

Value Creation and Knowledge Loss: The Case of Cremonese Stringed Instruments

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To understand how the value of cultural products is determined, one must consider how evaluations evolve over time and have an impact on the conditions supporting knowledge development. If evaluations do not fully recognize the potential value of a cultural product, the associated knowledge—especially tacit knowledge—may be lost rather than passed on, thus jeopardizing subsequent attempts to reproduce the valued product. We examine these dynamics by studying how value was attributed to Cremonese stringed instruments. The value the Cremonese masters created was first recognized in the 16th century, and in the early 18th century, new methods to strengthen instrument sound and sonority were developed. However, the value of these new developments was not widely recognized until the 19th century, when, in evaluating musical performance, performers, critics, and public audiences took over from royal courts, and they selected Cremonese instruments as the best for performing the emerging Romantic music. We consider how the dynamics of value determination over time have implications for knowledge management processes.

Key words: field; value creation; knowledge loss; apprenticeship; historical case; stringed instruments

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1. Introduction

Violins are among the most expressive of stringed instruments, and the violins made more than 300 years ago by Antonio Stradivari and Bartolomeo Giuseppe Guarneri (*del Gesù*) are still considered to be among the most expressive. Many performers believe they sound better when they play a violin made by a Cremonese grand master, and many also believe present-day violin makers cannot make an equivalent instrument. Whereas present-day luthiers agree that the Cremonese masters made wonderful violins, they claim to have more knowledge about making violins now than ever before and can make or reproduce violins like the Cremonese masters. With auction prices for Stradivari or *del Gesù* violins reaching into the millions of dollars,¹ it would seem that if modern violin makers can reproduce these instruments, the financial incentives to do so are in place. The problem of value creation and recognition is more complicated, however. While performers claim reproduction attempts are not (or are only partly) successful, scientific studies claim to explain how and why instruments sound as they do, and modern instrument makers believe they can reproduce them.

We focus on the stringed instrument makers who worked in Cremona because ultimately, their instruments were recognized as the best. By linking the knowledge management framework of Argote et al. (2003) with the focus of Csíkszentmihályi (1996, 1999) on a systems view of creativity, we clarify how changing evaluation criteria in the music field shaped (1) the conditions supporting knowledge creation, retention, and transfer over

time; and (2) the value accorded to Cremonese masters' stringed instruments. Our case analysis highlights how master–apprentice relationships facilitated the generation and transfer of the knowledge needed to make stringed instruments, how a diverse and changing musical field was a source of evolving evaluations for instruments and instrument makers, and how with the help of virtuoso performers, Cremonese stringed instruments gained extraordinary recognition. This recognition did not occur, however, until almost a century after the most famous Cremonese makers had done their best work. Despite many efforts to reproduce Cremonese masters' instruments, this significant recognition delay led to a concern that the knowledge for making such instruments had been lost. Our paper explores this issue by proposing a more refined conceptualization of the value assessment processes and determinants of value occurring in a field.

2. Theoretical Framework

People have made musical instruments for centuries. Our inquiry focuses on the knowledge processes used to make stringed instruments and how these were developed, preserved, and passed on. To trace these processes, the framework of Argote et al. (2003) is a natural starting point. The framework organizes the literature on knowledge management along two dimensions: knowledge management *outcomes* and properties of the knowledge management *context*. Knowledge outcomes refer to the processes leading to the creation, retention, and transfer of knowledge. The context

dimension refers to the contextual factors that influence knowledge outcomes, including the properties of production units (individuals, groups, or firms), the relationships between production units, and the distinguishing characteristics of the knowledge base. The framework suggests that contextual factors interact with knowledge outcomes and affect how knowledge is accumulated, retained, and transferred. Knowledge management research, for instance, highlights how production unit reputation and status affects knowledge creation and transfer (Allison and Long 1990, Crane 1965, Merton 1968). In a study of how institutional prestige influenced technology licensing, for example, Sine et al. (2003) found that institutional prestige increased a university's licensing rate over and above that expected based on past performance. Furthermore, a shared social identification makes knowledge transfer easier. In a lab experiment study, Kane et al. (2005) found that as personnel were rotated between groups, knowledge transfer was easier because they shared a superordinate social identity.

Links between production units also affect the creation of novel variation. Knowledge flow between individuals increases, for example, as they are embedded in densely connected networks (Reagans and McEvily 2003). If individual ties are critical conduits for knowledge transfer, then if they dissolve, transfer may stop, and eventually the knowledge associated with the broken tie may be lost. More generally, if contextual factors supporting knowledge outcomes change, this can jeopardize knowledge retention and transfer. The risk of knowledge loss increases when knowledge is tacit and not written down. Research shows that tacit knowledge (Polanyi 1962, Winter 1987) and difficult-to-articulate knowledge are harder to transfer than explicit knowledge. Tacit knowledge is transferred most effectively by direct observation, participation, and close interaction, as in master–apprentice relationships (Lave and Wenger 1991). Knowledge is harder to retain and transfer if it is not codified or in a written format, and causal ambiguities also hinder knowledge understanding and transfer (Szulanski 1996). When work is not standardized and work knowledge is not recorded, knowledge retention becomes harder and gets still more difficult as participant turnover increases (Rao and Argote 2006). Properties of the knowledge base, therefore, affect “the rate at which knowledge is accumulated, how much of it is retained, where it is retained, and how easily it diffuses within and across firm boundaries” (Argote et al. 2003, p. 574).

By focusing on the contextual factors that affect continuity in knowledge outcomes, the framework of Argote et al. (2003) identifies conditions that enhance the likelihood not only of generating cultural products (e.g., a new product, artifact, or technology) but also of reproducing them. In this sense it has important implications for our analysis of the value

determinants of Cremonese stringed instruments. If continuity in knowledge outcomes facilitates reproduction, then attempts to reproduce Cremonese stringed instruments will require complete and continuously available knowledge of Cremonese masters' methods and techniques. If this continuity is interrupted, knowledge of Cremonese methods and techniques may be lost, jeopardizing reproduction efforts.

An emphasis on contextual factors also introduces the possibility that continuity in knowledge outcomes may depend directly on how cultural products embodying that knowledge are evaluated in the broader environment and how such evaluations may change over time. In fact, the Argote et al. (2003) framework does not explicitly consider the role the wider context plays in determining which cultural products are recognized and valued. Hence, an account of how, and the extent to which, cultural products gain or lose recognition over time extends the framework. As a context recognizes cultural products as having value, it will endorse some and reject others, allocating symbolic and material resources to favored producers and withholding such resources from others to shape the conditions supporting knowledge outcomes.

How cultural products actually gain recognition has been studied extensively by cultural sociologists (e.g., Hirsch 1972; Peterson 1976, 1979; Becker 1982; Bourdieu 1993). Peterson (1976), for example, notes that cultural sociologists have long been concerned with the mechanisms by which originality and innovation are evaluated; the impact of gatekeepers such as museums, company executives, and editorial boards; the contexts in which cultural products are used; and the impact of consumers. Indeed, cultural industries can be conceptualized as networks that include creators (e.g., artists, musicians, actors, writers), brokers (e.g., agents, dealers), cultural product producers (publishers, studios), distributors (wholesalers, theatres), and users (consumers). Collectively, these actors constitute the context wherein cultural products are made, evaluated, recognized, and diffused (Hirsch 1972).

A cultural product originates as an individual produces a novel variation in a specific cultural field—for example, music, sculpture, painting, or literature (Csíkszentmihályi 1996, 1999). As a novel variation attracts attention, field experts seek a consensus on whether or not to include it in the field's domain, i.e., the accumulated knowledge, tools, values, and practices that identify the field. As consensus can be difficult to achieve, domain changes are infrequent. In fact, novel variations are adopted only when “they are sanctioned by some group entitled to make decisions as to what should or should not be included in the domain” (Csíkszentmihályi 1999, p. 315). Whereas individuals usually generate new and novel variation in a field, members of the field acting as gatekeepers (Hirsch 1972) determine which variations are recognized as good

(e.g., Von Wright 1963, Petersen 1979) and are to be retained in a field's knowledge domain (Cattani and Ferriani 2008). Indeed, value "can only be determined within the context of a set of preferences of individuals and groups that act as selectors" (Wijnberg and Gemser 2000, p. 323). The recognition accorded to cultural products is a critical contextual factor that affects the continuity of knowledge outcomes. If cultural products are not recognized or recognition is delayed, the flow of resources to producers is likely to be interrupted, jeopardizing their ability to generate new products and to pass their knowledge on to others (e.g., apprentices).

Focusing on the contextual factors shaping knowledge outcomes also allows consideration of how changes in those factors may have consequences over time. As contexts evolve, members of a field develop additional criteria to determine which "good" products are "right" in particular contexts. In this sense, the evaluations of members of a field continually reconstruct social reality (Berger and Luckmann 1966). Because field evaluations change, the immediate recognition granted to a product and/or its producer may or may not convert into long-term recognition. As a knowledge domain evolves, so also do the evaluation criteria for assessing contributions. There is often significant variation in the value attributed to cultural products and in the reputations accorded producers. Previous evaluations may be revised to allow some cultural products and their producers to achieve long-term recognition while others are forgotten. In art worlds (sculpture, painting, literature, etc.), reputations develop through consensus building and, like "all forms of consensus, the consensus on reputations, at every level, changes from time to time" (Becker 1982, p. 359).

As reputations develop, consolidate, and perpetuate, a field attracts symbolic and material resources, and a disproportionate share usually accrues to producers whose products have been accorded recognition. Because recognized producers have access to a regular flow of resources, they can perfect their work and enhance their reputation. Access to resources also allows producers to experiment with novel solutions and expand the knowledge base they and their collaborators use. An art or science field attracts creative individuals to the extent that it provides them with latitude for experimentation and promises rewards for success. Even if individuals are intrinsically motivated and enjoy work in a particular domain, money and fame remain extrinsic rewards that add to the attraction of a field (Bourdieu 1993).

The processes for producing creative work are distinct from the processes for attributing value to that work. Whereas knowledge outcomes facilitate the material production of cultural products, the continuity of those outcomes depends on the extent to which the broader field accords recognition to producers and thus supports them with material and symbolic resources (Csíkszentmihályi

1996, 1999). Recognition is not necessarily synchronous with the production of cultural products, and in fact, years may elapse between when new product variations are developed and when a field's knowledge domain recognizes them as valuable. As the temporal gap between material production and symbolic recognition increases, knowledge accumulation, retention, and transfer processes may be interrupted or stopped. In addition, evaluation criteria may change, affecting the value of cultural products. Accordingly, our goal in this paper is to explore how product value assessment processes and determinants actually occur in a cultural field, and so we propose the following:

PROPOSITION. *Changing evaluation criteria and delayed value recognition jeopardize the ability to make cultural products by affecting the continuity of knowledge outcomes and increasing the risk of tacit knowledge loss.*

Our case study sheds light on these interacting forces by describing how the Cremonese way of making stringed instruments gained recognition over time and diffused across Italy. Cremonese methods and instrument makers were in competition with other instrument-making methods and craftsmen, and for many years, all were recognized as creating value. At the beginning of the 18th century, Cremonese masters such as Antonio Stradivari and Guarneri (*del Gesù*) began experiments to strengthen instrument sound and tone. Although these masters were supported at the time by some performers, their efforts did not receive general recognition until the 19th century, when musical composition had further evolved and performance venues had changed. Given this belated recognition, 19th-century violin makers sought to find and replicate the Cremonese instruments made a century earlier and found that to do so, they had to rediscover the tacit knowledge used to make them.

3. Method

Like other cultural products, the value of stringed instruments depends on historically and socially determined standards that vary across contexts and over time. The Cremonese setting allows an in-depth analysis of the interplay between the individuals producing cultural products and other field participants, such as monarchs, players, composers, critics, and audiences. We describe how Cremonese masters made stringed instruments and how the field evaluated them. Historical case study research is appropriate for investigating situations with complex dynamics and context-specific meaning. The intent is to motivate, inspire, or illustrate theoretical insights by identifying the interplay of forces and actors over time (Geertz 1973, Kieser 1994). Historical analysis considers how the details and actions taken in particular situations reflect a larger system of meaning (Hargadon and Douglas 2001). By tracing the value determinants

of Cremonese stringed instruments, our study offers a more refined conceptualization of a more complex phenomenon (Siggelkow 2007). Our goal is not to test theory directly but to explore product value assessment processes and determinants in a cultural field.

Several bibliographical sources and books describe stringed instrument making in Cremona (e.g., Fry 1904; Hart 1883; Hill et al. 1902/1963, 1931/1989;² Marchi 1786; Pollens 2010; Sacconi 1972; and many articles in the *Strad* magazine and the *Journal of the Violin Society of America*) and the musical context in which violin making emerged and evolved (e.g., Brown and Polk 2001, Hart 1883, Twining 1882, Royal de Forest 1904). Other sources (e.g., Hart 1883; Hill et al. 1902/1963, 1931/1989; Johnson and Courtneall 1999; Pollens 2010; Rosengard 2000) offer primary data documenting how instruments were made, specific purchases including prices of Cremonese instruments, contemporary evidence of the reputations of Cremonese masters, the locations of their workshops, the names of their apprentices as reported in census data, the names of celebrated performers and where and when they played their Cremonese violins, how collectors worked, and other historical events and relationships. Many original documents come from the manuscripts of Don Desiderio Arisi, a contemporary of Antonio Stradivari, that are preserved in the public library of Cremona. Other documents are Stradivari's own notes and his molds for instrument design located in the civic museum of Cremona (Sacconi 1972). Additional original documents describing actors, events, and relationships critical for our analysis are available at the civic museum and the public library of Cremona.

We also conducted interviews with contemporary violin makers and music experts. More precisely, we interviewed three violin makers (one from Bolzano, Italy; one from New York; and one from Israel), the president of the New Jersey Symphony Orchestra, a violinist/composer (who plays a violin made by Giovanni Battista Guadagnini, one of the finest luthiers of his time), the curator of the Museo Stradivariano in Cremona, and the curator of the Berlin Musical Instrument Museum. The interviews were semistructured, lasted from one to three hours, and were aimed at unveiling how present-day experts see how the making of stringed instruments developed and how instrument makers think and work. By using several sources, we sought to build trust in the congruence of our data and information, and the triangulation from our multiple and distinct bibliographic sources reduced the risk of biased points of view.

4. Historical Case Study

4.1. The Development of Stringed Instruments

Musical performance in medieval Europe provided rhythm accompaniments for dancing and singing and

supported church worship (Brown and Polk 2001). Musicians might play several instruments, sing, and improvise, but most, like music itself, had low status. This status changed, however, as trade and commerce grew in 14th- and 15th-century Europe, and monarchs gained control over much of this new wealth. They established courts where they aimed to impress through magnificent entertainment. Music supported entertainment, and courts imported foreign musicians to further impress. Royal court sponsorship and resources gradually improved the status of music and the skills of musical performers and instrument makers.

In 16th-century Europe, musical performers might make their own instruments, and family-managed workshops also made musical instruments, so there was a wide variety of building methods and designs in the instrument-making field. In the Black Forest, Switzerland, and England, for example, stringed instrument building usually began with the hollowing out of a block of wood. In Tyrolean towns like Füssen, in contrast, makers built instruments by joining pieces of wood together around molds (Adelman and Otterstedt 1997). These different building methods led to instruments with different names, shapes, and sizes, and with varying numbers of strings played in different ways (Heron-Allen 1885, pp. 29–57). It was not clear which was a better instrument. When monarchs decided which instruments to buy for their courts, however, their purchases accorded reputation and financial resources to favored instrument makers. Such a decision occurred in 1560, when Catherine de Medici, who was born in Florence and became Queen of France, directed her son Charles IX to commission a set of 38 matched and decorated stringed instruments from the workshop of Andrea Amati in Cremona, Italy. In the 16th century, Cremona was a city that “exported musicians who certainly travelled around with their own instruments” (Chiesa 2007, p. 15). Violinists from Cremona played, for example, at the royal courts of Paris and London. Girolamo Magarini, a violinist of the King of France, “received a sum of money from his Lord in 1560 with instructions to return home [Cremona] and recruit more violin players. Four years later, Girolamo was living in Paris again receiving his salary as ‘suonatore di violini del Re’ (King’s violinist)” (Chiesa 2007, p. 16). The King’s records further show “payments were also made to two violinists from the Carubelli family, also from Cremona...” (p. 16).

We do not know much about how, where, and when Andrea Amati (circa 1505–1578) learned to make stringed instruments or why in the late 1530s he opened his workshop in Cremona, a commercially prosperous textile manufacturing town in northern Italy. We do know, however, that he was an outstanding craftsman, and by ordering from him, Catherine de Medici ensured that the French court had beautifully crafted

stringed instruments. Even as French court entertainment encouraged innovation, its main purpose was to praise the monarch and impress courtiers. Musical compositions were accompaniments and, per se, were neither important nor remembered. Royal buyers assessed the visual beauty of crafted instruments as more important than their sound. Visual beauty often meant not only craftsmanship but also decoration (Witten 1982).

Andrea Amati trained his sons, Antonio (circa 1540–1607) and Girolamo (Hieronymous I) (1551–1635)—“the Brothers Amati”—in stringed instrument making. When their father died, they took over his workshop (Bonetti 1938). Girolamo trained his son Nicolò, and in turn, Nicolò took over when Girolamo died. The Amati workshop reached its zenith in the 1650s under Nicolò. Census records show that between 1641 and 1686, Nicolò Amati housed at least 15 apprentices and workers (Pollens 2010, Kass 1992), including Antonio Stradivari. Most of these men eventually set up their own instrument-making workshops. Nicolò died in 1684, and his workshop passed to his son Girolamo Amati II (Hieronymous II), who involved himself in risky financial ventures that led to large debts and the demise of the workshop. Under Nicolò and through the apprentices he trained, however, the Amati workshop had established a community of practice where instrument-making knowledge was developed and passed on from master to apprentice.

Stemming from the Amati workshop, two family dynasties established new workshops to make stringed instruments in Cremona (see Table 1). The Guarneri dynasty began when, after being apprenticed to Nicolò Amati, the patriarch, Andrea Guarneri (1626–1698)

opened his workshop around 1654. Andrea concentrated on small-pattern violins and violas, and his innovations made these instruments easier to play. His instruments were not as beautifully crafted as those associated with the Amati workshop, however. His older son Pietro Giovanni (1655–1720) began work in his father’s workshop around 1670 and moved to Mantua in 1683 both to play in the Duke’s orchestra and to work as an instrument maker. Andrea’s younger son, Giuseppe Giovanni Battista (1666–1740), worked in his father’s workshop from 1676 until his father’s death in 1698, at which time he inherited the workshop (Johnson and Courtinall 2004). Giuseppe’s two sons apprenticed with him as instrument makers. Pietro (1695–1762) left in 1717 to be a violin maker in Venice. His other son, Bartolomeo Giuseppe (1698–1744), stayed in Cremona and may have worked as a musician before opening his own workshop in 1731. He made instruments from 1726 to 1744, working alone or with his wife, and he developed his violin-making skills throughout his career. By putting the letters JHS and a cross inside his instruments, Bartolomeo Giuseppe Guarneri came to be known as *del Gesù*.³ His violins had a remarkably mellow and sonorous tone and show an increasing focus on “the search for a better sound, or for a special sound in every instrument” (Chiesa 2004, p. 15). Like his father and grandfather, *del Gesù*’s craftsmanship was less concentrated on the finish; thus the visual appearance of his instruments compared unfavorably with those of Amati and *del Gesù*’s older contemporary, Antonio Stradivari. The focus of the Guarneri experiments was on simplifying playing and on enabling a more powerful sound.

The family dynasty led by Antonio Stradivari (1644–1737) also stemmed from the Amati workshop.

Table 1 Cremonese Masters’ Workshops and Apprentices

Amati	Guarneri	Stradivari
<i>Andrea</i> (c. 1505–1578), founder of the Cremonese school.	<i>Andrea</i> (1626–1698) was apprenticed to Nicolò Amati and worked as his employee before opening his own workshop in Cremona around 1654.	<i>Antonio</i> (1644–1737) worked as an employee of Nicolò Amati before opening his own workshop in Cremona around 1680.
<i>Antonio</i> (c. 1540–1607), son of Andrea Amati.	<i>Pietro Giovanni</i> (1655–1720), son of Andrea Guarneri, moved to Mantua in 1683.	<i>Francesco</i> (1671–1743), son of Antonio Stradivari.
<i>Girolamo (Hieronymous I)</i> (1551–1635), son of Andrea Amati.	<i>Giuseppe Giovanni Battista</i> (1666–1740), son of Andrea Guarneri, inherited his father’s workshop in 1698.	<i>Omobono</i> (1679–1742), son of Antonio Stradivari.
<i>Nicolò</i> (1596–1684), son of Girolamo. Nicolò’s apprentices included Andrea Guarneri, Giacomo Gennaro, Francesco Rugeri, Gian Battista Rogeri, Paulo Grancino, Giofredo Cappa, Leopoldi Todesca, the Malagamba brothers, Francesco Mola, Giorgio Fraiser, Bartolomeo Pasta, Girolamo Segher, Bartolomeo Cristofori, Giuseppe Stanza, Alessandro Gagliano, and Antonio Stradivari.	<i>Pietro</i> (1695–1762), son of Giuseppe Giovanni Battista Guarneri, moved to Venice in 1717.	<i>Carlo Bergonzi</i> (1686–1747) worked with Hieronymus Amati II and <i>del Gesù</i> before taking over over Stradivari’s repair work.
<i>Girolamo II (Hieronymus II)</i> (1649–1740), son of Nicolò, invested in financial ventures that led to large debts and the demise of the workshop.	<i>Bartolomeo Giuseppe (del Gesù)</i> (1698–1744), son of Giuseppe Giovanni Battista Guarneri, opened his own workshop in Cremona in 1731.	<i>Alessandro Gagliano</i> (c. 1700–1735) worked with Stradivari and later became founder of the Neapolitan school.

Stradivari began making instruments in the late 1650s while working for Nicolò Amati (Hill et al. 1902/1963). Around 1680, he opened his own workshop where his focus was on improving tone and increasing sound. To do so, he gradually abandoned Amati's patterns and increased his instrument dimensions, i.e., his "longish models." Around 1698, he returned to his pre-1690s sizes and embarked on his "golden period." During this time, he intensified his experimentation in some areas while in others he adhered to a specific approach (Hill et al. 1902/1963, Sacconi 1972). Stradivari had a traditional master-apprentice relationship with his sons Francesco (1671–1743) and Omobono (1679–1742) and his apprentice, Carlo Bergonzi (1686–1747). Bergonzi had worked with Hieronymus II and Giovanni Battista Guarneri before taking over Stradivari's repair work (Johnson and Courtinall 1999). In Stradivari's last years, his sons helped him make instruments, but their work was not considered to be good as the work he did alone in his golden period.

The Cremonese instrument-making community prospered for about two centuries. Around 1740, and within a few years of each other, however, all of the Cremonese masters died. *Del Gesù* left no heirs. In his testament, Antonio Stradivari declared that his son, Francesco, was his heir and owner of his workshop (Chiesa and Rosengard 1998). When Francesco died, Stradivari's remaining instruments and tools were passed on to his third son, Paolo Stradivari. Stradivari's testament explains that Paolo would not continue in stringed instrument making but would become a textile merchant (a copy of the original testament is in Chiesa and Rosengard 1998, p. 30). Paolo sold his father's remaining instruments to makers (e.g., Giovanni Battista Guadagnini) and collectors and used his father's workshop to sell textiles. On May 4, 1775, he wrote to Giovanni Michele Anselmi—a merchant who purchased on behalf of Ignazio Alessandro, Count Cozio di Salabue, a collector of violins and violin memorabilia:

I would like to give you, without a hitch, all moulds, patterns and tools I have, on condition that they do not stay in Cremona. Remember that I showed you all the tools I have as well as the model-box; in order to do you a favour I will give you all for eight *giliati*.⁴

(Cozio di Salabue's *Carteggio*, reported in Frisoli 1971, pp. 33–34, italics in original)

Financial arrangements were settled, and Paolo sent his father's remaining working materials and tools to Count Cozio di Salabue (Rosengard 2000).⁵ In the same year, he sold his grandfather's remaining instruments (four violins, two violas, and a violoncello) to a priest by the name of Padre Brambilla, for 125 *giliati*. Interestingly, on July 6, 1775, Count Cozio was offered a violin made by Nicolò Amati in 1656 for 40 *giliati*, four times the value of a Stradivari violin at the time (Hill et al. 1902/1963).

4.2. Developments in Musical Composition and Performance

In the 17th century, music for court entertainment became more expressive. In the early 1600s, for example, Claudio Monteverdi (1567–1643) wrote compositions for the Court of Mantua that used stringed instruments not just to provide accompaniment but also to enhance the meaning of words. In the second half of the 17th century, Jean Baptiste Lully's music for French court performances used stringed and other instruments to emphasize the pomp and circumstance or romance and charm of his court tales, ballets, and operas. Church music, too, began to emphasize expressive sound and links to the words of hymns.

The 17th century also saw music developing for different venues around dedicated platforms (e.g., church music, court music, opera music, chamber music). As far as the violin was concerned, Arcangelo Corelli (1653–1713) led developments in Italy. He performed across Europe as a virtuoso before settling in Rome in 1685, where he became a favorite court performer, teacher, and prolific composer (Taruskin 2005). He wrote many sonatas for string ensembles, and his *concerti grossi* allowed soloists to show off their technical virtuosity (Faber 2006, p. 42). Building on the foundations established by Corelli, 18th-century composers further developed music for stringed instruments. In Venice, for example, Vivaldi's (1678–1741) works included over 500 violin concertos; his *Four Seasons* concerto (1725) immediately became popular.

As music became more expressive, the evaluation criteria used to assess stringed instruments also broadened to include not only their physical beauty based on their wood craftsmanship but also the nature of their sound and tone. Although monarchs remained the primary sponsors of music and courts were the main performance venues, instrument assessment became more nuanced. The violins of Jacob Stainer (1617–1683), an Austrian maker, were widely sought-after. Stainer's instruments, like Amati's, were popular because of their craftsmanship—often, they were visually beautiful and elaborately carved. Heinrich Ignaz Franz von Biber, Johann Sebastian Bach, Francesco Maria Veracini, and Wolfgang Amadeus Mozart, for example, all owned and played Stainer violins. In the late 18th century, dealers estimated the value of a Stainer to be four times that of a Stradivari violin (Wechsberg 1973) and on a par with an Amati. Senn and Roy (1986) report that in 1776, a Stainer violin sold for 100 *giliati*, whereas a Stradivari sold in the range of 10–14 *giliati*. In London, a Stainer was sold for £136 in 1791; in contrast, a Stradivari had sold for £14 in 1775 (Hill et al. 1902/1963, pp. 266–269).

During the 1700s, Stradivari's productions "were, so to speak, on their trial; and unquestionably the easier production and lighter character of tone of the Amatis and Stainers, as compared with those of Stradivari,

especially in the earlier years of the existence of the latter, carried the day in favour of Amati and Stainer” (Hill et al. 1902/1963, p. 248). Writer John Hawkins (1776/1875, p. 688; also cited in Hill et al. 1902/1963) said in his *A General History of the Science and Practice of Music* that “the violins of Cremona are exceeded only by those of Stainer, a German, whose instruments are remarkable for a full and piercing tone.” Stainer’s style influenced Italian makers including *del Gesù* and Carlo Bergonzi, and his violins were recognized and popular in Italian courts. Inventories of the instrument holdings of the Medici family of Florence, for instance, show “that the Court was in possession of Stainers prior to 1700” (Hill et al. 1931/1989, p. 33). Charles Burney, a prominent English musical historian, reported that Francesco Veracini (1690–1768), a celebrated Italian violinist who owned and played two Stainer violins, was in a shipwreck and “lost his two famous Stainer violins, thought to have been the best in the world. . . . He used to call one of his violins St. Peter, and the other St. Paul” (Burney 1789, p. 569). While Stradivari and Guarneri were experimenting to improve tone and make louder sound, for the music performed in 18th-century royal courts, the instruments of Amati and Stainer were considered to have just the right tone and loudness.

Around the end of the 18th century, most notable violinists had acquired Stradivari instruments for public performances (Mertzanoff 1943). The period before the French Revolution and then the Napoleonic era heralded “the breakdown of princely and aristocratic patronage. Public concerts became more numerous and varied, concert halls became larger. Many permanent orchestras emerged as concert-giving organizations (London Philharmonic Society, 1813; Berlin Philharmonic, 1826. . .)” (Randel 2003, p. 195). A change “in the musical taste of both England and Germany has taken place and the once proud position held by the Stainer violins has been awarded to the creations of Cremona” (Royal de Forest 1904, p. 70). A letter dated May 4, 1791, says,

I have lately had a sort of fiddle mania upon me, brought on by trying and comparing different Stainers, Cremonas, etc. I believe I have got possession of a sweet Straduari-
us, which I play upon with much more pleasure than my Stainer; partly because the tone is sweeter, mellower, rounder, and partly because the stop is longer. My Stainer is undersized; and on that account less valuable, though the tone is as bright, piercing, and full as that of any Stainer I have ever heard. Yet when I take it up after the Straduari-
us, it sets my teeth on edge. The tone comes out plump all at once. There is a comfortable reserve of tone in the Straduari-
us, and it bears pressure, and you may draw upon it for almost as much tone as you please. I think I shall bring it to town with me, and then you shall hear it. 'Tis a battered, shattered, cracky, ruinous old blackguard. But if every bow that ever crossed its strings from its birth had been sugared instead of resined, more sweetness could not come out of its belly.

(Twining 1882, p. 149)

In the late 18th and early 19th centuries, “composers pursued careers as freelance composers and touring artists rather than holding appointments as court musicians” (Roeder 1994, p. 199), and the Romantic movement, with its focus on individuals, their emotions, and their sensibilities, influenced musical composition and performance. Following Ludwig van Beethoven’s (1770–1827) orchestrations, the concerto soloist “represented this new sense of the individual’s importance in society, and thus gained greater prominence” (Roeder 1994, p. 199), and the cult of the virtuoso emerged (Hebbert 2006). As royal courts withdrew from patronage, public halls became the venues for performance, and value recognition depended increasingly on audiences, critics, and performers. Particularly fine instruments were named, coupling the name of the virtuoso with that of the instrument maker, e.g., the *Viotti Stradivarius*.⁶ A general consensus emerged that the tone and powerful sound of Cremonese stringed instruments, particularly those made by Stradivari and *del Gesù*, were best for public concerts given by virtuosi performers.

There was a significant delay, however, between when the best Cremonese instruments were made in the early 18th century and when their superior sound for concert performance was recognized in the 19th century. Recognition came about because the musical performance context changed, moving from the limited space of royal courts to the extended space of public concert halls. As performers in the 19th century recognized the value of Cremonese instruments, they also recognized that the best instruments had been made over a century earlier. In response, famed 19th-century dealers such as Luigi Tarisio searched across Europe to find Cremonese masterpieces (Berr 1949), even as 19th-century instrument makers also sought to reproduce them. To do so, however, they had to rediscover the tacit knowledge the Cremonese masters had developed.

5. Analysis

5.1. Properties of Units: Reputations of Cremonese Instrument Makers

The conceptual framework of Argote et al. (2003) highlights how the properties of production units (instrument makers and individual workshops) affect knowledge creation, retention, and transfer. Unit reputation and status, in particular, influence these outcomes. A letter written by Fra Fulgenzio Micanzio (a former Galileo student) to Galileo in response to his request for advice on purchasing a violin confirms the enduring price premium associated with the established reputation of Amati workshop instruments. Fra Fulgenzio explains that a Cremonese instrument’s high price is due to its superior craftsmanship.⁷ This recognition facilitated the creation, retention, and transfer of knowledge across several Amati generations and allowed Nicolò Amati to employ a large number of apprentices.

After the Amati workshop closed, many royal courts moved their patronage to Stradivari, who also made beautifully crafted instruments: “Kings, princes, noblemen, the dignitaries of the Church, and the most renowned musicians of the day were among his patrons, and all were unanimous in their testimony to the unsurpassed merit of his productions” (Hill et al. 1902/1963, p. 244). Table 2 lists purchasers of Stradivari instruments, including several monarchs who bought instrument sets for their courts. This order flow confirmed and enhanced Stradivari’s reputation, giving him the financial latitude to conduct tone and sound experiments. In contrast, his contemporary, *del Gesù*, made fewer instruments; they appeared less finished and thus he never received an order from a royal court. Yet there was a close bond between the Stradivari and Guarneri families, and at times, Stradivari helped the Guarneris financially (Hill et al. 1931/1989).

As music developed and became more expressive, performers started buying the instruments they wished to play. By doing so, performers, in addition to buyers

from royal courts, began according recognition within the instrument-making field. One of the first performers to recognize the value of Stradivari’s instruments was Giuseppe Tartini (1692–1770), a pupil of Gasparo Visconti, who in 1726 founded a violin school in Milan that attracted students from across Europe and helped establish the modern style of violin bowing. Tartini owned a 1715 Stradivari violin that became known as the *Lipiński Stradivarius*. Gaetano Pugnani (1731–1798), another eminent 18th-century violinist, owned a *del Gesù* violin and founded a school for violin playing in Turin, where Giovanni Battista Viotti (1755–1824) became his most celebrated pupil. When Viotti performed with a Stradivari violin at the Concert Spirituel in Paris in 1782, his performance was hailed as a sensation. As Viotti gave more public performances in London and Paris, audience acclaim for Stradivari’s instruments grew and became widespread (Hill et al. 1902/1963, p. 257). Viotti was a Stradivari advocate (Stowell 2006, Lister 2009) and had each of his virtuoso students—Pierre Rode, Rodolphe Kreutzer, and

Table 2 Orders to the Stradivari Workshop for Stringed Instruments

- On September 8, 1682, the Venetian banker Michel Monzi ordered from Stradivari a complete set of instruments (violins and a violoncello) to be presented to King James II of England.
- On March 12, 1685, Cardinal Orsini, Archbishop of Benevento, ordered a violoncello and two violins that were sent to the Duke of Natalona in Spain. The Cardinal expressed his appreciation by conferring on Stradivari a title of appointment.
- On September 12, 1685, Bartolomeo Grandi, called il Fassina, first violin at the Court of H.R.H. of Savoy, now King of Sardinia, ordered from him an entire set of instruments for the service of this King.
- On April 5, 1685, a violoncello was ordered by H.R.H. Sovereign of Modena, who wished Stradivari to carry it to him in person to know him by sight.
- On August 22, 1686, Marquis Michele Rodeschini ordered from him a violoncello for the court of Spain.
- On August 7, 1687, D. Agostino Da[ria], a General of the Cavalry of the State of Milan, while he was lodging in Cremona, wished him to make a violoncello for him.
- On September 19, 1690, Stradivari received the following letter from the Marquis Bartolomeo Ariberti, who bought a set of instruments for the Grand Duke of Tuscany, Cosimo de Medici:

“Not many days ago I made the present of the two violins and violoncello to His Highness the Prince of Tuscany, and assure your worthy self that he was so pleased by this gesture, that I could not have wished for more. All the virtuosi gathered in his court are of the same sentiment that they are perfect, but above all else pronouncing that they had never heard a violoncello that was as pleasing and sonorous. Of his Royal Highness, I know not how to express his sense of satisfaction sufficiently. Having brought your work to the attention of a house where it has gained notice of your mastery, you are assured of further commissions. In earnest, I must beg you to commence at once with two violas, that is to say the tenor and contralto, which are lacking, to make the entire concerto” (Pollens 2010, p. 51).

- On May 10, 1701, Stradivari received a letter from Madrid in which Antonio Cavezudo declares that he has never received better instruments than those of Antonio. Because of these instruments he has received further commissions from the court and from many dukedoms, princes, and grandees in Spain. This subject of which is the Maestro di Capella of King Charles II and the present Duke of Anjou.
- On November 10, 1702, the Marquis Giovanni Battista Toralba, General of Cavalry and Governor of Cremona, sent for Stradivari, and, after complimenting him on his peculiar genius, ordered two violins and a violoncello, which were sent as a present to the Duke of Alba.
- In 1707, the Marquis Desiderio Cleri wrote to Stradivari, by order of King Charles III of Spain, from Barcelona, ordering for the royal orchestra six violins, two tenors, and one violoncello.
- On July 17, 1714, Stradivari received a letter from Lorenzo Zustignan di Campiel dei Squellini, a Venetia aristocrat, stating that “on this day there is in the world no more renowned and expert maker of instruments than Stradivari of Cremona” (Pollens 2010, p. 51).
- On June 10, 1715, Jean Baptiste Volumier, Flemish violinist and composer and director of the private orchestra of the King of Poland, a famous patron of music and the arts, arrived in Cremona, by order of the King to await the completion of 12 violins that had been ordered from Stradivari. He remained three months until all the instruments were ready and took them with him to Poland.

Source. Original document appeared in the manuscripts of Don Desiderio Arisi, cited in Pollens 2010, pp. 50–51. See also Hill et al. 1902/1963, pp. 25 and 125.

Pierre Baillot—own and play a Stradivari. Recognition for Stradivari's instruments increased as these virtuosi too gave public concerts.

Although Viotti owned a *del Gesù* made in 1735, *del Gesù*'s reputation is most closely linked to another virtuoso, Niccolò Paganini (1782–1840). According to legend, Paganini lost an Amati violin because of gambling and gained possession of a *del Gesù* violin. This instrument became known as *Il Cannone Guarnerius* because of its power and resonance (Giordano 2004, Polko 1876). When Paganini played it at a Paris concert in the early 19th century, audiences applauded its powerful sonority.⁸ By the mid-19th century, compositions featured the violin as a solo instrument, and many virtuosi were advocates for Stradivari and *del Gesù* instruments. Joseph Joachim (1831–1907), an influential soloist, summarized developments:

While the violins of Maggini are remarkable for volume of tone, and those of Amati for liquidity, none of the celebrated makers exhibited the union of sweetness and power in so pre-eminent a degree as Giuseppe Guarneri [del Gesù] and Antonio Stradivari. If I am to express my own feeling I must pronounce for the latter as my chosen favourite. It is true that in brilliancy and clearness, and even in liquidity, Guarneri, in his best instruments, is not surpassed; but what appears to me peculiar to the tone of Stradivari is a more unlimited capacity for expressing the most varied accents of feeling . . .

(Original letter in Hill et al. 1891, pp. 7–8)

As virtuoso performers recognized the power of Cremonese instruments and played them, musical field members (e.g., audiences, dealers, collectors, and makers) endorsed their choice. At this stage, however, the value producer was no longer the person who made the original instrument, i.e., Stradivari or *del Gesù*. Instead, and as Bourdieu (1993, p. 77) pointed out, it was the new “discoverer” or “creator of the creator” who gained recognition. Specifically, recognition was accorded the virtuosi of the late 18th and 19th century who advocated Stradivari and *del Gesù* instruments. Their authority to gain and accord recognition was itself credit-based, i.e., as virtuosi they had earned their own recognition that they then leveraged to accord recognition to Cremonese instruments. Indeed, for the musical field, they “consecrated” Cremonese stringed instruments as the best for public performance.

5.2. Relationships Between Units: The Cremonese Instrument-Making Community of Practice

Relationships linking production units also shape knowledge outcomes. Both dyadic relationships (e.g., between mentors and apprentices) and connections between units (e.g., relationships between violin-making community members) help explain how instrument-making knowledge was retained and transferred. Indeed, relationships vary along “a set of key dimensions, including intensity

of connection, communication or contact frequency, and social similarity” (Argote et al. 2003, p. 573). Within an apprenticeship system, direct, intense, and frequent interactions between mentor and apprentice effectively transfer knowledge. Knowledge flow is further facilitated as individuals are embedded in a web of third-party connections (e.g., Reagans and McEvily 2003) and as mentors and apprentices belong to a larger community of practice. Indeed, rich communication mechanisms such as face-to-face interactions are capable of “capturing and transferring subtle nuances and tacit knowledge” (Argote 1999, p. 93).

Communities of practice use apprenticeship relationships to create, retain, and transfer knowledge (Lave and Wenger 1991). The apprenticeship relationship encompasses technical knowledge (e.g., how to make a stringed instrument) and knowledge about a profession (i.e., what it means to be a maker of stringed instruments). The apprentices trained in Nicolò Amati's workshop became members of a community of practice that used the same knowledge to make stringed instruments. Apprentices “pass through levels of knowledge acquisition. In trades, one thinks of first apprenticing, then becoming a journeyman, before attaining the status of a master violin maker or plumber” (Swap et al. 2001, p. 101). Most of Nicolò Amati's apprentices lived in his house, and the Amati family's census return for 1650 (reproduced in Hill et al. 1931/1989, p. 7) shows, for example, that Andrea Guarneri, aged 26, was Nicolò's assistant. Daily close contact meant knowledge was not codified and instructions were not written down because apprentices learned from face-to-face mentoring, demonstration, and coaching. Knowledge was communicated orally, and its use was directly observed. After being an apprentice in Stradivari's workshop, Carlo Bergonzi had intimate knowledge of his master's work, and when he took over Stradivari's repair work, he lived next door. Working close to Stradivari's workshop in Cremona's San Domenico square, *del Gesù* would have had “every opportunity of acquainting himself with the greater master's achievements” (Hill et al. 1931/1989, p. 119).

Besides giving them the knowledge needed to become instrument-making experts, an apprenticeship socialized participants into what it meant to be a member of the stringed instrument-making field. Lave and Wenger (1991) call this socialization process *legitimate peripheral participation*, and it is ubiquitous in art and science fields. In her study of Nobel laureates, for example, Zuckerman (1977) discussed the impact of master-apprentice relationships on scientific knowledge development. Laureates generally agreed that the acquisition of substantive knowledge was not the most important part of an apprenticeship—some apprentices knew more than their masters about the literature of their field. The main benefit of an apprenticeship was in becoming aware of the work standards and modes of thought

typical of a field. In particular, an apprenticeship was a period of *socialization* that inducted apprentices into the culture of a knowledge domain. This involved acquiring the norms, standards, values, and attitudes, along with the knowledge, skills, and behaviors associated with the roles and statuses of a field.⁹ The social ties between masters and apprentices are “enduring and consequential, for it is in the course of apprenticeships that young scientists learn the scientific role” (Zuckerman 1977, p. 96). In violin making, an apprentice relationship was a way to learn “work-related knowledge . . . from detailed technical skills and tacit cultural values to career development advice, in a relationship that ideally allows the expert to monitor the degree to which knowledge is actually being absorbed” (DeLong 2004, p. 107; see also Kram 1983).

The Cremonese community of practice was embedded early on in broader Italian and European networks that included royal courts and then later, as music evolved, composers, performers, and others interested in stringed instrument sound and tone. Being embedded in these networks influenced developments in Cremona. For example, the Guarneri family members¹⁰ were either performers or directly interested in instrument sound and tone. While Stradivari was making his instruments, musicians such as Tarquinio Merula, Andrea Zani, and Carlo Zuccari would visit him. He developed a close relationship with the Cremonese violinist Gasparo Visconti and interacted for substantial periods with performers like Jean Baptiste Volumier (1670–1728), a Flemish violinist and composer. Hill et al. (1902/1963) claim that Visconti’s suggestions helped Stradivari. Visconti also contributed to the diffusion of Stradivari’s work when in 1703 he published *Solos for a Violin with Thorough Bass* in London. After learning about Stradivari’s style from Visconti, for example, the prominent English violin maker Daniel Parker reported that he departed from “the orthodox Amati or Stainer models in vogue at the time” (Hill et al. 1931/1989, p. 110).

Members of the community of practice trained in Cremonese methods distributed themselves across Italy’s cultural centers, where they saw and heard how instruments were used in performance. Kane et al. (2005) have shown that in the presence of a shared superordinate social identity, effective knowledge transfer occurs as people doing similar activities rotate between groups. The identity and knowledge base shared by the Cremonese instrument makers would have ensured that given performance needs, they would have adjusted instrument sound and sonority in similar ways. Those who were not part of the community, however, would not have easily understood such innovations. This may partially explain the mythos that began to develop around instrument makers using Cremonese methods.

The Cremonese community of practice relied on master–apprentice relationships to create and pass on knowledge. If a master dies without apprentices, such a death may not only signal the end of the master’s knowledge accumulation process but also the loss of the master’s accumulated knowledge. For instance, when Stradivari died, his sons—Francesco and Omobono—took over their father’s workshop and made violins for a short time before they too died. In contrast, *del Gesù* had no apprentices, and so when he died, there was nobody except possibly his wife to continue his approach based on his knowledge. This is important for knowledge outcomes in contexts where a product is distinctive and production knowledge is largely tacit, as with Cremonese instrument makers. Knowledge retention and transfer may stop if the frequent interactions associated with apprenticeship relationships cease. If members gradually leave (and death might be a reason) or decrease their activity in a community of practice without being replaced by new members, there is a risk that critical knowledge may be lost (Gongla and Rizzuto 2004).

5.3. Properties of Knowledge: The Cremonese Instrument-Making Knowledge Domain

Andrea Amati’s contribution to violin making was the development of an efficient construction method based on a mold. The mold defined the internal profile of an instrument’s body, and the entire instrument was built and assembled around the mold. A mold made a violin maker “capable of precisely and quickly building instruments that were always similar or identical and of making controllable modifications to each new instrument . . .” (Chiesa 2007, p. 12). Although the procedural basis of Amati’s craftsmanship was well known, how he actually made instruments was a secret, and no records describe what he did. Antonio Stradivari did make notes (copies can be found in Sacconi 1972), but these were often scribbles providing just clues about what he did. Knowledge within an apprenticeship system is usually created, retained, and transferred without written records. Cremonese instrument makers were also wary of disclosing their methods because they thought of them as trade secrets that they were reluctant to share with anyone outside of family members (Hill et al. 1931/1989). Andrea Amati, for instance, had no apprentices other than his sons and his grandson Nicolò, son of Girolamo Amati. Following Girolamo’s death in the plague that afflicted Cremona in 1630, Nicolò became sole master of the Amati workshop. As orders for instrument from royal courts continued, Nicolò took on apprentices only because he did not have sufficient sons of his own to satisfy demand (see Table 1).

Knowledge properties also affect knowledge generation, accumulation, and transfer (Argote et al. 2003, Winter 1987). If knowledge is explicit, one can use words or symbols to record the information to be stored,

copied, or transferred. In contrast, the interdependencies between stringed instrument parts generate sound and tone puzzles that instrument makers then resolve with tacit knowledge. They do not record or transfer this tacit knowledge for no formula “can describe the all-important quality of each element, each piece of wood that comes together to make a violin” (Wali 2010, p. 31). Rather, such tacit knowledge is a matter of experience and intuition, artistry, and craftsmanship.

In the early 18th century, Stradivari, Guarneri, and other Cremonese makers experimented to improve tone and strengthen instrument sound, leading to novel variations in stringed instrument making. At the time, only a small number of performers valued their efforts. When public concerts became the norm, however, performers wanted to play such instruments. In 1786, the Bolognese violin maker Giovanni Antonio Marchi (1727–1807) described the situation:

The outlines I have seen by such masters [as Jacob Stainer, Nicolò Amati, Francesco Ruggieri, and Bartolomeo Giuseppe Guarneri] were not only very beautiful, but they were also extraordinarily proportioned, and I think no one will be able to do better.... Owing to the carelessness in outlining modern violins I can only rail against [their makers] until they do their utmost to outline an instrument not only by taking into account the right size, but also the form itself that pleases our eyes and serves our ends as well.... There have been violin makers who have outlined their violins as if they were outlining a shoe. (Marchi 1786, pp. 29–30)

In the 19th century, when the value of Cremonese instruments for public performance was widely recognized, instrument makers grappled with how to reproduce Cremonese instruments. In the 19th and 20th centuries, Cremonese instruments were made subject to scientific study using acoustical measurement and physical experiments in order to develop explanations for how these instruments generated their sonorous tone and powerful sound (for a comprehensive discussion, see Wali 2010).¹¹

Know-why Knowledge. One theory of why Cremonese instruments sound as they do relates to the wood used and the minimal tree growth that occurred during the Maunder Minimum/Little Ice Age from 1645 to 1715. Climate changes in the late 17th century caused trees to grow uniformly in summer and winter and thus create the dense growth rings and renowned wood quality of Stradivari’s instruments (Burckle and Grissino-Mayer 2003). Limited tree growth improved wood quality and so could influence instrument sound. In addition, the minerals found embedded in instrument wood suggested that it might have been immersed in a mineral salt solution. Researchers speculate that Stradivari and others used wood preservatives to affect sound quality. Using nuclear magnetic resonance and

infrared spectroscopy, Nagyvary et al. (2006, p. 565) concluded that “the wood used by the masters could indeed have been chemically treated.” However, the high concentration of mineral salt in Stradivari’s violins might also reflect the fact that the wood was rafted from the mountains to the plains. As Stradivari often used logs rejected by the Venetian navy, his wood might well have been soaked in seawater. Or Cremonese luthiers could have deliberately placed their wood in salt solutions.

An instrument’s varnish is another variable that influences tone and sound. Fry (1904, p. 32) says that whether “the quality of varnish applied to the wood of which violins... are constructed has any decided influence on their tone, must be... answered in the affirmative.” Similarly, Hill et al. (1902/1963, p. 179) stress how “the future of any perfectly constructed instrument is determined by the coat it is clothed in. Fine varnish will not compensate for bad material or faulty construction; but that it makes or mars the perfectly formed instrument is, in our opinion, beyond dispute.” They point out that while Stradivari’s apprentice, Carlo Bergonzi, followed his master’s construction principles, his varnish was like that used by *del Gesù*, “and consequently the tone of his violins more resembles that of this master’s works” (1902/1963, p. 180).¹² Jean Baptiste Vuillaume (1798–1875), the renowned French instrument maker, spent his career replicating Cremonese construction principles and making and trading such instruments (Hill et al. 1902/1963). In varnishing his violins, however, he did all of them the same way whether they were copies of Stradivari, Guarneri, or Amati. As a result, the tonal quality of his replicas varies little. In general, varnish affects instrument tone but does not change sound strength. Rather, its effect “is to damp vibrations, and because its main function is to form a hard protective layer over the exterior of the instrument, it is highly implausible that any varnish could selectively damp very high frequencies” (Hsieh 2004, p. 34). Furthermore, ultraviolet photography indicates that most Stradivari and Guarneri violins today do not have their original varnish but have been recoated with modern varnishes. There is a lack of expert consensus for explaining instrument sound strength, although the wood receives more credit than the varnish. Indeed, a scientific approach based on the impact of isolated variables may simply demonstrate how too many potentially influential variables are in play to work out which ones constitute the critical causal relationships.

Know-how Knowledge. In contrast to the emphasis on materials and acoustical science, Simone Fernando Sacconi (1895–1973), an Italian instrument maker and restorer, describes how Stradivari made his instruments. Sacconi (1972) based his analyses on Stradivari’s molds, drawings, sketches, templates, and the notes originally given by Paolo Stradivari to Count Cozio di Salabue

and now housed in the civic museum of Cremona. His analysis is also based on his personal experience repairing approximately 350 Stradivari instruments. By combining study of Stradivari's plans, sketches, and molds with his own knowledge of Stradivari's finished products, Sacconi reconstructs how Stradivari made his instruments and how, through his notes, he consciously directed his "learning-by-doing" process. Sacconi believes Stradivari's intuitions led him to experiments and findings consistent with the principles of modern acoustical physics. He reports that the craftsmanship typical of Stradivari's instruments is similar to that achieved by the Amati workshop. Stradivari's experiments, however, were directed toward building instruments with a more sonorous and powerful tone. Sacconi describes Stradivari's work routines to justify his claim that there are no secrets about how Stradivari built his instruments (Sacconi 1972, p. 189). Sacconi learned Stradivari's work processes, but this does not mean he acquired Stradivari's tacit knowledge. Like Vuillaume, who also repaired and reproduced many Stradivari instruments, Sacconi did not have the face-to-face interactions that masters use to transfer tacit knowledge, and Stradivari's molds, drawings, sketches, templates, and notes are imperfect substitutes.

5.4. Recognition and Conditions Supporting Knowledge Outcomes

Knowledge outcome continuity was critical for Cremonese instrument making. Interruptions constituted a challenge to the retaining and transferring of such knowledge—whether tacit or explicit—and this challenge increased as the elapsed time before resurrection attempts began increased. Whereas classic learning curve studies assume knowledge accumulates and persists indefinitely, empirical studies demonstrate that this is not so (e.g., Dutton and Thomas 1984, Yelle 1979). Knowledge depreciates as a result of disuse, and interruptions disrupt knowledge transfer and workflow (Argote et al. 1990, Argote and Eppe 1990, Seshadri and Shapira 2001). When production "was resumed after an interruption at a manufacturing firm such as a strike, unit cost was higher than the level achieved before the interruption" (Argote 1999, p. 36). Recent experience is "a more important predictor of current productivity than experience in the distant past" (Argote 1999, p. 61). Although the cost of recovering explicit knowledge is just the time it takes to return to previous productivity levels, the cost of interruptions to the use of retained tacit knowledge can be the loss of the knowledge itself.

The likelihood of knowledge loss increases as individuals become the repositories for knowledge. If knowledge is embedded in organizational structures and technologies, in contrast, it "is more resistant to depreciation and more easily transferred than knowledge embedded in individuals" (Argote 1999, p. 93). To the

extent that individuals are the knowledge repositories, turnover also hinders organizational memory, especially as it involves skilled workers performing unstructured tasks (Nelson and Winter 1982, Argote 1999) or using difficult-to-codify tacit knowledge (Polanyi 1962, Winter 1987). The fact that knowledge cannot only depreciate but also be lost after interruptions may help explain why attempts to resurrect the Stradivari and Guarneri instrument-making traditions have not succeeded. The attempts by instrument makers like Vuillaume to resurrect Cremonese masters' knowledge occurred, for example, around a century after these makers had done their best work.

An advantage of a community of practice is that at a master's death, the loss of his knowledge is not inevitable if his apprentices have learned it and continue his art, or if other community members have interacted with him and learned his methods.¹³ As MacKenzie and Spinardi (1995, p. 46, italics in original) noted, "Barring social catastrophe, explicit knowledge, if widely diffused and stored, cannot be lost. Tacit knowledge, however, *can* be lost. Skills, if not practiced, decay. If there is no new generation of practitioners to whom tacit knowledge can be transmitted it may die out altogether." Tacit knowledge recovery "cannot simply be a matter of copying the original, because there is no sufficient set of explicit information or instructions to follow" (MacKenzie and Spinardi 1995, p. 46). In fact, one must actually reinvent lost tacit knowledge because its transmission "is not done through the medium of the written word" (Collins 1974, p. 177).

The essence of a superb instrument depends not just on how it looks or sounds but also on how it feels to play. This suggests that instrument-making knowledge cannot be ascertained by focusing on separate instrument parts—the bow, bridge, scroll, purfling, wood, or varnish, for example. In reverse-engineering efforts, one must also consider the interrelationships that characterize these interdependent parts that affect sound, tone, and feel. Stradivari attempted to deal with the myriad of possible relationships by keeping notes to help make decisions. Scientific study has also enhanced understanding of how "the violin works, how each component works, and how we can develop theoretical models" (Wali 2010, p. 71), but replication attempts focusing on instrument parts neglect holistic effects. A violin has a holistic aesthetic that defies "literal" replication. This holistic aesthetic reflects the instrument maker's tacit knowledge about stringed instrument making.

Masters transmitted their holistic, tacit knowledge to apprentices through intense daily interactions. Only after years would apprentices absorb their master's knowledge and grasp the interdependencies between the interrelated parts of a stringed instrument and how to manage these interrelationships. As knowledge was passed on to apprentices, a master's tacit knowledge could be

preserved and survive his death. Stradivari and the various members of the Guarneri family, for instance, built upon and developed Amati's methods to enhance sound and tone, and they knew each other's work and the methods each used. Andrea Amati's violin-making methods and techniques also survived his death because his apprentices knew them and continued to apply them. Although the death of a master meant the loss of his unique knowledge, his knowledge would only be truly lost if the broader Cremonese violin-making community would dissipate.

This did, in fact, occur. After the mid-18th century, violin making ceased to be an activity patronized by the wealthy, i.e., monarchs, noblemen, and clergy (Hill et al. 1931/1989). At this time, however, many fine instruments were already in circulation, and many skilled instrument makers lived in France, Germany, England, Spain, the Tyrol, and elsewhere. From about 1700 on,

all these countries were producing instruments that sufficed amply for the average musician, with the result that overproduction (rather than underproduction) was becoming the order of the day. Italian violins of a cheaper kind were however still in request; for the majority of players could as yet have gained no deep understanding of the lasting merits of instruments made by the great Cremonese of the past. (Hill et al. 1931/1989, p. 150)

As violins with superior tonal qualities were not commanding higher prices, however, experimentation dropped. By 1750, violin making in Cremona had also halted even as later efforts by Cremonese violin makers such as Lorenzo Storioni (1744–1816) and his followers (e.g., Giovanni Battista Ceruti (1756–1817)) sought to revive it. Born shortly after Stradivari and after *del Gesù* had died, Storioni and his followers faced the challenge of resurrecting the Cremonese masters' tradition, particularly their tacit knowledge. Because they had no direct link to the Cremonese masters, they had to "reinvent" stringed instrument making in Cremona (Rosengard 1992). Indeed, their experiences further illustrate how interruptions compound the challenge of retaining and transferring knowledge with how this challenge increases with the elapsed time before resurrection attempts begin.

Between 1750 and 1800, as the members of the Cremonese violin-making community died and its apprenticed descendants closed their workshops, the knowledge they had accumulated for making stringed instruments dissipated.¹⁴ In other parts of Europe in the late 18th and early 19th centuries, musical fields and tastes continued to evolve. Increasingly across Europe, public audiences replaced the royal courts, and virtuosi playing in concert halls reported their "discovery" of the powerful Cremonese instruments. Through the 19th century, then, Cremonese instruments received increasing recognition and acclaim.

6. Discussion

We have related how the field of Cremonese stringed instrument making evolved to the Argote et al. (2003) conceptual framework describing knowledge management processes and to Csíkszentmihályi's (1996, 1999) description of how a field accords recognition to cultural products. We identified events that enabled instrument makers in Cremona to gain early recognition. Because Nicolò Amati took over his father's workshop and took on apprentices from outside the family, a unique feature of the Cremonese community was that many of the new masters apprenticed with the same master—Nicolò Amati. Another result was that the same basic knowledge was embedded within the community, and later generations used this knowledge as a benchmark to imitate and improve upon. Particularly when Stradivari and *del Gesù* were active, experiments occurred across the community to improve tone and generate more powerful sound.

Our study extends Argote et al. (2003) by highlighting the impact of changing evaluations over time on the conditions supporting the creation, retention, and transfer of knowledge within the Cremonese community of practice. Specifically, although apprenticeship relationships effectively generated and passed on knowledge, the accumulation, retention, and transfer of knowledge depended on a continuing flow of resources to support the direct, intense and frequent interactions between a master and his apprentices. When for whatever reason the continuity of the master-apprentice relationship was interrupted, knowledge transfer was in jeopardy because instrument-making knowledge was based on direct, face-to-face daily interactions. As masters also wanted to protect their secrets, they did not codify their knowledge, increasing their community of practice's dependence on individuals. Only apprentices could observe how the master worked, the wood he picked out, how he treated and molded it, how he combined varnish ingredients, etc. Stringed instrument sound and tonal quality depended on how an instrument's interdependent components were developed and combined, and Cremonese masters explored many possibilities. No formula sets out these interdependencies or how to manage them. This was the master's tacit knowledge. A community can mitigate the consequences of relationship interruptions if it can function as a knowledge repository. For instance, Antonio Stradivari and Andrea Guarneri were both apprenticed to Nicolò Amati and contributed to the preservation and further refinement of his methods and techniques, even though his workshop ended shortly after his death. When the community itself disappears, however, the knowledge embedded in it is also necessarily lost, as was the case with the death of most of the Cremonese instrument makers by the mid-1750s (see Table 1).

Our analysis also shows how broader contextual developments change evaluations and how the resulting recognition impacts the conditions that support knowledge management processes. In the case of Cremonese building methods, royal courts provided positive recognition early on for the visual beauty of the craftsmanship used to make stringed instruments. In contrast, the recognition for the experiments by Stradivari and *del Gesù* to improve tone and strengthen sound was limited initially to a small group of Italian virtuosi and performance students. Broad recognition came later when performance moved from royal courts to public concert halls and after virtuosi had proclaimed the value of Cremonese instruments and audiences confirmed their views.

Recognition is critical because it determines whether the individuals who produce cultural products will get the resources they need to continue their work, directly affecting the conditions shaping knowledge outcomes. Recognition seen as a resource-mobilizing process shifts attention away from the idea that cultural products are mostly an individual creation as, at one level, they probably were for Stradivari and *del Gesù*. The later recognition granted to Stradivari and *del Gesù* instruments reflects a collective process, however, as do the efforts of virtuosi “discoverers” to persuade public audiences. Earlier, Stradivari’s relentless experimentation was facilitated as a result of his superb wood craftsmanship, enabling visually beautiful instruments that ensured a steady flow of instrument orders from royal courts. *Del Gesù*, in contrast, did not make visually beautiful instruments and did not enjoy an associated resource flow—in fact, he was much less productive than Stradivari (Hill et al. 1931/1989). As the broader music field evolved, stringed instruments that were once played only in royal courts or churches were played increasingly in public concert halls for larger, secular audiences. This evolution helped music free itself from aristocratic and ecclesiastical tutelage and the aesthetic and normative demands of these institutions. Stradivari’s experiments led to beautiful instruments with powerful sound, anticipating the movement toward artistic autonomy that emerged at the end of the 18th century and accelerated in the 19th century. Expressive developments in the evolving musical field coupled with interruptions to the transfer of the tacit knowledge associated with Cremonese methods eventually led to the consecration of Cremonese instruments as unique pieces of art in the 20th century.

Although royal courts early on recognized the visual craftsmanship of Cremonese violins, few recognized the value of experiments to improve tone and make more powerful sound. At the beginning of the 19th century, and as virtuosi performed in public concert halls across Europe, the broader European musical field learned of and recognized the excellence of Cremonese instruments, and demand thus increased for the surviving

instrument inventory. Also during the 19th century, audiences found more expressive music increasingly appealing, and performers playing Cremonese instruments gained recognition. Given that most virtuoso performers wanted to build reputation, they had a strong incentive to play on an instrument made by a famous Cremonese grand master rather than an excellent, modern instrument made by a little-known contemporary. Instrument dealers also emerged as a new expert role that evaluated stringed instruments, assigned monetary value to them, and pursued trade in them. They also favored instruments made by Cremonese masters.

Our analysis has also revealed a lack of synchronization between the time when the value of the powerful sound of Cremonese instruments was recognized by musical field participants, and the earlier time when those instruments were actually made, and the knowledge to make them was developed and available. If the recognition accorded cultural products is not synchronous with their production and so recognition is delayed, the resources needed to support the continuity of knowledge outcomes may not be forthcoming. Even as the value of Cremonese instruments was eventually recognized, a concomitant concern was that the knowledge to make them had in the interim been lost. When tacit knowledge is lost, its recovery requires that it be reinvented, and this becomes more difficult as the time increases before attempts are made to resurrect it (Collins 1974, MacKenzie and Spinardi 1995). Today, we know how Cremonese instruments sound and in part why they sound as they do. We do not know how to make them exactly as Stradivari or *del Gesù* did because these masters’ tacit knowledge was not passed down directly and so has been lost.

7. Conclusion

This study has clarified how changing evaluation criteria reflecting changed performance venues and delayed value recognition are key determinants of the ever-increasing prices of Cremonese instruments. The reason is that the time elapsing between the production of cultural products and their final recognition significantly affects the conditions that support the creation, retention, and transfer of the tacit knowledge needed to make them. Focusing on delayed recognition suggests that value attribution calls for a careful consideration of evaluations in the broader environment and whether they recognize the long-term value of specific types of knowledge, thus ensuring support for organizations that generate such knowledge.

The dynamic underlying the value determinants of Cremonese stringed instruments may also occur in other cultural fields such as art, theatre, music, film, and photography, as well as in craft and design industries such as food preparation and fashion, where task knowledge

is gained through apprenticeships. A key feature of these fields is that “symbolic and aesthetic attributes are at the very core of value creation” (DeFilippi et al. 2007, p. 512; see also Lampel et al. 2000). This implies that the value attributed to cultural products depends largely on third parties, such as critics, dealers, foundations, and users (Hirsch 1972, Wijnberg and Gemser 2000). For instance, Escoffier’s *Guide Culinaire* (1903) established classical French cuisine for training chefs. Escoffier saw classical cuisine as a “codified grammar of culinary practice: a product can be cooked in different ways, served with different sauces, and accompanied with different fillings” (Rao et al. 2003, p. 800, italics in original). Nouvelle cuisine, in contrast, stresses the chef’s role as innovator and creator. It emphasizes tacit knowledge in terms of transgressions (e.g., old cooking techniques with new ingredients or new cooking techniques with old ingredients) and acclimatization (e.g., importing “exotic” foreign cuisine traditions like seasonings and spices) in cooking knowledge that are transmitted to apprentices via learning-by-doing processes rather than in a codified grammar for culinary practice. Representing the selective processes of the broader culinary field, the *Michelin Guide* assigns stars to outstanding restaurants and lists three signature dishes for each selected chef. The fate of a restaurant depends on the chef’s knowledge, the presence of apprentices to whom this knowledge can be passed, and the recognition of the *Michelin Guide*’s critics who award a chef’s restaurant more or fewer stars on behalf of the broader culinary field. As in nouvelle cuisine, knowledge is not often codified or written down and may be lost if a chef’s restaurant does not receive prompt critical recognition—and this may also be a necessary condition for attracting apprentices.

Although the knowledge management literature has identified conditions affecting knowledge outcomes, it can benefit from explicitly considering how value attributions in broader environments shape the value accorded to creative work and the continuity of knowledge outcomes. In this sense, the study extends the Argote et al. (2003) conceptual framework by showing how time, particularly delayed recognition, can be an important factor affecting the value of cultural products. To understand value determination processes, one must consider how evaluations evolve over time and impact the conditions supporting knowledge outcomes continuity. If evaluations do not fully recognize the potential value of a cultural product when it is being produced, the associated knowledge—especially tacit knowledge—may be lost rather than passed on. By jeopardizing subsequent reproduction attempts, loss of knowledge can become a primary determinant of a product’s ever-increasing value over time. The proposition we made in §2 talked about the effect of delayed value recognition on tacit knowledge loss. The industries mentioned above

provide very good settings for empirically testing the proposition in future research.

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Endnotes

¹BBC News (2006) reports, for example, that Christie’s auctioned a Stradivari violin (the *Hammer Stradivarius*) for around \$3.5 million, and the *New York Times* (Wakin 2009) reports that a *del Gesù* violin (the *ex-Kochanski*) was sold privately for around \$10 million. Bloomberg News (Majendie and Bennett 2011) reports that the *Lady Blunt Stradivarius* fetched \$15.9 million at Tarisio’s Auction House in London.

²Two years separated by a slash represent the original date and modern edition date of publication, respectively. Page numbers reflect the modern edition.

³The monogram JHS stands for the Greek abbreviation of Jesus, or *Gesù* in Italian. As Hill et al. (1931/1989, p. 71) explain, the practice of “inscribing this monogram on private and public buildings . . . was very prevalent in the north of Italy in the fifteenth, sixteenth, and seventeenth centuries . . .”

⁴A *gigliati* is a Tuscan gold coin.

⁵As Nicolò Amati’s apprentices set up their workshops, Cremonese methods for stringed instrument making diffused across Italy. For example, in 1664, Giovanni Battista Rogieri went to Brescia. There, he combined his craftsmanship learned from Nicolò Amati with Brescian instrument-making traditions emphasizing sound and tone performance and became one of Brescia’s leading instrument makers. After apprenticing with Nicolò Amati, Bartolomeo Pasta (circa 1640–1685) moved to Milan, where he opened a workshop. When he went to the Court of Mantua in 1683, Pietro Guarneri (1635–1720) introduced Cremonese methods, and his nephew, also called Pietro Guarneri (1695–1762), contributed in a similar way when he went to Venice in 1717. Before Pietro’s arrival, “the use of an internal mold for the building of instruments, which was a trademark of the Cremona tradition, was not a consolidated technique in Venice . . .” (Pio 2004, p. 214); after his arrival, many Venetian makers adopted Cremonese methods. Alessandro Gagliano worked in the workshops of Nicolò Amati and Antonio Stradivari, and after returning to Naples around 1700, he founded the Neapolitan school of instrument making. In these various ways, Cremonese instrument making diffused across Italy.

⁶The *Viotti Stradivarius* was purchased by the Royal Academy of Music for GB£3.5 million in September 2005.

⁷“Concerning the violin which your nephew on passing through here wished to buy, I have spoken to the Musical Director of the Concerts of St. Mark’s . . . who tells me that I can easily find Brescian violins, but that those of Cremona are incomparably better—in fact, they represent the *non*

plus ultra/... The difference in the price will show you the superiority, for those of Cremona cost at the lowest /twelve ducats/ each, whilst the others (Brescian) can be had for less than /four ducats/..." (Hill et al. 1902/1963, p. 241).

⁸Hill et al. (1931/1989, p. 121) write further, "Though the fascination of Paganini's playing added greatly to the reputation of *del Gesù*, in that it centred public attention on the maker's violins, a stronger proof of their intrinsic merits is afforded... by the many other soloists of eminence who have them the instruments of their choice. Simultaneously with the great virtuoso, Mayseder, Pixis, Lipinski, and Rovelli were performing on them; and subsequently Mori, David, Saint-Leon, Alard, Sainton, Carrodus, Vieuxtemps, Wieniawski, and Bazzini all became exponents of the Guaneri tone."

⁹A Nobel laureate in chemistry noted, "It's the contact: seeing how they operate, how they think, how they go about things. [Not the specific knowledge?] Not at all. It's learning a style of thinking, I guess. Certainly not the specific knowledge; at least not in the case of Lawrence. There were always people around who knew more than he did. It wasn't that. It was a method of work that really got things done" (Zuckerman 1977, p. 122).

¹⁰Pietro Guarneri joined the Mantuan Court Orchestra in 1680, and in 1690, the Duke of Mantua appointed him Master of the Violins of the Court. The appointment warrant says, "Wishing to avail Ourselves of the services and the virtuoso's talents of Pietro Guarneri and taking into account his upright conduct and great skill in playing the violin, we are pleased to honour him by conferring on him our Warrant of Appointment, by virtue of which we elect, and promote him to be Our Master of Violins..." (reproduced in Hill et al. 1931/1989, p. 30).

¹¹The existence of acoustical differences between the violins made by Stradivari and *del Gesù* and contemporary violins was demonstrated in a series of experiments by Heinrich Dönnwald, a German violin maker. He compared the waveforms of 10 Cremonese violins made by Stradivari and *del Gesù* with two control groups, one made up of 10 violins built by modern craftsmen and one made up of 10 factory-made violins (Dönnwald 1991). His results showed that the characteristic sound of Cremonese violins reflected the selective amplification of several identifiable harmonics. More recent double-blind tests (Fritz et al. 2012) confirmed that performers could not distinguish between Stradivari and *del Gesù* violins and new violins, though these particular experiments were conducted in a hotel room with dry acoustics rather than in a concert hall where historically the superiority of Cremonese instruments for solo performance was recognized. As a result, it is just not clear whether or how these and other tests could resolve the issue of whether a modern replica of a Stradivari or a *del Gesù* instrument may or may not have very similar sound and tonal qualities to the 300-year old original.

¹²"Again, take the violins of J. B. Guadagnini and the finer specimens of the various members of the Gagliano family. They are constructed on the principles of Stradivari, the material used is in many cases acoustically equal, yet they have by no means the same character of tone as a Stradivari. And why? Because their varnish and their methods of applying it were in most cases very different" (Hill et al. 1902/1963, p. 180).

¹³Preserving Stradivari's or *del Gesù*'s methods and techniques is but a necessary condition for replicating their instruments, as their unique skills cannot be replicated.

¹⁴Demand for stringed instruments in northern Italy dropped significantly during the second half of the 18th century. From the 1750s until the end of the century, northern Italy endured several wars that created widespread hardship. As the French and Austrians went back and forth conquering northern Italy, they dismantled the social and economic structure. The nobles and royal houses lost power, and the French and the Austrians imposed heavy taxes on the conquered populations to pay for their wars (Rosengard 1992). Also at this time, the pope suppressed the Jesuit fathers whose educational institutions had been major patrons for instrument makers. Elite performers and performance training schools continued to support the use of Stradivari and *del Gesù* instruments, but the broader market for more expensive stringed instruments with improved tone and strengthened sound essentially evaporated. In addition to the death of several Cremonese masters, all these events combined to end the Cremonese community.

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