri dedicates to his patron, Lord Don Antonio Medici, states that "Having taken much pains for many years about the art of glass...I have compiled a treatise of them, with as much clearness as

[49] R. Barovier (ed.), *Antonio Neri's L'Arte Vetraria 1612*, (Edizioni il Polifilo, Venice: 1980) p. liii. The English version of this was published in 1662 and translated by Christopher Merrett.

I could, to the end to publish it to the world, to please and delight...".

Neri was a learned Florentine priest who travelled extensively around Europe in his lifetime. In 1601 he was employed at the Medici glasshouses in Florence and Pisa where he conducted experiments on different Venetian-style glass compositions. In 1603 he journeyed to the Netherlands, possibly making a stop in Venice along the way. In the Netherlands, Neri made Venetian-style luxury glass compositions in a glass furnace in Antwerp owned by Sir Filippo Ghiridolfi. He is thought to have stayed in the Low Countries for several years, returning to Florence around 1611 and dying there in 1614[50].

Neri's book can be favourably compared to other XVI[th] and XVII[th] century technological treatises which also address specific crafts from a practical point of view. Examples of these include Biringuccio's *Pirotechnica* and Agricola's *De Re Metallica* (both mainly concerned with mining and metallurgy) and Piccolpasso's *Three Books of the Potter's Art*. All of these were intended for publication. Yet Neri's book differs noticeably from the works of Biringuccio and Agricola. While the latter authors wrote primarily qualitative descriptions of glassmaking, Neri's book is a collection of very specific recipes with little offered in the way of general description of the craft. It was prepared with the intent of providing a quantitative, careful, systematic, and empirically-based set of instructions for the glass craft. Neri's treatise was written and published in Florence in 1612. While it was the first known book written specifically about glassmaking and intended for public dissemination, it does not seem to have initially aroused much interest[51]. *L'Arte Vetraria* was relatively unnoticed until about half a century later. Neri's book was of considerable interest to other European countries attempting or continuing to make luxury glass

[50] See Barovier (no. 49 above), p. xliii.

[51] W.E.S. Turner, "The Tercentenary of Neri-Merrett's The Art of Glass," in *Advances in Glass Technology* (1963), pp. 181-201.

in the Venetian style[52]. The first English translation of the book was done by Christopher Merrett, an English doctor and naturalist, in 1662. The revitalization of Neri's text also benefited from a 1679 German translation of the Neri-Merrett version by Johann Kunckel, a German glassmaker who is perhaps best known for his successful application of Venetian techniques for making gold-ruby glass. In the next 100 years, there were no fewer than 12 different editions of Neri's book, appearing in several different languages including English, German, Latin, French, and Spanish[53]. In this fashion, *L'Arte Vetraria* aided in the distribution of sophisticated Venetian glassmaking practices to all parts of Europe. It was, until the late XVIII[th] century, the standard technical manual for glassmaking and excerpts from it appeared in several different XVIII[th] century encyclopedias concerning glass production. Even these later publications drew heavily from the Venetian based descriptions and instructions given by Neri.

The recipes in Neri's book and the Darduin collection are alike in that both offer numerous recipes for the same glass compositions which can be made with variable results and costs depending on the needs of the glassmaker. In the tradition of technological "openness", both texts are free from the use of secretive or ambiguous language in their description of particular processes. While both the Darduin book and Neri's *L'Arte Vetraria* were written for different audiences by authors from disparate social backgrounds and education, they share similar features in the type of material presented, the way in which it is organized, the goals of the author, and the manner in which the technical information is presented to the reader.

How effective such collections of recipes for glassmaking were in spreading technical knowledge? Recipes are a technological representation[54]. They allow for the situation of technological

[52] Barovier (no. 49 above), p. lix.
[53] Turner (no. 52 above), p. 200.
[54] S. Lubar, "Representation and Power," *Technology and Culture (supplemental volume)* 36, no. 2 (1995), pp. s54-s81.

knowledge into a more managerial context. They permit better control of the work process. Recipes offer a means by which tacit knowledge and experience are condensed into a series of mechanical acts[55]. However, recipes for glass production are inherently incomplete or inaccurate. There are many aspects of the craft which cannot be recorded succinctly in words and which were, instead, passed on through the apprentice system, trial and error, and shop practice. Glassmaking is primarily a empirically-centred skill gained, as Neri and Darduin say, from experience. There is a tremendous amount of knowledge required to make a workable glass batch or pleasing glass objects successfully and cost-effectively that is tacit-based. Neri refers several times to a particular operation being carried out at the wishes or on the judgment of the *conciatore* (the person responsible for preparing the glass batch), for example. Recipes for glassmaking must be seen as merely guides; there are many parameters of glass production that would change on a daily basis - the furnace temperature, the quality and purity of the raw materials, and so forth. This cannot be easily communicated through the pages of a book.

How useful would such specific recipes for glassmaking be to the typical glassmaker? Firstly, employing such instructions presupposes that the craftsperson was literate. Evidence suggests that literacy was on the rise among craftspeople in the XVIth and XVIIth century, especially in urban areas[56]. In addition, the recipes would only have been of use to someone who had prior experience in a glass factory. Accordingly, the information presented to the public by Neri would still have required skilled and knowledgeable artisans in order to be effectively used as part of a successful technological transfer. At the same time, the recipe book summarized a tremendous amount of technical information regarding processes and raw materials.Therefore, while skills and

[55] Eamon (no. 38 above), p. 360.

[56] For example, see R. Houston, *Literacy in Early Modern Europe: Culture and Education 1500-1800*, (Longman, London, 1988).

knowledge were primarily transferred via worker movement, printed material provided an invaluable time, labour, and money saving aid to relocated glassworkers attempting to learn or improve upon sophisticated and complex glass compositions[57].

The Creation of "Networks of Skill": The Case of England

Thus far I have discussed how glassmaking technology was transferred from Venice to other locations via the dual and synergistic means of worker movement and printed information. The transformation of England's glass industry in the latter half of XVIth and XVIIth centuries offers a clear example of how these mechanisms, coupled with the prerequisites of perceived demand, government support, and the necessary economic infrastructure, resulted in a successful technology transfer. The general historical and technical circumstances surrounding the establishment and eventual success of the English glass industry are well established[58]. The issue I wish to explicitly examine here is the roles of worker relocation and available printed material in aiding the transfer of glassmaking technology to England.

England received glass manufactured in Venice by the end of the XIVth century. The domestic glass industry in England prior to the mid-XVIth century largely produced simple utilitarian objects such as basic and relatively crude vessel forms and window glass. One of the reasons for this inhibited development was the limited demand for glass, at least in terms of vessels and tableware, in comparison to other parts of Europe. Metals and pottery were preferred and whatever small demand existed for more sophisticated glass was

[57] See C. Cipolla, "The diffusion of inovations in early modern Europe," *Comparative Studies in Society and History*, 16, no. 1 (1972), pp. 46-52, for a discussion of the general role of craftsperson migration in spreading technological innovation.

[58] For a general description and account of the English glass industry in the XVIth and XVIIth centuries see E. Godfrey, *The Development of English Glassmaking 1560-1640*, (Clarendon Press, Oxford, 1975) or R. Charleston, *English Glass*, (Allen and Unwin, London, 1984). Macleod (no. 28 above) discusses the technical and economic circumstances surrounding the specific innovation of English lead crystal.

filled by imports[59]. Gradually, however, demand for higher quality glass increased and it was a natural consequence to attempt to manufacture it domestically. Lacking were skilled workers and their accompanying knowledge and, by the middle of the XVI[th] century, Venetian glass workers had landed in England.

The earliest record of Venetian glassmakers practising their trade in England dates from 1549. Several glassmakers from Murano arrived in London during the Venetian industry's off-season with the intent of setting up a workshop to make *façon de Venise* drinking glasses[60]. This, however, was a short-lived operation and all but one of the glassmakers returned to Murano within two years, presumably under threats of reprisal against them or their families by the Venetian government[61].

The real beginnings of the first significant English glass industry whose products could rival the goods imported from Venice date to 1567. Jean Carré, formerly of Antwerp, received a licence from the English government to make window glass and drinking glasses. Within a few years, Venetian glassmakers were working at Carré's furnace at the Hall of Crutched Friars in London[62]. When Carré died in 1572, the master of the Crutched Friars glasshouse was a Venetian named Jacob Verzelini. Verzelini petitioned for and received a 21-year monopoly from the Crown in December 1574 to make drinking glasses in the Venetian style. The terms of his grant stipulated several conditions: he was free to sell glasses provided that the prices and the glasses were "as good cheape or rather better cheape" than those commonly imported; no others could infringe on his rights to make glasses *façon de Venise*; importation of Venetian glasses was prohibited; and Verzelini was expected to teach the craft to Englishmen[63]. Clearly this hurt the Muranese industry in two ways. Not only were they denied a readily accessible

[59] Godfrey (no. 59 above), pp. 13-15.
[60] Charleston (no. 59 above), pp. 52-53.
[61] Godfrey (no. 59 above), p. 16.
[62] Charleston (no. 59 above), p. 53.
[63] *Ibid.*, p. 53-55.

market for their wares in England but soon English glassmakers would learn their trade secrets. Under the management of Verzelini, other Venetian glassmakers soon arrived in London to practise their trade. By the early XVIIth century, the making of Venetian-style luxury glass in England became an accepted situation such that a common peddler's cry was "Venice glasses fine were newly made in London to drinke your beere or wine..."[64].

Glass houses in England manned by emigrated Venetian workers were created in the late XVIth and XVIIth century. While the English government decided in 1623 to reverse its decision and allow continued importation of glass from Venice, skills and secrets relevant to successful luxury glassmaking had already been lost to the English. The price and amount of Venetian fine glass imported to England continued to drop in the XVIIth century[65].

Furthermore, English glass sellers looked more and more to domestic suppliers for high-quality drinking glasses. In the 1670s, the Venetian ambassador in London, Alberti, unhappily wrote home with the news that "the glass trade from Venice...now suffers from the extreme beauty of the English drinking glasses. They are white and very thick, in imitation of rock crystal...they strike the eye and surpass those of Venice."[66]

In the latter part of the XVIIth century, another development occurred which ultimately displaced Venice from its long-held position as Europe's preeminent supplier of fine luxury glass as well as the arbiter of fashion and taste with regard to glass design. In 1674, George Ravenscroft secured a patent for the production of a new type of glass composition used to make vessel glass - lead crystal glass[67]. While this glass composition underwent numerous

[64] *Ibid.*, p. 64.

[65] *Ibid.*, pp. 66-67; MacLeod (no. 28 above), p. 783.

[66] Charleston (no. 59 above), p. 108.

[67] MacLeod (no. 28 above); for a description of George Ravenscroft's life, see B. Moody, "The life of George Ravenscroft," *Glass Technology* 29, no. 5 (1988), pp. 198-210 and B. Moody, "The life of George Ravenscroft: An addendum," *Glass Technology* 30, no. 5 (1989): 191-192. Watts (no. 28 above) provides a discussion of the more technical aspects of English lead crystal production.

technical refinements in the next fifteen years, it formed the basis for the rise of the English and Irish glass industries beginning in the late XVIIth century. Moreover, the styles of drinking glasses made in England were altered in response to the new glass composition and its visual and working properties. As Charleston notes, "...the glassmen gradually developed fresh forms which would have been wholly inappropriate in (Venetian) soda-lime glass but which were brilliantly successful in glass of lead..."[68].

The development of English lead crystal was not the revolutionary result of altering a single step in the glassmaking process[69]. Rather, like the innovation of Venetian *cristallo* centuries earlier, lead crystal became a successful innovation due to several changes in the production sequence. These were introduced over a broader period of time. Furthermore, the manufacture of English lead crystal must be considered as a partial response to perceived consumer demand for objects made with it. A number of this alterations in the glassmaking process can be identified which had precedent in Venice's workshops

George Ravenscroft was responsible for making the glass into a relative commercial success[70]. Ravenscroft lived in Venice for several years prior to 1674 as a merchant specializing in import goods to Britain including glass. It is reasonable to assume that he had the opportunity to observe Muranese glassmakers as they worked. During the period when lead crystal was introduced, Ravenscroft also maintained contact with his brother in Venice. Furthermore, George Ravenscroft employed Italian glassmakers at his Savoy glasshouse in London. These men were Venetian or at least knowledgeable of Venetian practices[71]. One of the "secrets" employed by Venetian glassmakers in the formulation of their own high-quality colourless glass was to use a very pure source of silica. In their case, river pebbles (*cogoli*) from the Ticino River near Milan

[68] Charleston (no. 59 above), p. 133.
[69] MacLeod (no. 28 above), p. 803.
[70] *Ibid.*; see also Moody (1989) in no. 68 above.
[71] Moody (no. 68 above).

were imported to Venice, crushed, ground, and used as a primary raw material for luxury glass production. This was the practice in Venice from as early as 1394 and several authors of technological treatises including Biringuccio and Neri refer to it explicitly. Robert Hooke visited the Savoy glasshouse in 1673 and noted the use of "calcined flints as white as flour"[72]. The use of a high quality silica source was one of the ingredients responsible for the successful production of lead crystal. As it was also a key ingredient in Venetian luxury glass production, it is not unreasonable to think that either Ravenscroft or the Italians in his employ suggested its use in England. Recipes for luxury glass manufacture in the Venetian style also explicitly refer to the use of a very pure source of silica[73].

The addition of two other raw materials into the glass batch have also been noted in previous studies as essential to the successful innovation of English lead crystal - potassium nitrate and lead oxide. The use of both of these have a precedent in the glass furnaces of Murano. More commonly used in ordnance manufacture, potassium nitrate was added as a fluxing agent to the glass batch[74]. It also had the advantage of clarifying the glass by removing unwanted tints from the glass[75]. Watts notes that Neri's *L'Arte Vetraria* refers to nitre in the manufacture of nitric acid but is mistaken when he states that it was not used in Italian glassmaking. The use of potassium nitrate as an ingredient in glassmaking cannot be seen solely as an English innovation. Tuscan recipes for glassmaking from as early as the 1470s mention the use of "*salnitro*" as an ingredient[76]. It is likely that Venetian glassmakers knew of its use as a glass ingredient in the light of the traffic in recipes between the two regions while perhaps choosing not to use this material due to their monopoly on high quality and readily available soda-rich ash from the Levant. By the end of the XVIIth century, perhaps in response to the increased

[72] *Ibid.*, p. 191.
[73] Chapter 2 of Neri's book is quite explicit in the need for a good, high-quality source of silica for glassmaking.
[74] Watts (no. 28 above).
[75] *Ibid.*, p. 208.
[76] Zecchin (no. 2 above (1990)), p. 224.

English use of saltpeter in their lead crystal, potassium nitrate appears quite frequently in Venetian recipes for colourless and opalescent vessel glass[77]. The flow of technical information concerning glassmaking was a two-way street in this case.

The use of lead oxide in the glass batch was an obvious and important component of English lead crystal. Its use in glassmaking was not an English innovation. Lead was an essential component in diversely coloured glasses used to make enamels and fake gems, among other items. An Italian, Signor da Costa, was employed by Ravenscroft at the Savoy glasshouse in the 1670's. This man knew the practice of making coloured lead glass gems[78]. At the same time, Neri's book, available in English since 1662, contains several dozen recipes for the manufacture of lead glasses and the raw materials associated with it. It is very likely that Ravenscroft, or his workmen, knew of the book and the explicit instructions it contained.

Glassmakers in Venice had been making *coloured* blown vessels from lead-containing glass as early as the mid-XVth century. Numerous recipes for *lattimo* (an opaque white glass) and *chalcedony* (a variegated glass of many swirling colours) exist from this period which describe the addition of lead[79]. Neri also refers to the making of coloured vessel glass with a high lead glass composition in Chapter 64 of his book and states that it is difficult to work with unless special precautions and attention is given[80]. Merrett's translation of Neri's book in 1662 notes that lead glass for vessel production was not made in English furnace at that time[81]. By

[77] P. McCray, Zoe Osborne, and W. D. Kingery, "Venetian girasole glass: An investigation of its history and properties," *Rivista della Stazione Sperimentale del Vetro*, no.1/2 (1995), pp. 19-35.

[78] Moody (no. 68 above), p. 191.

[79] P. McCray, Z. Osborne, and W. D. Kingery, "The culture and technology of Renaissance Venetian chalcedony glass," *Rivista della Stazione Sperimentale del Vetro*, no. 5/6 (1995), pp. 259-278. The presence of lead in these glasses has also be confirmed via chemical analyses conducted by the author.

[80] A. Neri, *The Art of Glass*, trans. Christopher Merrett (London, 1662).

[81] *Ibid.*, p. 315.

the 1670s, this situation had changed. What was unique about the English practice introduced by Ravenscroft and his workers was the incorporation of large amounts of lead to make clear, thick, and *colourless* glass vessels.

The raw materials employed in the production of English lead crystal were previously used in the production of diverse glass types in Venice and Italy. Antonio Neri's *L'Arte Vetraria* was translated into English in 1662, more than ten years before the introduction of English lead crystal. All of the raw materials, as well as hints to some of the production steps, used to make English lead crystal can be found in this book. Neri's text is clearly derived, at least in part, from the glassmaking traditions of Venice. George Ravenscroft spent a good deal of time in Venice and was involved with importing Venetian glass. He also employed several workmen of Italian, if not Venetian, origin. One can conclude that Venetian glassmaking workers and Venetian techniques available now in print via Neris' book clearly played a role in the creation of a new English glass composition that would supplant the luxury glass of Venice.

Comments on the Process and Results of Technology Transfer

In the XVIIth century, the Venetian vessel glass industry declined in importance. Where can the blame for this be placed? The "art-oriented" literature on Venetian glassmaking offers a relatively simplistic evaluation of the industry's decline. The blame is laid to rest on the shoulders of the glassmakers and their products. For example, one writer has noted that a concentration on "virtuoso effects could force a style into an imbalance which could readily cause it be toppled into disfavour."[82] Certainly, such concepts as fashion and form played a role in terms of what types of products were demanded of European glass houses. However, such an

[82] R. Charleston, "Venetian glass of the XVIIth century: An essay in identification," *Apollo* 110 (1979), p. 400.

analysis does not consider the nature of the market, the effect of government policy, or the availability of raw materials and skilled workers as part of the decline of the Venetian glass industry.

Over time, as more and more Venetian glassmakers migrated to other parts of Europe, the production technology and tacit knowledge of the industry left Venice. This transfer of information was aided by the publication and dissemination of technological treatises such as that of Neri's which specifically explained the actual practice of glassmaking. Many of these foreign industries, set up with either Venetian workers and/or using Venetian techniques achieved their success with what the Venetians described as unfair practices[83]. The typical method of foreign competitors was to introduce products - clothes, soap, and glassware, all former Venetian specialties - into Near Eastern or European markets at bargain prices. The Venetians, of course, resented the superficial resemblance of these cheaper products to their own goods. In some cases (although not, as far as I know, for the case of glass), counterfeit trademarks of Venice were used to mark these newer and cheaper goods. The production of *façon de Venise* glass was part of this overall pattern. Made in the Venetian style, this glass was produced outside of Venice in places such as France, Spain, the Netherlands, and England and exported all over Europe. The quality of these glass pieces was not always of the same standard as the Venetian wares. These cheaper imitations, in glass and other products, were doubly damaging to Venice's economy. Not only were they undercut in terms of prices but the shoddy quality passed off in imitation of true Venetian products further hurt Venice's reputation and economic potential.

In one case, the actions of the Venetian government and glass guild served to limit the growth of a potentially successful branch of the glass industry. Renaissance Florence has been called the "optics capital" of the Renaissance[84]. This is in contrast to Venice's

[83] Sella (no. 26 above), pp. 119-120.

[84] V. Ilardi, "Renaissance Florence: Optics capital of the world," *The Journal of European Economic History* 22, no. 3 (1993): 507-541.

domination in almost all other aspects of glass production. Furthermore, we know that Venice had been active in the manufacture of glass and rock crystal lenses since the late XIIIth century. Yet, by the middle of the XVth century, Florence had emerged as the centre of production for the best eyeglasses. For instance, the Gonzaga family, who purchased numerous pieces of fine luxury glass from Venice, chose instead to buy their eyeglasses from Florentine sources[85]. The optics industry of Florence received substantial support from the Medici family. With the backing of Cosimo II and the development of new methods of lamp working, the Florentine artisans made instruments not available in Venice. Muranese craftsmen refused to develop a purer and more optically homogeneous glass for lenses. Instead, they concentrated their efforts on the production of more traditional and profitable glass and glass compositions for mirrors or blown wares[86].

Why the sluggish interest in this field among Venetian policy makers and glass producers? The Venetian government does not seem to have readily recognized the potential of this new market for "scientific" glass. Few Muranese glassmakers responded to the demand for such glass. Ilardi notes the gradual decline in the support of creativity in Venice as the city's power began to wane. Venetian nobility were increasingly bound by tradition and discouraged over the loss of Venice's political and economic power. They did not or would not seek out new business opportunities as aggressively as before[87]. The long-term consequences of not investing time and money into making a more clear, colourless, and defect-free glass suitable for optics would be profound for its glass industry. The English, using techniques derived from Venetian sources, would develop lead crystal and replace, to a large extent, the Venetian *cristallo*. The Bohemian glass industry would refine its

[85] *Ibid.*, p. 526.
[86] Zecchin (no 2 above (1989)), pp. 255-265.
[87] G. Cozzi, "La Politica Culturale della Republica di Venezia nell' Età di Giovani Battista Benedetti," in *Cultura, Scienze, e Techniche Nella Venezia del Cinquecento* (Venice, 1987), pp. 9-27.

potash-chalk composition, also offering competition in the arena of "colourless" glass[88]. Rather than being ahead in the field, as it had been for centuries, the Venetian glass industry had to quickly develop new compositions that could rival the English and Bohemian glasses.

The Council of Ten, coupled with the glass guild, continued to enact numerous new rules and decrees of limited beneficial effect to the industry. Instead of opting for a freer and less restricted practice of the glass craft, the state and guild chose to attempt to achieve success via greater regulation. As mentioned previously in connection to the optics industry, the ruling classes of Venice had a damaging role in not recognizing when industrial and market changes were afoot. The upper classes of Venice have been described as too conservative in terms of their commercial policies[89]. Instead of furthering innovation, Venetian patricians tended to relive past glories and support outdated policies[90]. Of course, this analysis does not absolve the glass workers of Venice from guilt in the overall decline of the industry. In comparison with other European workers, the wages paid to glassworkers in Venice were relatively greater. Furthermore, the presence of a well-developed guild system within the Venetian glass industry had negative effects. Acting on the wishes of the state, guilds typically directed their efforts at improving quality rather than reducing costs. As the guilds also tended to reduce competition between members, innovation and new forms of production were not generally encouraged.

It would be an oversimplification to say that the establishment of a successful English glass industry and development of lead crystal (along with the relative decline of Venice's glass industry) occurred solely in response to the transfer of Venetian glassmaking technology. Several writers have commented on the beneficial effects that the English patent system had on the glass industry[91]. The

[88] Hettes in (no. 28 above).
[89] Rapp (in no. 1 above), p. 176 and Ilardi (no. 85 above), p. 536-538.
[90] Cozzi (no. 88 above).
[91] Godfrey (no. 59 above), pp. 16-33; see also MacLeod (no. 28 above), p. 784.

glass industries in countries that offered competition to Venice such as England and the Netherlands were organized differently. Each, at least initially, relied on the importation of skilled Venetian workers and materials and the extensive use of enforced long-term monopolies and patents granted to groups or individuals to achieve success[92]. Furthermore, the success of the English and Dutch glass industries was enhanced and furthered by their expanding role in the changing world economy.

Certain features inherent in the competing English, Dutch, and Bohemian glass industries (in terms of organization, patent protection, and their nation's position in a powerful world-economy) provided permissive cause for the overshadowing of the Muranese industry. The continued migration of workers to other centres of production and the availability of glassmaking knowledge in technical treatises gave many of these places the extra advantages they needed to compete with their Venetian glassmaking. These mechanisms of technology transfer helped cities such as London to compete successfully for a share of the glass market. In this manner, "networks of skill" were formed and maintained.

In the failure to respond to new market practices, in the continued confusions over quality and regulation, and in the loss of workers and technological knowledge, the failure of Venice's superiority in glassmaking can be seen as, at least partly, self-inflicted. The English glass houses, after acquiring the necessary skills and knowledge from Venetian craftsmen, could employ their own countrymen. The development of English lead crystal eventually made the previously popular Venetian compositions and forms unfashionable. By 1674, Alberti already could note that the glassworkers of Murano residing in London "are unemployed; they die of hunger or emigrate"[93].

[92] For a discussion of Venetian glassmakers in Amsterdam see J. Baart, "Ceramic Consumption and Supply in Early Modern Amsterdam," in *Work in Towns: 850-1850*, ed. D. Keene and P. Corfield (University of London, London, 1990), 74-85.
[93] Moody (no. 68 above), p. 205.