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The Diffusion of New Institutions: Evidence from Renaissance Venice's Patent System

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The Diffusion of New Institutions: Evidence from Renaissance Venice's Patent System

Abstract

What factors affect the diffusion of new economic institutions? This paper examines this question exploiting the introduction of the first regularized patent system which appeared in the Venetian Republic in 1474. We begin by developing a model which links patenting activity of craft guilds with provisions in their statutes. The model predicts that guild statutes that are more effective at preventing outsider's entry and at mitigating price competition lead to less patenting. We test this prediction on a new dataset which combines detailed information on craft guilds and patents in the Venetian Republic during the Renaissance. We find a negative association between patenting activity and guild statutory norms which strongly restrict entry and price competition. We show that guilds which originated from medieval religious confraternities were more likely to regulate entry and competition, and that the effect on patenting is robust to instrumenting guild statutes with their quasi-exogenous religious origin. We also find that patenting was more widespread among guilds geographically distant from Venice, and among guilds in cities with lower political connection which we measure exploiting a new database on noble families and their marriages with members of the great council. Our analysis suggests that local economic and political conditions may have a substantial impact on the diffusion of new economic institutions.

JEL-Codes: O330, O340, K230.

Keywords: patents, competition, guilds, institutions.

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1 Introduction

The social, economic, legal, and political organization of a society, its ‘institutions’, is a primary determinant of economic growth (Acemoglu and Johnson, 2005). The impact of new economic institutions - such as novel forms of contracts or property rights – depends on the rate at which they are adopted and displace older institutions (Acemoglu et al., 2005). The development literature has identified a variety of factors that explain the international diffusion of new institutions, such as human capital (Glaeser et al., 2004), culture (Tabellini, 2010), and geography (Ashraf and Galor, 2011). On top of these macro variables, the rate of adoption of novel economic institutions is also likely to be affected by local conditions - such as industry composition or the presence of elites - which vary at a much narrower geographical level, such as a region or a city. The empirical evidence on the role of these micro-level factors is scarce.

In this paper, we aim to address this gap by studying the pattern of local diffusion of one of the main economic institutions that governments use to increase innovation incentives and spur economic growth: patent rights. Patents provide temporary monopoly rights over a new technology that generate rents to the innovator and support private contracting. The innovation literature has documented a large variation in the rate of patenting across industries and in the perceived effectiveness of patents across firms (Levin et al., 1987; Cohen, Nelson, and Walsh, 2000). These findings have typically been interpreted as suggesting that the social and economic value provided by intellectual property rights is highly heterogeneous. Understanding the roots of this heterogeneity - i.e., why some inventors choose to heavily rely on patents and why others do not - is essential for the design of patent policies. If, for example, a substantial share of innovation occurs in industries in which patents do not play an important role, policies that strengthen intellectual property rights may do little to raise the overall level of innovation (Machlup and Penrose, 1950; Moser, 2012). Similarly, when only a few industries rely heavily on patent rights, changes in patent policies may dramatically affect the direction of technical change (Moser, 2005). Finally, if the effects of patent rights are highly heterogeneous across firms and industries, it is likely that a one-size-fits-all patent system, like the one currently in place, is second best (Acemoglu and Akcigit, 2012).

This paper provides new insights into the determinants of patenting activity, exploiting the introduction of the first regularized patent system, which appeared during the Renaissance in the Venetian Republic. In 1474 the Venetian Senate passed a patent act that regulated the granting of patents for novelty, ingenuity, and utility. The dominant view among patent

law historians is that this act established an administrative-centered system, strikingly similar to the modern Anglo-American system (Merges and Duffy, 2013). Therefore, the patents awarded in the late fifteenth century in the Venetian Republic provide a unique opportunity to study the diffusion of a drastically new form of property rights. This is not common in the innovation literature, where most studies typically examine marginal changes of pre-existing patent rights (Hall and Harhoff, 2012). Moreover, the historical nature of our data is useful in understanding whether heterogeneity in the use of patents is persistent over time, or is a more recent phenomenon linked to modern technology trends.

We begin our analysis with a simple theoretical model that describes the patenting decision of inventors at the time of the Venetian Republic. The theoretical framework highlights two key differences between the modern patent regime and the Venetian system. First, Venetian patents provided not only the negative rights to exclude through monopoly power, but also the positive rights to enter into craft guilds for innovators that were not guild members (Mandich, 1948; Sichelman and O'Connor, 2012). Second, guilds had the power to oppose and block patent applications (Berveglieri, 1995;1999; Trivellato, 2008). We show that the interplay of these two features implies that the level of patenting can vary substantially across guilds, and that this is true both for guild members and for outside inventors. More specifically, the model shows that the level of patenting in a technology area is strongly related to the ability of guild statutes to prevent entry of outsiders and to mitigate competition among members. Greater statutory restrictions allow guild members to extract high rents, and this increases their incentives to prevent patenting by other members and external innovators.

Our empirical analysis exploits a new dataset which combines information on the patents granted by the Venetian Senate with detailed digitized data on craft guilds operating in the cities of the Venetian Republic. Our sample comprises 340 guilds of the Venetian Republic whose statutes have been examined and coded by a team of Italian historians as part of a research project financed by the Italian Ministry for Education, Universities and Research.

The main findings are as follows. First, we show a strong negative association between patenting in the technology sector of a guild and the presence of statutory rules which strongly limit entry and competition. Results are robust to including controls for city and guild characteristics, and to using alternative econometric models. A variety of placebo tests show that only restrictions to entry and competition are correlated to patenting and no other provisions in guild statutes.

To address the concern of unobserved heterogeneity, we exploit as instrumental variable the religious origin of some of the guilds in our sample. A number of the guilds in Northern Italy originated from medieval religious confraternities formed a couple of centuries before the patent act. The history literature suggests that establishment of these confraternities was driven by idiosyncratic reasons related to the local success of religious movements in the 13th century (Mackenney, 1994). To confirm the quasi-exogenous nature of this variable, we show that it is orthogonal to many observable guild characteristics such as industry, location and a variety of statutory rules. At the same time, religious origin is a strong predictor for statutory provisions restricting entry and competition. This is because religious confraternities followed strict rules regulating members' admission and interaction, and such rules often inspired guild statutes (Mackenney, 1994). The instrumental variable analysis confirms the negative relationship between patenting and the strength of guilds' statutes.

Our second finding is that patenting was more frequent for guilds located in cities geographically distant from Venice. This suggests that patents were particularly beneficial for non-elite inventors with limited access to political power (Khan, 2005). To study this issue in more detail, we construct a measure of political connection exploiting a unique database of Venetian nobility and marriages between patrician families and members of the Great Council. We find that guilds located in cities with less political connection were more likely to patent their technologies, supporting the idea that politically connected guilds could substitute intellectual property rights with other forms of formal and informal protection.

Taken together, our findings suggest that local economic and political conditions may have a substantial impact on the diffusion of new economic institutions.

Our analysis is connected to the economic history literature on the role of craft guilds. A common view is that medieval craft guilds were technophobic (North, 1981). Recent studies provide a more nuanced view, recognizing that some guilds were much more receptive to novelties and technological advances than others (Epstein, 2004). In her analysis of the Venetian silk and glass production, Trivellato (2008) emphasizes the crucial role of intra-guild interactions and argues that experimentation took place only when statutory norms were not too restrictive. Our findings are consistent with Trivellato's thesis, and highlight a link between guild statutes and technology management.

While there is a growing theoretical literature examining the economics of guilds (inter alia see Greif et al., 1994; de la Croix et al., 2016; Greif and Tabellini, 2017), one of the diffi-

culties in studying these institutions is the lack of comprehensive data. Our paper contributes to this line of research and introduces a novel dataset, which may also prove useful for future research.

Our paper is also related to studies that investigate the effects of occupational licensing. Kleiner (2000) provides a survey of the literature. Persico (2015) develops a theory showing how internal politics of a licensing association can lead to expansion of the licensure. Our analysis illustrates how occupational licensing and self-regulation may interact with the diffusion of new economic institutions. The role of internal rules and how they influence technology adoption is also the focus of Bridgman (2015), who studies why unions may favor restrictive work regulations and how these regulations may induce resistance to technology adoption. Finally, our paper adds to the literature on the relationship between competition and innovation (Aghion et al., 2005; Cohen, 2010). Our findings suggest that market power may affect not only the level of innovation but also the propensity to rely on patent protection.

The paper is organized as follows. Section 2 provides a brief description of the origin and functioning of the Venetian patent system. Section 3 develops a model showing the link between guild statutory norms and patenting. Section 4 describes the data and discusses the econometric specification. Section 5 presents the empirical results. Concluding remarks briefly summarize the findings and their implications.

2 Renaissance Venice and its patent system

This section provides a brief historical overview of the Venetian Republic between the fifteenth and sixteenth century, and illustrates the main features of the 1474 patent act.

2.1 The Venetian Republic in the 15th and 16th centuries

During the period of our study, the ‘Serenissima’ Republic of Venice was one of the largest regional economies of Renaissance Europe. Its center was the maritime city of Venice with roughly 150,000 inhabitants at the end of the 16th century, about half of the population of north-east Italy at that time (Costantini, 1987). The Venetian state included the ‘Terraferma’ dominion, a compact and densely populated area which included large cities such as Verona and Vicenza. Figure 1 (from Knapton, 2013) illustrates the state boundaries around the period of our study. A number of additional cities in the Greek peninsula and in South-East Europe, such as Corfu, Andros, and Cyprus were also under the control of the Venetian Republic and were

instrumental ports for long-distance trade between Western Europe and the Levant (Borelli, 1980).

The Venetian Republic was based on a careful balance of power that originated as an attempt to restrain the power of a single person or governing body and led to remarkable political stability (Lane 1973). Membership in the main governing institutions was precluded to lower classes, such as artisans and shopkeepers. Moreover, following the ‘Serrata’ (closure) in 1297, political functions were restricted to a hereditary nobility that had the exclusive right to sit in the great council, the legislative assembly of the Republic. Because of the large size of the great council, most legislative functions were delegated to the senate, a smaller assembly (about 300 senators) elected by the great council (Borelli, 1980). Some members of the senate had the right of legislative initiative (‘metter parte’), others were only entitled to vote (‘metter ballotta’). Among the senators entitled both to vote and to propose new laws, there were three ‘Provveditori di Comun’ who also oversaw transport infrastructures and mercantile trade (Borelli, 1980; Zaggia, 2004; Di Stefano, 2011). The doge was the personal embodiment of the Republic, it was elected by a committee of 41 nobles chosen by the great council. In 1474 the doge was Nicolo’ Marcello, and eleven doges took office between 1474 and 1550 (Rendina, 1984).

At the time of our study, the main threat to Venice’s trade supremacy and the preservation of its economic power was the Ottoman Empire, which was expanding dramatically under the leadership of sultan Selim I (Borelli, 1980). Moreover, the 1492 discovery of America started shifting the center of long-distance trade away from the Mediterranean toward the Atlantic.

The economy of the capital was driven by the vast trading activity in spices, dying materials, silk, cotton, slaves, and precious metals (Pezzolo, 2013). On top of this vibrant trade, artisan production also flourished both in Venice and in Terraferma. The Arsenal was one of the largest industrial sites in Europe, and glassmaking was among the most prestigious urban occupations at the time (Trivellato, 2008). The mainland was marked by a lively wool and silk production (Demo, 2013).

Merchants and craftsmen were organized in guilds, self-governed organizations that controlled various aspects of economic activity. Guild statutes prescribed technical characteristics of products and regulated entry, apprenticeship, and competition (Belfanti, 2004). The Venetian government fostered guild membership for fiscal reasons, and about 20 percent of

the population of the city of Venice belonged to a guild.¹ Guild members were excluded from government, but the Venetian constitution guaranteed them the right of judicial appeal against the government and guild officers (Lane, 1973).

2.2 The 1474 patent act

On March 19, 1474 the Venetian senate passed by a large majority a ‘parte’ (act) regulating the granting of patents. While there is evidence that a small number of ad-hoc privileges for new inventions and mineral extraction were granted by the Venetian government before this act (only five patents according to Mandich, 1936), the parte of 1474 is the very first law regulating the patent application and granting process, and has been recognized by numerous historians and law scholars as the legal foundation of the modern patent system (inter alia see Mandich 1948; Duffy, 2007; Golden, 2013).

The act indicates that patent applications (or ‘suppliche’) were to be filed with the Provveditori di Comun and the patents (or ‘privative’) were typically granted after senatorial approval (Berveglieri, 1995). The subject matter to be patented was required to be a “new and ingenious device” and the effect of a patent was to stop “every other person in any of our territories and towns to make any further device conforming with and similar to said one without the consent and license of the author” (Mandich, 1948). The novelty content was evaluated on the basis of the technical knowledge available in the Venetian dominion, implying that a patent could be granted to products or processes already in use elsewhere (Molà, 2014). The patentee was required to implement the invention (‘messa in opera’) within a specified period of time. In cases where the patentee failed to use the device, the patent was revoked (Berveglieri, 1995).²

There are three main features of the Venetian patent system that are central to our analysis. First, patents could be granted to all inventors regardless of their citizenship status or guild membership. Thus, patents were both ‘negative’ rights to exclude but also ‘positive’ rights to practice the invention and operate in industries controlled by guilds (Mandich, 1948; and Sichelman and O’ Connor, 2012). For example, Florentine inventor Cosmo Scatini was granted a patent for high quality black silk dyeing, which permitted him to enroll in the dyer’s

¹This share remained stable, with minor fluctuations, from the 16th century until 1797, the end of the Venetian state (Costantini, 1987).

²The act established a patent length of 10 years, but it was common for applicants to request longer protection. Mandich (1936) describes cases in which patent rights lasted 25 and even 70 years.

guild of Venice (Belfanti, 2004).

Second, guilds were often involved in the patent granting decision process, through the evaluation of the novelty content of the application. This examination involved, most of the time, a test of the new product or process (the ‘*esperienza*’) to verify, before granting the patent, whether the invention was actually working. Trivellato (2008) describes the opposition of the Venetian silk spinners’ guild to the patent application of Iseppo Giovan Perin Mattiazzo for a new hydraulic mill for spinning and throwing silk.³

Third, patent holders were expected to share the technology with guild members through the payment of an appropriate licensing fee. Such a licensing requirement is often mentioned in the patent records, without specifying the precise amount but requesting a “discrete sum” of money for the transfer or payment of an “adequate reward” (Belveglieri, 1995).

While a number of historians have examined the administrative details of the Venetian patent system and collected detailed information on patent records, very few studies have addressed the question of why the senate passed the patent act in 1474. Lane (1973) and May (2002) suggest that the growing economic and trading power of the Ottoman empire and Antwerp led Venetian policy makers to focus on industrial activities. Berveglieri (1995, 1999) and Belfanti (2004) emphasize the goal of attracting foreign inventors to the Venetian Republic to compensate for the lost supremacy of Venetian guilds in various industrial sectors.⁴ Mandich (1936) suggests that successful experimentation with monopolies in mineral rights may have led Venetian authorities to legislate on patent rights.

3 Theoretical model

In this section, we develop a simple theoretical model to describe patenting incentives in the Venetian Republic and to examine the effects of guild statutes on firms’ intellectual property strategies.

3.1 Set-up

Consider an industry with three firms and two periods $t = 1, 2$. Two firms belong to a guild, while the third one is an outsider. In the absence of innovation, guild members sell a standard

³Molà (2000) reports a number of other opposition cases, such as the 1583 spinning machine patent of Urbano Bonturelli and the 1597 silk bleaching patent of Giacomo di Bianchi and Innocente Soardo.

⁴There is a growing literature which exploits historical data to study the relationship between immigration flows, growth, and innovative activities (Akcigit et al., 2017a; Akcigit et al., 2017b).

product to consumers. The surplus created by the standard product is π per period. We assume that the guild can appropriate a fraction $\alpha(\theta)$ of this surplus, with $\alpha'(\theta) > 0$. The appropriated surplus is shared equally among guild members. The parameter θ captures the strength of the guild's internal statute, with a larger value of θ indicating larger collusive power among the members, which allows greater profit extraction.

At $t = 1$, one of the firms develops an innovation that increases the surplus to $\pi + \Delta$ per period. Innovations are distributed with cumulative distribution $F(\Delta)$ with support $[0, \infty]$. To patent the innovation costs c and patent protection lasts for one period. The patent grants the innovator the right to extract the full surplus for the period. The patent holder negotiates licensing deals with the other guild members by making take-it-or-leave-it offers to them. At $t = 2$, once the patent has expired the technology becomes freely available to all guild members.

The outsider firm cannot enter the guild without an innovation. Entry is guaranteed if the outsider firm obtains a patent. If it innovates but does not apply for a patent, entry occurs with probability $\beta(\theta)$ with $\beta'(\theta) < 0$, which captures the idea that the stronger guild statutes are, the more difficult it is for an outsider to enter.

Before a patent is granted, each guild member can oppose the patent application by paying an opposition cost, κ . If the patent is opposed, the technology is appropriated and shared among all the guild members during both periods. If the patent of the outsider is opposed, entry to the guild is blocked as well.

We solve the game by backward induction, starting from the opposition decision. We distinguish two cases, depending on whether the innovation is developed by a guild member or by the outsider firm. For simplicity, we set $\alpha(\theta) = \theta$ and $\beta(\theta) = 1 - \theta$ (we relax this assumption in section 3.4). We also assume that $\pi > 3c$ to focus on the cases in which the cost of obtaining a patent is not too large relative to the baseline surplus.

3.2 Innovation by a guild member

We first focus on the case in which the inventor is a guild member. Suppose that the innovator applies for a patent and consider the incentives of the other guild member to oppose it. If opposition takes place, the technology is shared between the two firms for two periods. Therefore, by choosing to oppose the patent, the guild member obtains $\theta(\pi + \Delta)/2$ per period, net of the opposition cost, κ .

If the patent is not opposed, the innovation is freely shared among guild members only in the second period, once the patent has expired. In the first period, the patentee and the

other guild member negotiate a licensing deal and the licensee obtains $\theta\pi/2$, i.e., the status quo profits in the absence of innovation.⁵ Therefore, opposition is profitable if

$$\theta(\pi + \Delta) - \kappa > \frac{\theta\pi}{2} + \frac{\theta(\pi + \Delta)}{2}$$

which is satisfied if

$$\Delta > \widehat{\Delta}(\theta) = \frac{2}{\theta}\kappa.$$

Notice that $\frac{d\widehat{\Delta}(\theta)}{d\theta} < 0$, which implies that guild members block patents of other guild members more often as the strength of the internal statute increases.

Consider now the innovator's choice of whether to apply for a patent or not. Clearly, if it anticipates that there will be opposition (i.e., $\Delta > \widehat{\Delta}(\theta)$), then patenting is not profitable. Hence, applying for a patent may be beneficial only when there is no opposition (when $\Delta \leq \widehat{\Delta}(\theta)$). In this case the profits of the patentee are equal to

$$\pi + \Delta - \frac{\theta\pi}{2} + \frac{\theta(\pi + \Delta)}{2} - c.$$

Specifically, in the first period, patent protection allows the firm to extract the full surplus $\pi + \Delta$. At the same time, the licensing negotiation with the other member implies that $\theta\pi/2$ is transferred through licensing. At $t = 2$, once the patent has expired, the total surplus guild members appropriate reduces to $\theta(\pi + \Delta)$, and each of them obtains half of it. When choosing not to patent, the innovator obtains $\theta(\pi + \Delta)/2$ in each period because the technology is shared starting from $t = 1$. Therefore, patenting is more profitable than not patenting only if

$$\pi + \Delta - \frac{\theta\pi}{2} + \frac{\theta(\pi + \Delta)}{2} - c > \theta(\pi + \Delta)$$

or

$$\Delta > \widetilde{\Delta}(\theta) = \frac{2}{2 - \theta}(c - \pi(1 - \theta)).$$

Notice that $\widetilde{\Delta}(\theta) > 0$ only if θ is large enough. Moreover, $\frac{d\widetilde{\Delta}(\theta)}{d\theta} > 0$, which implies that as the strength of the internal statute increases guild members patent only their more valuable innovations, i.e., the propensity to patent decreases in θ .

The above discussion implies that the likelihood of patenting goes down as the strength of the statute increases because guild members are less likely to apply for a patent and more

⁵The implicit assumption here is that in case of disagreement the innovation is not implemented for one period until the patent is expired, so that each firm gets $\theta\pi/2$. Results are robust to considering alternative outside options, as we discuss in section 3.4.

likely to block patents of other members. Formally, patenting occurs when $\Delta \in [\tilde{\Delta}(\theta), \hat{\Delta}(\theta)]$ with a probability equal to

$$P(\theta) = F(\hat{\Delta}(\theta)) - F(\tilde{\Delta}(\theta))$$

which decreases in θ .

3.3 Innovation by an external innovator

Suppose now that the inventor is the outsider firm and consider the opposition decision. By opposing the patent, a guild member prevents entry of the outsider and shares the technology with the other guild member from $t = 1$, obtaining $\theta(\pi + \Delta)/2$ per period net of opposition cost, κ . Without opposition, a guild member receives a payoff of $\theta\pi/2$ for one period (net of paid licensing fees) and shares the technology with the other two firms (the other guild member and the external innovator) in the second period. Therefore, opposing the patent is more profitable than accommodating entry if

$$2\theta \frac{(\pi + \Delta)}{2} - \kappa > \frac{\pi}{2}\theta + \frac{\theta(\pi + \Delta)}{3}$$

or

$$\Delta > \hat{\Delta}_E(\theta) = \frac{3}{2\theta} \left(\kappa - \frac{\pi}{6}\theta \right).$$

One can easily check that $\hat{\Delta}_E(\theta)$ is decreasing in θ , i.e., opposition is more likely with high θ .⁶

Similar to what happens with an internal innovator, patenting is profitable for the outsider only when there is no opposition (when $\Delta \leq \hat{\Delta}_E(\theta)$). In this case, by patenting, the external innovator obtains

$$\pi + \Delta - \theta\pi + \frac{\theta(\pi + \Delta)}{3} - c.$$

In the first period, the innovator extracts the full surplus and strikes licensing deals with the guild members, offering $\theta\pi/2$ to each of them. In the second period, the innovation is shared among the three firms. Without a patent, the external innovator enters the guild with probability $1 - \theta$ and the technology is immediately shared with the guild members. Therefore, patenting is more profitable than entering without patent if

⁶For simplicity, our focus here is on pure strategy Nash equilibria between the guild members. Similar predictions are obtained: (i) in a model in which guild members cooperatively decide whether or not to oppose the outsider's patent, (ii) in a symmetric mixed-strategy Nash equilibrium in which each guild member opposes the outsider's patent with probability p .

$$\pi + \Delta - \theta\pi + \frac{\theta(\pi + \Delta)}{3} - c > (1 - \theta)\frac{2\theta(\pi + \Delta)}{3}$$

which occurs if

$$\Delta > \tilde{\Delta}_E(\theta) = \frac{3c - 3\pi + 4\pi\theta - 2\pi\theta^2}{3 - \theta + 2\theta^2}.$$

One can easily check that, when $\pi > 3c$, $\tilde{\Delta}_E(\theta) < 0$ for each θ , which implies that, absent opposition, the external innovator always patents, no matter the strength of the guild statutes.⁷ Intuitively, for low values of θ , patenting is beneficial because the innovator appropriates a large share of the profits generated by the innovation during the first period. When θ is large, patenting is useful to overcome the difficulties of being admitted to the guild.

Therefore, conditional on the outsider innovating, the likelihood of patenting is

$$P(\theta) = F(\hat{\Delta}_E(\theta))$$

which is also decreasing in θ .

3.4 Discussion

Our simple model illustrates how the propensity to patent in a technology area is affected by the strength of the statutes of the guilds operating in the field. As the strength of the statute increases, the collusive power of a guild goes up, and the value of the monopoly rent generated by the patent decreases. Thus, strong statutes reduce the patenting incentives of guild members. Moreover, statute strength allows guild members to extract high rents from the technologies that they appropriate through patent opposition. This implies that, in the presence of strong statutes, patents by guild and non-guild members are more likely to be opposed. Together, these two effects generate the testable prediction that patenting activity is likely to be less prominent in technology fields in which guilds have strong statutes.

The model builds on a number of assumptions that are worthy of additional discussion. First, to obtain a closed form threshold for the patenting and opposition strategies we set the impact that guild statutes have on rent sharing and entry equal to $\alpha(\theta) = \theta$ and $\beta(\theta) = 1 - \theta$. In the appendix, we show that the main predictions are robust to considering more general functions $\alpha(\theta)$ and $\beta(\theta)$. Specifically, we show that our comparative statics hold under mild assumptions on these functions and derive a sufficient condition that generalizes our main

⁷ Assumption $\pi > 3c$ implies that $\tilde{\Delta}_E(0) = (3c - 3\pi)/3 < 0$, $\tilde{\Delta}_E(1) = (3c - \pi)/4 < 0$ and $\frac{d\tilde{\Delta}_E(\theta)}{d\theta} > 0$.

results. Second, our baseline setting assumes that the patentee has full bargaining power during the licensing negotiations and that it can appropriate the whole surplus of the innovation (while the other guild members obtain the status-quo profits $\theta\pi/2$). In the appendix, we relax this assumption and study a more general set-up in which the surplus is shared through Nash bargaining. We show that our main results are robust, as long as the bargaining power of the patentee is not too small. Finally, our model assumes that opposition cannot be avoided through side payments from the patentee to guild members. In the appendix we extend our setting and allow patentees to negotiate with incumbents to avoid opposition, and we show that also in this case patenting is less likely for larger values of θ .

A feature of the Venetian patent system highlighted in our model is the opportunity for guild members to oppose patent applications. This resembles modern administrative processes at the European and United States patent offices (Harhoff and Reitzig, 2004; Hall and Harhoff, 2004). Our simple model suggests that these opposition systems may have a variety of effects on entry and patenting behavior. On the one hand, opposition allows incumbent firms to screen out inefficient patenting by external innovators (i.e., technologies with $\Delta < c$). On the other hand, opposition allows non-innovating incumbents to protect their short- and long-term rents, which creates an incentive to block entry and oppose efficient technologies. This trade-off suggests that a well-designed opposition system needs to balance screening and rent-preservation incentives.

4 Data and methods

Our empirical analysis combines data on craft guilds active in the Venetian Republic during the Renaissance with information on the patents granted by the Venetian senate during this period.

Our main source of data on craft guilds is the dataset ‘Istituzioni Corporative, Gruppi Professionali e Forme Associative del Lavoro nell’Italia Moderna e Contemporanea’ (Istituzioni Corporative, henceforth) which is the outcome of a research project financed by the Italian Ministry for Education, Universities and Research involving a variety of leading history departments across multiple Italian universities. The goal of the project was to release a dataset with detailed information on the universe of Italian guilds for the period 1400-1700.⁸

⁸The researchers start from the sample of 73 Italian cities with more than 10,000 inhabitants in 1300, and successfully retrieve information on guilds for 50 of these cities (no data were available for smaller cities in southern Italy, where the economy was predominantly based on agriculture). The final dataset comprises more

Key variables include the name of each guild, the time period of its activity, and its geographical location. The data provide a detailed description of the manufacturing operations and trading activities of each guild. The dataset also reports a variety of indicators related to the internal organization of the guild, such as the presence of restrictions to market competition or the existence of a structured apprenticeship system.

Our analysis focuses on 340 craft guilds identified in Istituzioni Corporative as active in the Venetian Republic before 1600. Costantini (1987) estimates that at the end of the 16th century Venetian guilds included about 34,000 members, which was roughly 20 percent of the population and about half of the economically active labor force. The guilds in our sample capture a large fraction of the European economic activity at that time, because Venice was the third largest city in Europe and a leading international trading center (Pezzolo, 2013).

The books by Berveglieri (1995, 1999) are our main data sources on Venetian patents, as they report information on the patent rights granted by the senate and retrieved from the state Archives of Venice. Berveglieri's work extends previous research by Mandich (1936, 1948), who classified and translated into modern Italian 109 Venetian patents for the period 1474-1550. For the same period, Berveglieri (1995) identifies 169 patents. Appendix Table A1 shows the technological breakdown of these patents: mills account for roughly half of the inventions, followed by drainage devices (11 percent), and hydraulic pumps (7 percent).

We manually match guilds with patents, exploiting the description of each guild's manufacturing operations provided in Istituzioni Cooperative and the patent technology classification provided in Berveglieri (1995).

The main variables used in the empirical analysis are described below.

Patents. This is the endogenous variable in the analysis. It captures the number of patents granted by the Venetian senate from 1474 to 1550 in the primary technological field of the guild. While Berveglieri (1995) reports patents for a longer period, our main analysis focuses on patenting for the period 1474-1550 to avoid the 1575-76 plague, which had a profound impact on the Venetian economy. Pezzolo (2013) documents the large demographic effects of the plague, with an estimated decrease in population of between 15 and 26 percent.

Guided by the work of historians, we construct a variable capturing the strength of guild statutes. A number of statutes in our sample include restrictions on competition, such as price

than 1,000 guilds active in Italy during the period 1400-1700. Guilds for which researchers were not able to retrieve enough information are missing from the sample -these are likely to be smaller institutions of little economic importance. A comprehensive description (in Italian) of the data is provided in Moiola (2004).

fixing, minimum distance between workshops (‘botteghe’) or a ban on serving customers of other guild members. Granting privileges to sons and sons-in-law of members was a typical way to restrict entry of local potential competitors (Moioli, 2004). In some cases, such as the goldsmith guild of Venice, entry was completely precluded to those who were not descendents of guild members. In other statutes, entry fees or exams were required for those who were not sons of guild members. To preclude the entry of foreigners, various statutes included additional provisions targeting all foreigners, or specific ethnic groups. This leads us to generate the following variable.

Strong internal regulation. This dummy variable is equal to one if the guild has internal rules that: (i) limit competition among the members, (ii) grant privileges to sons of guild members, and (iii) restrict entry rights of foreigners.

It is likely that all guilds operating in the Venetian Republic adopted some formal or informal restriction to limit competition and entry. Thus, one has to interpret *Strong internal regulation* as capturing guilds for which historians have identified statutory provisions that are more severe than those of other guilds in the sample.⁹

We now introduce some of the other control variables to be used in our empirical analysis.

Distance to Venice. This variable captures the distance (in kms) between the city of the guild and Venice. We construct this measure by exploiting a variety of historical maps describing the most important transportation routes in the Venetian Republic in the period of our study. These include the ‘Atlantic Map’ of the state Archive of Venice and various maps in Lanaro Sartori (1985) illustrating trade routes in the Venetian Republic.¹⁰

Trade Guild. This dummy equals one for guilds that are only involved in trade and not in manufacturing. Roughly 46 percent of the guilds in our sample are trade guilds.

Guild Members. This information is available only for 169 guilds. On average, guilds in our sample have 164 members (with median equal to 48 and a standard deviation of 392).

Table 1 provides summary statistics and illustrates the geographical distribution of the guilds in our sample across the main cities of the Venetian Republic. On average, there are 1.47

⁹Unfortunately, the Istituzioni Corporative dataset describes the exact statutory provision for only a small subset of guilds. For most guilds the information is available only as a dummy (i.e., restriction to competition? Y/N; Privileges to sons? Y/N, etc...). This is the main reason why our empirical analysis exploits these binary variables.

¹⁰Our results are robust to using the modern road network (from Google maps, excluding highways) as an alternative source of distance. The correlation between the two distance measures is very high because of the historical nature of the Italian road system (with many roads built during the Roman Empire).

patents in the main technology field in which a guild operates, with a standard deviation of roughly 5 patents. About 21 percent of the guilds in our data have strong internal regulation. Roughly 50 percent of the guilds are located in Venice. Verona, Padua, and Brescia are the cities with more guilds in the mainland (Terraferma).

4.1 Econometric specification

Building on the theoretical analysis of Section 3, our main econometric model focuses on the relationship between our measure of patenting, $Patents_{ij}$, related to guild i located in city j and the indicator for the strength of internal regulation of the guild. We typically model the conditional expectation of patenting activity as

$$E(Patents_{ij}) = \exp(\alpha \text{Strong internal regulation}_{ij} + \beta x_{ij} + \gamma_j)$$

where x_{ij} is a vector of guild-specific control variables and γ_j is a city-specific idiosyncratic effect. The log-link formulation is appropriate in our setting because of the non-negative and highly skewed nature of our count-based dependent variable.

Following a long-standing tradition in the economics of innovation literature (Hausman et al., 1984), we estimate this model via Poisson, with robust standard errors to account for over-dispersion. Consistency of the Poisson estimates is guaranteed as long as the mean of the dependent variable is correctly specified (Gourieroux et al, 1984).

The coefficient α captures the relationship between statutory provisions restricting entry and competition and patenting in the technology area of the guild. When $\alpha < 0$ strong statutes are associated with lower patenting, which is the prediction of our theoretical model. A finding of $\alpha = 0$ would indicate that statutory clauses generating market power are not associated with patenting in the technology area. When $\alpha > 0$ we would conclude that patenting is more frequent in technology areas in which guilds have strong statutes.

We want to emphasize that α should not be interpreted as a relationship between innovation and statutory clauses. This is because the novelty content of the patents was evaluated on the basis of the knowledge available in the Venetian dominion and patents could involve technologies already available elsewhere (Molà, 2014). Moreover, historians have documented substantial innovation activity by guilds for which we observe little patenting, such as the Arsenal or Murano’s glassblowers (Caniato, 1996; Trivellato, 2008). Thus, α speaks more to the propensity to use intellectual property rights to protect technologies (i.e., to adopt the new institution) than to the propensity to innovate and develop new technologies. We leave for

future research an examination of the effect of Venetian patents on city growth and innovation investments.

5 Empirical results

Table 2 provides the first set of results. The regressions show a strong negative association between the patents granted in the technology field of a guild and the strength of its internal rules. All regressions include a control for trade guilds, which indicates substantially lower patenting activity for this type of organization. In column 2 we control for the geographic distance between the city in which a guild is located and Venice. The likelihood of patenting increases with the distance from Venice, and the coefficient on internal regulation remains stable. Column 3 shows that the relationship between guild statute strength and patenting is robust to the inclusion of city fixed effects. Exponentiation of the coefficient implies that patenting is roughly 65 percent lower when guilds adopt strong internal regulation. In column 4 we show that results are similar when we control for the number of guild members, even if this restricts the analysis to a much smaller sample. The coefficient on the number of members is positive (but statistically insignificant), suggesting that patenting is more frequent in technology fields where guilds are larger.¹¹

Overall, the results in Table 2 document a negative correlation between patenting and statutory provisions limiting entry and competition, which is consistent with our theoretical model. We perform a variety of additional empirical tests to confirm the robustness of this finding. First, we show that the estimates of the strength of internal regulation and of geographical distance are unaffected once we include additional controls for city characteristics. In column 1 of appendix Table A2 we show robustness to the inclusion of controls for the size of the city measured with population in 1300, 1400, and 1500 (data from Malanima, 1998). Interestingly, population controls do not appear to explain much of the variance in patenting activity, suggesting that the number of patents is not simply driven by city size. In a model with city effects, column 2 of Table A2 shows that the negative correlation between strength of the statute and patenting is robust to including a variety of additional controls for guild characteristics, such as the age of the guild (in 1600) and a dummy for the presence of an apprenticeship

¹¹In unreported regressions we capture guilds with a large number of members with a dummy variable equal to one if the number of members is above the top quintile (180 members). In such specifications the dummy is positive and statistically significant at the 0.1 level, supporting the idea that patenting is more likely in fields where guilds have many members.

system.¹² The regression also includes industry effects for guilds in agriculture, construction, and textile. In column 3 of Table A2 we show that results also hold when we expand the time period, considering the patenting activity (in the main technology field) up to 1600. Column 4 shows that results are robust including a dummy for guilds whose operations require the use of mills. While the magnitude of the coefficient on *Strong internal regulation* drops by about one quarter, the correlation remains negative and statistically significant, indicating that our results are not exclusively driven by patents related to mills.

In unreported regressions we also confirm that results are robust if we use an alternative (less restrictive) mapping between guilds and patent technology sectors. More precisely, we construct a new dependent variable imputing to each guild patents in the two technology sectors that are closer to the guild activity. In a second set of unreported tests, we confirm the robustness of our main findings to estimating alternative econometric specifications, such as OLS and a linear probability model for the presence of at least one patent for the guild. We also show that results are robust to dropping from the sample the guilds located in Venice, as well as to dropping trade guilds.¹³

There is the concern that the effect of statutory norms on patenting is not driven by specific provisions related to entry and competition, but by other statutory rules. Specifically, the reader may worry that *Strong internal regulation* simply captures statutes that are very detailed, and that some other rule in these statutes may affect patenting more than those related to entry and competition. To address this concern, we perform a number of placebo tests, constructing variables that identify statutes containing detailed regulations of guilds, activities not directly related to entry and competition. For example, in column 5 of Table A2 the variable *Placebo* equals one if the statute includes: (i) a list of manufacturing activities precluded to women, (ii) the name of the guild's patron saint, and (iii) a description of the hierarchical structure of the guild. The coefficient on this variable is positive, statistically insignificant, and

¹²De la Croix et al (2016) discuss how apprenticeship was a key determinant of knowledge transfer and economic growth in Medieval cities.

¹³We also run a regression that separately includes dummies for each of the three components of the strong guild variable (i.e., limits to competition, privileges to offspring of the guild members, and limits to foreign members). All coefficients are insignificant and we cannot reject that they are equal to each other. Including the strong guild indicator together with the three dummies also leads to insignificant coefficients for the three individual components, but a negative and statistically significant effect for strong guild, with a magnitude similar to the one in our baseline regression. Moreover, dropping one of the components of the strong guild dummy leads to insignificant coefficients, but we cannot reject that they are equal to our baseline coefficient. These robustness checks suggest that it is not only one feature of the statute that drives the effect and that only guild statutes with detailed rules on all three features correlate with lower patenting.

small in magnitude. We obtain similar estimates (positive, small, and statistically insignificant) with alternative placebo tests that exploit various combinations of the above variables and other statutory clauses, such as the presence of an apprenticeship system, or of technical restrictions on the quality of the products. These findings support the idea that patenting propensity is strongly related to provisions in guild statutes restricting entry and competition, but not to other statutory rules.

One may also be concerned about changes in statutory clauses over time. Two things need to be noted here. First, Istituzioni Corporative typically relies on documents that are contemporaneous with the patent act (Moioli, 2004). Second, historians have emphasized how changes in guild statutes over time typically led to lower entry barriers and greater competition (Costantini, 1987). This implies that in constructing *Strong internal regulation* we are more likely to classify as strong, statutes that are not strong, and that measurement error will bias our estimates toward zero. While the dataset provides information on whether the statute of a guild changes over time, we do not know the exact clauses that are affected by the change, which precludes us from using the longitudinal nature of the data. Nonetheless, we exploit this information to perform robustness tests. Specifically, we identify statutes that changed during the period 1474-1550. In roughly 81 percent of the sample there was no statutory change during the time period, for about 18 percent of the guilds the statute was changed once, and for the remaining 1 percent it was changed twice. In column 6 of Table A2 we show that our baseline estimates are robust to dropping guilds that change their statutes during our sample period. The coefficient is roughly 15 percent larger than our baseline, confirming the idea that measurement error biases our estimates toward zero.¹⁴

We turn next to two extensions that are of independent interest.

First, we examine whether the determinants of patenting differ between local and foreign inventors. We obtain information on the origin of the inventor from Berveglieri (1995) that shows that only 6.5 percent of the patents in the sample were granted to foreign inventors. Columns 1 to 4 of Table 3 show statistically significant associations between geographical distance and strength of internal rules for patenting both of local and of foreign inventors. The magnitude of these correlations is much smaller for foreign inventors. Nonetheless, our estimates show that the characteristics of the city and the guild seem to affect patenting propensity of

¹⁴We confirm this result in regressions: (i) that include a control for statutory changes, and (ii) consider changes over different time windows.

inventors independently of their origin. It is possible to reconcile the larger magnitude of the effect for local inventors with our theoretical model. In fact, under standard assumptions on the distribution of the parameter Δ (e.g. uniform, exponential, etc.) the derivative of the probability of patenting with respect to θ has a smaller magnitude for external innovators than for guild members.¹⁵

Second, we examine the relationship between statutory clauses and patenting, exploiting a different source of patent data. Specifically, rather than matching guilds and patents using the data and the technology classification of Berveglieri (1995, 1999), we construct a new dependent variable that relies on the patents collected and described by Mandich (1936). Interestingly, this smaller sample also includes information on the geographical scope of patent rights. Even though the wording of the 1474 act indicates that patents were enforceable in the entire dominion, about 12 percent of the patents described in Mandich (1936) appear enforceable only in specific locations (e.g. only in Venice or other specific cities). We use this information to construct an alternative measure of patenting that imputes patents with limited geographical scope only to the guilds located in the relevant cities. Columns 5 and 6 show that our results on the geographical distance and on the strength of internal rules are robust to exploiting this alternative data source.

5.1 Instrumenting guild's regulation strength

Our analysis has shown a strong negative association between the strength of a guild's internal rules and patenting in the technology area in which the guild operates, which is consistent with the predictions of our theoretical framework. We have documented robustness of this finding in a variety of specifications that include city effects and control for several guild characteristics. But still, to interpret this result causally is challenging, because unobservable variables may be correlated both with *Strong internal regulation* and with patenting.

In particular, there are two alternative explanations that need to be addressed. First, guilds with strong statutes may be more likely to operate in technology areas in which secrecy can be used more effectively and there is less need for patents. Specifically, the concern is that *Strong internal regulation* is spuriously correlated with low information leakages, which would imply that our estimates do not capture the effect of statutory clauses restricting market power.

¹⁵Following Berveglieri (1995), we refer to an inventor as foreign if he is not Italian. Results are similar if we extend the definition to non-members of the Venetian Republic (about 20 percent of patents were held by foreign inventors with this definition).

Our industry controls partially address this concern, because information leakages are likely to be similar for guilds operating within the same industry. Moreover, one would expect guilds facing high information leakages to be more likely to adopt clauses to restrict entry, which would generate a positive rather than a negative correlation between patenting and *Strong internal regulation*.¹⁶

Second, the 1474 patent act may have been introduced as a response to technology shocks affecting guilds without strong statutes, or as a political move to curb the power of stronger guilds. There are two reasons why we think this is unlikely. First, one would expect the Venetian government to react to technology shocks in specific industries with targeted policies rather than with a one-size-fits-all patent act affecting all the guilds in the dominion (we describe examples of such targeted policies in section 5.2). Second, senatorial records show that the act passed with a very large majority (116 votes in favor, 10 against, and 3 abstentions), which is inconsistent with a politically contentious act harming powerful guilds (Berveglieri, 1995).

Addressing these issues and other unobservable heterogeneity concerns more constructively requires an instrumental variable correlated with the presence of statutory norms restricting entry and competition and uncorrelated with patenting strategies. In this section, we propose an instrument that relies on the religious origin of some of the guilds in our sample.

A number of the guilds active in the Venetian Republic during the Renaissance find their origin in religious confraternities that arose from the spread of the Flagellant movement during the 13th century. A confraternity (also called ‘scola’ or ‘fratalea’) was an association of lay people driven by Christian devotion and works of charity (Gasparini, 1987). While people from all social classes could join a confraternity, most of the members were craftsmen. Confraternity members were required to follow rules and bylaws in exchange for help in times of hardship and the security of a good funeral (Monticolo, 1896; Pullan, 1971).

During the 14th and 15th centuries the Venetian government promoted the formation of craft and trade guilds as a way to collect tax revenue and to recruit soldiers, and this led members of confraternities to set up craft guilds linked to the various confraternities (Constantini, 1987; Gasparini, 1987). For example, in Venice the guild of ironmongers was connected to the confraternity of San Lorenzo, fishermen with that of San Nicolò, and goldsmiths with San

¹⁶At the time of our study, knowledge circulation was closely linked with circulation of people, and enforcement of trade secrets required restrictions to guild access and cooperation between members. Therefore, in our model one can interpret the larger surplus appropriation from an increase in θ as capturing both greater market power and lower information leakage.

Mattio's (Mackenney, 1994).¹⁷

Istituzioni Corporative shows that roughly 30 percent of the guilds in our sample originated from a religious confraternity. There is no clear pattern linking the religious origin of guilds with their geographic location or their industry. For example, the barbers' guild in Verona originated from a confraternity, but none of the barber guilds in the other cities in the sample have religious origins. Similarly, the blacksmiths' guild of Udine is linked to a confraternity, whereas those of Padua, Venice and Vicenza are not.

More than half of the guilds in Venice are linked to a confraternity, whereas in the other cities the proportion is typically below 20 percent. Nonetheless, once we control for city effects, we do not find any significant correlation between the religious origin of the guild and other observable characteristics, such as its age, the presence of an apprenticeship system, or the industry. Table A3 in the appendix illustrates this result in a series of regressions in which religious origin is the dependent variable. In all cases the correlations are close to zero and statistically insignificant. These results support the idea that the religious origin of a guild is likely to be driven by idiosyncratic reasons related to the local success of the Flagellant movement centuries before the patent act, and thus unlikely to be correlated with shocks affecting patenting strategies after 1474.

Historians also documented how religious confraternities followed a strict set of rules - which were recorded in a book called 'Mariogola'- regulating both admission of new members and day-to-day interactions among members (Monticolo, 1892; 1896; Gasparini, 1987). Statutes of guilds that originated from confraternities were often inspired by the Mariogolas of the related confraternities (Mackenney, 1994). Moreover, entry restrictions may have been required to limit access to the public good provided by the associated confraternity (Greif and Tabellini, 2017). This suggests that guilds with religious origin were more likely to adopt internal rules restricting entry and competition.

In Table 4 we exploit the linkages between guilds and confraternities as instrumental variable. Column 1 reports the first stage regression, which indicates a strong positive correlation between the religious origin of the guild and the strength of its internal rules. Columns 2 and 3 contrast the OLS estimates and the 2SLS estimates of similar linear regression models. Both specifications confirm the strong negative relationship between patenting and the guild's

¹⁷These connections generated obligations on both sides. For example, guilds were required to make financial contributions to the confraternity, but were also allowed to use the confraternity venues as meeting places.

internal rules. The estimates of the IV regression are larger in magnitude but not statistically different from those in the OLS model. The larger magnitude of the coefficient is consistent with measurement error in statutory strength biasing the estimates toward zero, as discussed above.¹⁸

Following Galasso et al (2013), we also instrument *Strong internal regulation* with the predicted probability of a strong statute obtained from a probit model in which the endogenous variable is regressed on the instrument and other first-stage covariates. When the endogenous regressor is a dummy, this estimator is asymptotically efficient in the class of estimators where instruments are a function of the religious origin of the guild and other covariates (Wooldridge, 2002). The 2SLS estimate with this alternative model is essentially identical in magnitude and of stronger statistical significance than the one presented in column 3 of Table 4.¹⁹

One concern with our IV strategy is that the religious origin of the guild may be correlated not only with statutory clauses on competition and entry, but also with other unobservable characteristics affecting patenting. For example, religious guilds may be more risk averse, i.e., less likely to implement changes in their statutes and business practices, and therefore less likely to use patents internally and more likely to oppose patents of external innovators. While we cannot rule out this possibility, in column 3 of Table A3 we show that guilds originating from religious confraternities were as likely to change their statutes during the period of our study as those not linked to religious confraternities. This finding mitigates the concern that the religious origin of a guild is simply a proxy for the risk aversion of the guild many decades in the future.

5.2 Distance from Venice and patenting

Our empirical analysis has shown that patenting was more pronounced in technology fields of guilds located in cities geographically distant from Venice. A possible interpretation of this finding is that formal protection through patent documents was more beneficial to innovators operating further away from the center of political activity. In other words, innovators who were close to Venice may have had access to alternative (formal or informal) mechanisms to

¹⁸We obtain qualitatively similar results with an IV Poisson model, but our estimates are much larger in this case. We also experience convergence issues with some specifications of the IV Poisson model, which are common for this estimator, as described in Silva and Tenreiro (2011).

¹⁹Following Angrist and Pischke (2009), we exploit the first stage estimates to compute the proportion of the treated who are compliers which is 0.22. This indicates that our estimates are not specific to a small compliant subpopulation.

protect their technologies.

To explore in more detail this issue, we develop an additional measure capturing the political strength of each city. To construct this variable, we collect data on the noble families residing across the different cities of the Venetian Republic and their marriages with members of the great council, the legislative assembly of the Republic. After the 1297 serrata, great council membership was patrilineal hereditary and this restricted political power to families of ‘nobili veneti’ the high nobility of the Venetian Republic. While the vast majority of these high nobles resided in Venice, in the other cities of the dominion some families were recognized with lower nobility statuses such as ‘nobili’, ‘conti’ or ‘nobili palatini’. Marriages between nobles residing in a city and members of the great council could be used strategically to increase the political influence and create stronger connection between the city and the center of political power.²⁰

To identify high and low nobility families residing in each city of our sample we digitize the census of the patrician families residing in Veneto and nearby regions compiled in the nineteenth century by Schroeder (1830). For each noble family Schroeder reports the date in which the family obtains the nobility title and the city in which it resides. This allows us to identify the number of noble families residing in each city at the time of the patent act. On average there are about 60 noble families for each city in our sample. More than 100 noble families were located in Venice and smaller cities, such as Udine or Treviso, had less than 30 families.²¹

We combine this digitized census of patrician families with additional data to generate our measure of political power. First, exploiting the information in Raines (2004), we identify the names of the families with great council membership. Second, we obtain data on marriages involving a noble husband during the period 1400-1599. Records of these marriages are available from the ‘Avogaria di Comun’ of the Archivio di Stato di Venezia. Puga and Treffer (2014) digitized these records, building on the work of nineteenth century archivists. Combining these data sources, we construct the indicator variable *Politically connected families*, which equals one if we identify in the city at least one family belonging to the great council or linked through

²⁰Other studies in economics and sociology have examined the network of marriages in Medieval Italy. Padgett and Ansell (1993) show that the success of the Medici family in Florence was driven by strategic marriage alliances. Puga and Treffer (2014) document the use of marriage alliances in Venice to monopolize the galley trade.

²¹Six observations had to be dropped from our sample because they are associated with smaller cities that were not covered by Schroeder (1830).

marriage to a family in the great council.²²

In column 1 of Table 5 we show that there is a positive and statistically significant correlation between the number of noble families in a city and patenting by the guilds in the city. At the same time, the regression also shows that the number of noble families in a city explains much more of the variance in patents than does its population. Including these controls has no effect on the estimates of the effect of geographical distance and internal strength of the guild. This finding suggests that patenting is not simply driven by the sheer size of the city, but it is likely to be related to other regional characteristics. For example, the presence of noble families in a city may affect the quality of its human capital and the availability of financing, and thus spur technological activity.

In column 2 we introduce the variable *Politically connected families*, which captures the political strength of the city. We find a negative and statistically significant association between the presence of politically connected families and patenting, suggesting that formal intellectual property protection may have been a substitute for alternative forms of protection available to guilds with stronger political connections.

There is the concern that the results of columns 1 and 2 are driven by Venice because most of the noble families and members of great council resided in Venice or because of other legal and judicial differences with other cities (Knapton, 2013). To address this issue, in column 3 we drop from our sample all the Venetian guilds. All our findings are robust to focusing on this smaller sample of guilds located in Terraferma.

An additional concern is that more distant cities differ in their human capital or growth potential and this may be correlated with their political power and the propensity to patent. An important determinant of growth and human capital for European cities in the 1400s was the availability of the printing press, as documented by Dittmar (2011). To take this issue into account, we collect data on the number of printed books available in each city of our sample in 1500. This information is obtained from ‘Incunabula Short Title Catalogue,’ a database of the British Library that includes nearly all books printed in Europe before the year 1501. For each item, the dataset provides authors, titles, language and, more importantly for our scope, date and place of printing. In column 4 of Table 5, we introduce this control and find a positive but statistically insignificant correlation between the number of books in a city and patenting.

²²More than half of the cities in our sample are not connected to the great council according to this measure. We use an indicator variable because of the limited variance in this variable (apart from Venice, in all the other cities the number of linked families ranges between 0 and 3).

At the same time, all other results on geographical distance and political power are robust.²³

Many other factors may vary across cities, and it is quite likely that omitted variables correlated with geographical and political distance are important for the propensity to patent. Nonetheless, the correlations reported in Table 5 suggest that the diffusion of patents was shaped by geographic and political forces. From a theoretical perspective, the relationship between patenting and political or geographical distance from Venice is ambiguous. On the one hand, patents might have been easier to enforce for inventors located closer to the capital. On the other hand, inventors and guild members with greater political connections might have been able to obtain protection from the government through other formal or informal channels. Our empirical evidence suggests that the second effect dominated the first, and that patents were not as widespread among guilds located in the proximity of Venice and among those in cities with stronger political ties. A variety of historical accounts can support this interpretation of our findings. First, the *Giustizia Vecchia* - which was the main magistracy enforcing guild statutes and solving disputes between guild members- was located in Venice (Monticolo, 1892; Shaw, 2002). Closer interaction with guilds located in the vicinity of Venice may have allowed resolution of disputes on new products and processes without the need of formal patent documents. Second, some of the guilds located in the proximity of Venice - such as those active in the Arsenal or Murano's glassblowers - were under close scrutiny by the Venetian government, which often passed laws to complement their statutes and to provide additional regulation of the sector. Some of these guild-specific regulations involved technology adoption. Caniato (1996) describes various legislative acts related to the Arsenal guild members that protected local production (e.g. by burning ships not built in Venice) and that rewarded selected foreign shipbuilders. Davanzo Poli (1984) describes a senate decision in 1462 that contained provisions supporting the tanner and shoemaker guilds of Venice. Manno (1995) describes similar forms of protection for glassmakers, blacksmiths, and the silk guild of Venice.

Our finding that patents were especially valuable to innovators located in frontier cities without political connections is also related to Khan's analysis of the origin of modern patent rights. Khan (2005) argues that the British and French patent systems were designed to support and increase the market power of elites. Differently, she shows that the United States system was more democratic, with patents accessible to non-elite inventors. In this respect,

²³We obtain similar qualitative and quantitative estimates in regressions run on the smaller sample in which observations are collapsed at the city level.

our findings suggest that the American patent system was closer to the Venetian experience than were the French and British laws.

6 Conclusions

In this paper we study the diffusion of patent rights in the Venetian Republic following the 1474 senate act, which instituted the very first regularized patent system. There are two key empirical findings in the paper. First, we find a strong negative association between the number of patents granted in the technology sector of a guild and the presence of statutory provisions limiting entry and competition. Second, we find that patenting was more frequent for guilds located in cities geographically distant from Venice and in cities with lower political connection.

Overall, our findings indicate that the diffusion of new economic institutions may be strongly affected by features of the local economic and political environment. This has potential implications for the design of patent policies, because it suggests that policy outcomes may vary substantially across locations and industries, even within a region. Our estimates are also in line with the more recent innovation literature, which has documented substantial variation in the rate of patenting across industries and in the perceived effectiveness of patents across firms (Levin et al., 1987; Schankerman, 1998; Cohen, Nelson, and Walsh, 2000). Our data show that even in the very first patent system, the private economic value provided by intellectual property rights appears highly heterogeneous. Finally, our analysis underscores the importance of considering the potential substitution between new institutions and existing alternatives.

While our results provide new insights into the diffusion of the very first patent rights, they do not imply that greater patenting is equivalent to greater innovation. If anything, historians have documented substantial innovation activity by guilds for which we observe little patenting, such as the Arsenal or Murano's glassblowers (Caniato, 1996; Trivellato, 2008). We leave for future research an examination of the effect of Venetian patents on city growth and innovation investments.

References

- [1] Akcigit, Ufuk, John Grigsby, and Tom Nicholas (2017a) “The Rise of American Ingenuity: Innovation and Inventors of the Golden Age,” NBER Working Paper 23047
- [2] Akcigit, Ufuk, John Grigsby, and Tom Nicholas (2017b) “Immigration and the Rise of American Ingenuity,” *American Economic Review* 107: 327-31
- [3] Acemoglu, Daron, and Ufuk Akcigit (2012) “Intellectual property rights policy, competition and innovation,” *Journal of the European Economic Association* 10: 1-42
- [4] Acemoglu, Daron, and Simon Johnson (2005) “Unbundling Institutions,” *Journal of Political Economy* 113: 949-995
- [5] Acemoglu, Daron, Simon Johnson, and James Robinson (2005) “The rise of Europe: Atlantic trade, institutional change, and economic growth,” *American Economic Review* 95: 546-579
- [6] Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt (2005) “Competition and Innovation: An Inverted-U Relationship,” *Quarterly Journal of Economics* 120: 701-728
- [7] Angrist, Joshua David and Jörn-Steffen Pischke (2009) *Mostly harmless econometrics: an empiricist’s companion*, Princeton university press, Princeton
- [8] Ashraf, Quamrul, and Oded Galor (2011) “Cultural diversity, geographical isolation, and the origin of the wealth of nations,” National Bureau of Economic Research working paper 17640
- [9] Belfanti, Carlo (2004) “Guilds, patents, and the circulation of technical knowledge: Northern Italy during the early modern age,” *Technology and culture* 45: 569-589
- [10] Berveglieri Roberto (1995), “Inventori Stranieri a Venezia (1474-1797). Importazione di tecnologia e circolazione di tecnici artigiani inventori,” Istituto Veneto di Scienze, Venezia.
- [11] Berveglieri Roberto (1999), *Le vie di Venezia. Canali lagunari e rii a Venezia: Inventori, brevetti, tecnologia e legislazione nei secoli XIII-XVIII*, Cierre, Verona
- [12] Borelli, Giorgio (1980) *Stato Economia e Societa’ nella Repubblica Veneta tra ‘400 e ‘700*, Libreria Universitaria Editrice, Verona

- [13] Bridgman, Benjamin (2015) “Competition, work rules and productivity,” *Journal of Economic Dynamics and Control* 32: 136-149
- [14] Caniato, Giovanni (1996) “L’Arsenale: maestranze e organizzazione del lavoro,” in Tenenti and Tucci, *Storia di Venezia: dalle origini alla caduta della Serenissima*, Istituto della enciclopedia italiana, Roma
- [15] Cohen, Wesley, Richard R. Nelson, and John P. Walsh (2000), “Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not),” NBER working paper 7552
- [16] Cohen, Wesley (2010), “Fifty years of empirical studies of innovative activity and performance,” in Brownyn Hall and Nathan Rosenberg, *Handbook of The Economics of Innovation*, North-Holland, Amsterdam
- [17] Costantini, Massimo (1987), *L’albero della libertà economica: il processo di scioglimento delle corporazioni veneziane*, Arsenale, Venezia.
- [18] David de la Croix, Matthias Doepke, Joel Mokyr (2016), “Clans, Guilds, and Markets: Apprenticeship Institutions and Growth in the Pre-Industrial Economy,” NBER Working Paper No. 22131
- [19] Davanzo Poli, Doretta (1984) “*I mestieri della Moda a Venezia nei sec. XIII-XVIII*” *Edizioni del Gazzettino* 1: 139-140
- [20] Demo, Edoardo (2013) “Industry and production in the venetian terraferma,” in Dursteler, Eric. *A Companion to Venetian History, 1400-1797*, Brill, Leiden
- [21] Di Stefano, Giovanni (2011) *Enciclopedia Storica di Venezia*, Supernova, Venezia
- [22] Dittmar, Jeremiah (2011) “Information technology and economic change: the impact of the printing press,” *The Quarterly Journal of Economics* 126: 1133-1172
- [23] Duffy, John (2007) “Inventing Invention: A Case Study of Legal Innovation,” *Texas Law Review* 86: 1-73
- [24] Dursteler, Eric (2013) “*A Companion to Venetian History, 1400-1797*,” Brill, Leiden
- [25] Epstein, Stephan (2004) “Property rights to technical knowledge in premodern Europe, 1300-1800,” *American Economic Review* 94: 382-387

- [26] Galasso, Alberto, Mark Schankerman, and Carlos J. Serrano (2013) “Trading and enforcing patent rights,” *RAND Journal of Economics* 44: 275-312
- [27] Gasparini Giuseppina (1987) “Il Movimento delle Confraternite nell’Area Veneta,” *Publications de l’École française de Rome* 97: 361-394
- [28] Glaeser, Edward, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer (2004) “Do institutions cause growth?” *Journal of Economic Growth* 9: 271-303
- [29] Golden, John M. (2013) “Patent Privateers: Private Enforcement’s Historical Survivors,” *Harvard Journal of Law and Technology* 26: 545-553
- [30] Gourieroux, Christian, Alain Monfort, and Alain Trognon (1984) “Pseudo maximum likelihood methods: Applications to Poisson models,” *Econometrica* 52: 701-720
- [31] Greif, Avner, Paul Milgrom, and Barry R. Weingast (1994) “Coordination, commitment, and enforcement: The case of the merchant guild,” *Journal of Political Economy* 102: 745-776
- [32] Greif, Avner and Guido Tabellini (2017) “The Clan and the Corporation: Sustaining Cooperation in China and Europe,” *Journal of Comparative Economics*, forthcoming
- [33] Hall, Bronwyn and Dietmar Harhoff (2004) “Post-grant reviews in the US patent system—design choices and expected impact,” *Berkeley Technology Law Journal*: 989-1015
- [34] Hall, Bronwyn and Dietmar Harhoff (2012) “Recent research on the economics of patents,” *Annual Review of Economics* 4: 541-565
- [35] Harhoff, Dietmar and Markus Reitzig (2004) “Determinants of opposition against EPO patent grants—the case of biotechnology and pharmaceuticals,” *International Journal of Industrial Organization* 22: 443-480
- [36] Hausman, Jerry, Bronwyn Hall, and Zvi Griliches (1984) “Econometric Models for Count Data with an Application to the Patents-R&D Relationship,” *Econometrica* 52: 909-38
- [37] Khan, B. Zorina (2005) “*The Democratization of Invention: patents and copyrights in American economic development, 1790-1920*” Cambridge University Press, Cambridge
- [38] Kleiner, Morris, (2000) “Occupational licensing,” *Journal of Economic Perspectives* 14: 189-202

- [39] Knapton Michael (2013) “The terraferma state,” in Dursteler, Eric. *A Companion to Venetian History, 1400-1797*, Brill, Leiden
- [40] Lane, Frederic (1973) *Venice. A Maritime Republic*, John Hopkins University Press, Baltimore
- [41] Lanaro Sartori Paola (1985) “Venezia e le grandi arterie del commercio internazionale: strade, flusso di merci, organizzazione dei trasporti tra ‘500 e ‘700,” in Borelli Giorgio (a cura di), *Mercanti e vita economica nella Repubblica Veneta (secoli XIII-XVIII)*, Banca Popolare di Verona, Verona
- [42] Levin, R. C., Klevorick, A. K., Nelson, R. R., Winter, S. G., Gilbert, R., & Griliches, Z. (1987) “Appropriating the returns from industrial research and development,” *Brookings Papers on Economic Activity* 3:783-831
- [43] Machlup, Fritz, and Edith Penrose (1950) “The Patent Controversy in the Nineteenth Century,” *Journal of Economic History* 10:1-29
- [44] Malanima, Paolo (1998), “Italian Cities 1300-1800. A quantitative approach,” *Rivista di Storia Economica* 14, 91-126
- [45] Mandich, Giulio (1936), “Le privative industriali veneziane : 1450-1550,” *Rivista del Diritto Commerciale* 34, 101-143
- [46] Mandich, Giulio (1948) “Venetian Patents (1450-1550),” *Journal of the Patent and Trademark Office Society* 30: 166-189
- [47] Manno, Antonio (1995) *I mestieri di Venezia. Storia, arte e devozione delle corporazioni dal XIII al XVIII secolo*, Biblos, Cittadella
- [48] May, Christopher, (2002) “The Venetian Moment: New Technologies, legal innovation and the institutional origins of intellectual property”, *Prometheus* 20: 159-177
- [49] Mackenney Richard (1994) “Continuity and change in the scuole piccole of Venice, c. 1250 - c. 1600,” *Reinassance Studies* 8: 388-403
- [50] Merges, Robert P., and John F. Duffy (2013) *Patent law and policy: Cases and materials*, Carolina Academic Press, Durham

- [51] Moioli, Angelo (2004), “I Risultati di un’Indagine sulle Corporazioni nelle Città Italiane in Età Moderna,” in *Dalla Corporazione al Mutuo Soccorso. Organizzazione e Tutela del Lavoro tra XVI e XX Secolo*, Paola Massa e Angelo Moioli editori. Franco Angeli Edizioni, Milano
- [52] Molà, Luca (2000) *The silk industry of Renaissance Venice*, Johns Hopkins University Press, Baltimore
- [53] Monticolo, Giovanni (1892) *L’Ufficio della giustizia vecchia a Venezia dalle origini sino al 1330*, Volume II, A spese della Società, Venezia
- [54] Monticolo, Giovanni (1896) *I Capitolari delle arti veneziane*, Forzani EC tipografi del senato, Roma.
- [55] Moser, Petra (2005) “How Do Patent Laws Influence Innovation? Evidence from Nineteenth Century World’s Fairs,” *American Economic Review* 94:1214-1236
- [56] Moser, Petra (2012) “Innovation without Patents – Evidence from World’s Fairs” *Journal of Law and Economics* 55: 43-74
- [57] North, Douglass (1981) *Structure and Change in Economic History*, Norton, New York
- [58] Padgett, John and Christopher Ansell (1993) “Robust Action and the Rise of the Medici, 1400–1434,” *American Journal of Sociology* 98: 1259–1319.
- [59] Persico, Nicola (2015) “The political economy of occupational licensing associations,” *Journal of Law, Economics, and Organization* 31: 213-241
- [60] Pezzolo, Luciano (2013) “The venetian economy” in Dursteler, Eric. *A Companion to Venetian History, 1400-1797*. Brill, Leiden
- [61] Pullan, Brian (1971), *Rich and poor in Renaissance Venice: the Social Institutions of a Catholic State, to 1620*, Harvard University Press.
- [62] Schankerman, Mark (1998) ”How Valuable is Patent Protection? Estimates by Technology Field,” *RAND Journal of Economics* 29, 77-107
- [63] Schroeder Franz (1830) *Repertorio genealogico delle famiglie confermate nobili e dei titolati nobili esistenti nelle Provincie Venete*, Vol. 1 and 2, Forni, Bologna

- [64] Shaw, James (2002) "Retail, Monopoly, and Privilege: the Dissolution of the Fishmongers' Guild of Venice, 1599," *Journal of Early Modern History* 6: 396-427.
- [65] Sichelman, Ted and Sean O'Connor (2012), "Patents as Promoters of Competition: The Guild Origins of Patent Law in the Venetian Republic," *San Diego Law Review* 49: 1267-82
- [66] Silva, Santos and Silvana Tenreyro (2011) "Poisson: some convergence issues," *Stata Journal* 11: 207-212
- [67] Tabellini, Guido (2010) "Culture and institutions: economic development in the regions of Europe," *Journal of the European Economic Association* 8: 677-716
- [68] Trivellato, Francesca (2008) "Guilds, Technology, and Economic Change in Early Modern Venice," in *Guilds, Innovation and the European Economy, 1400-1800*, eds. S.R. Epstein and Maarten Prak (Cambridge: Cambridge University Press, 2008), pp. 199-231.
- [69] Puga Diego and Dan Treffer (2014), "International Trade and Institutional Change: Medieval Venice's Response to Globalization," *Quarterly Journal of Economics* 129: 753-821
- [70] Raines Dorit (2004), "Cooptazione, aggregazione e presenza al Maggiore Consiglio: le casate del patriziato veneziano, 1297-1797," *Storia di Venezia* 1:1-64
- [71] Rendina, Claudio (1984) *I dogi*, Newton Compton Editori, Roma
- [72] Zaggia, Stefano (2014) "Far la città: Il ruolo dei Provveditori di Comun nell'evoluzione dell'ambiente urbano di Venezia. Strade, ponti, pozzi, case," *Mélanges de l'Ecole française de Rome Italie et Méditerranée* 116: 665-681

Appendix: Extensions of the theoretical model

Generalized impact of guild statutes

In this Appendix we extend our baseline model generalizing the impact that guild statutes have on rent sharing, $\alpha(\theta)$, and entry, $\beta(\theta)$. We assume that the ability to appropriate rents increases with θ , $\alpha'(\theta) > 0$ while the probability of entry decreases, $\beta'(\theta) < 0$. Finally, we assume that $\alpha(0) = \beta(1) = 0$ and $\alpha(1) = \beta(0) = 1$.

We analyze first the case in which a guild member is the innovator. As in Section 3, we solve the model by backward induction considering first the opposition decision. Opposition is profitable if

$$\frac{2\alpha(\theta)(\pi + \Delta)}{2} - \kappa > \frac{\alpha(\theta)\pi}{2} + \frac{\alpha(\theta)(\pi + \Delta)}{2}$$

which is satisfied if

$$\Delta > \widehat{\Delta}(\theta) = \frac{2}{\alpha(\theta)}\kappa.$$

Notice that $\frac{d\widehat{\Delta}(\theta)}{d\alpha} < 0$ which combined with $\alpha'(\theta) > 0$ implies that, as the strength of the internal statute increases, guild members block patents of other guild members more often. If the innovator anticipates opposition it will not apply for a patent. If, instead, $\Delta \leq \widehat{\Delta}(\theta)$ the guild member will patent when:

$$\pi + \Delta - \frac{\alpha(\theta)\pi}{2} + \frac{\alpha(\theta)(\pi + \Delta)}{2} - c > \frac{2\alpha(\theta)(\pi + \Delta)}{2}$$

or

$$\Delta > \widetilde{\Delta}(\theta) = \frac{2(c - \pi(1 - \alpha(\theta)))}{2 - \alpha(\theta)}.$$

Notice that $\widetilde{\Delta}(\theta) > 0$ only if $\alpha(\theta)$ is large enough. Moreover $\frac{d\widetilde{\Delta}(\theta)}{d\alpha} > 0$ which combined with our assumption that $\alpha'(\theta) > 0$ implies that, as the strength of the internal statute increases, guild members patent only their more valuable innovations and the propensity to patent decreases in θ . This also shows that our results on opposition and patenting by guild members presented in the text are robust to assuming a more general relationship between rent-sharing and θ .

Consider now the case of an external innovator. A guild member finds opposing the patent more profitable than accommodating it when:

$$2\alpha(\theta)\frac{(\pi + \Delta)}{2} - \kappa > \frac{\pi}{2}\alpha(\theta) + \frac{\alpha(\theta)(\pi + \Delta)}{3}$$

or

$$\Delta > \widehat{\Delta}_E(\theta) = \frac{3}{2\alpha(\theta)} \left(\kappa - \frac{\alpha(\theta)\pi}{6} \right)$$

It is easy to see that $\widehat{\Delta}_E(\theta)$ is decreasing in $\alpha(\theta)$. This, combined with our assumption that $\alpha'(\theta) > 0$, implies that the likelihood of opposition increases in θ . When $\Delta \leq \widehat{\Delta}_E(\theta)$ and the external innovator anticipates the patent will not be opposed, patenting is more profitable than entry without patent if

$$\pi + \Delta - \alpha(\theta)\pi + \frac{\alpha(\theta)(\pi + \Delta)}{3} - c > \beta(\theta) \frac{2\alpha(\theta)(\pi + \Delta)}{3}$$

that occurs if

$$\Delta > \widetilde{\Delta}_E(\theta) = \frac{3c - 3\pi + 2\pi\alpha(\theta) + 2\pi\alpha(\theta)\beta(\theta)}{\alpha(\theta) - 2\alpha(\theta)\beta(\theta) + 3}$$

Given that $\alpha(0) = \beta(1) = 0$ and $\alpha(1) = \beta(0) = 1$, it follows that $\widetilde{\Delta}_E(0) = (3c - 3\pi)/3$ and $\widetilde{\Delta}_E(1) = (3c - \pi)/4$ which are both negative because $\pi > 3c$. Moreover, we have that

$$\begin{aligned} \frac{d\widetilde{\Delta}_E(\theta)}{d\theta} &= 3 \frac{3\pi - c + 2\beta(\theta)c}{(\alpha(\theta) - 2\alpha(\theta)\beta(\theta) + 3)^2} \alpha'(\theta) \\ &\quad + 6\alpha(\theta) \frac{c + \pi\alpha(\theta)}{(\alpha(\theta) - 2\alpha(\theta)\beta(\theta) + 3)^2} \beta'(\theta) \end{aligned}$$

which is positive under the following condition:

$$-\frac{\alpha'(\theta)}{\beta'(\theta)} \geq \frac{2(\alpha(\theta)(c + \pi\alpha(\theta)))}{3\pi - c + 2\beta(\theta)c}$$

The right hand side of the above inequality is bounded by $(2c + 2\pi)/(3\pi - c)$ which in turn is bounded by 1 because $\pi > 3c$. This implies that $|\alpha'(\theta)| \geq |\beta'(\theta)|$ is a sufficient condition for $\frac{d\widetilde{\Delta}_E(\theta)}{d\theta} \geq 0$. In other words, patenting decreases in θ when changes in the statute strength have greater impact on rent sharing than on entry.

Generalized licensing negotiations

In the baseline setting, the innovating firm has the full bargaining power during the licensing negotiations and it appropriates the whole surplus of the innovation (while the other guild members obtain the status-quo profits $\theta\pi/2$). In this Appendix, we generalize the analysis assuming that the surplus is shared according to a parameter $\gamma \in [0, 1]$. More specifically,

during the period of validity of the patent, the innovating firm obtains its status-quo profits plus a share γ of the innovation surplus, $\pi + \Delta - \theta\pi$; the remaining $(1 - \gamma)$ share is appropriated by the other guild member(s). Parameter γ represents the bargaining power of the inventor during the licensing negotiations. Note that $\gamma = 1$ corresponds to the baseline setting.

Below, we show that the comparative static results of the baseline setting are still valid in this more general framework provided γ is large enough. Consider first the case of innovation by a guild member. The other guild member opposes the patent if

$$\frac{2\theta(\pi + \Delta)}{2} - \kappa > \frac{\theta\pi}{2} + (1 - \gamma)(\pi + \Delta - \theta\pi) + \frac{\theta(\pi + \Delta)}{2}.$$

When choosing not to oppose the patent, in the first period, the guild member obtains $\theta\pi/2 + (1 - \gamma)(\pi + \Delta - \theta\pi)$, the status-quo profits plus a share $(1 - \gamma)$ of the innovation surplus. Hence, opposition is optimal if

$$\Delta > \hat{\Delta}(\theta) = \frac{2\kappa + 2(1 - \gamma)(1 - \theta)\pi}{(\theta - 2(1 - \gamma))}.$$

A simple inspection of $\hat{\Delta}(\theta)$ reveals that $\frac{d\hat{\Delta}(\theta)}{d\theta} < 0$: the larger is θ the more likely that guild members oppose patents by other guild members.

Consider now the patenting decision. When $\Delta \leq \hat{\Delta}(\theta)$, patenting generates an overall profit

$$\frac{\theta\pi}{2} + \gamma(\pi + \Delta - \theta\pi) + \frac{\theta(\pi + \Delta)}{2} - c.$$

In the first period, the firm obtains the status-quo profits, $\theta\pi/2$, plus the share γ of the innovation surplus $(\pi + \Delta - \theta\pi)$. Hence, patenting is more profitable than non-patenting only if

$$\frac{\theta\pi}{2} + \gamma(\pi + \Delta - \theta\pi) + \frac{\theta(\pi + \Delta)}{2} - c > \frac{2\theta(\pi + \Delta)}{2}$$

or

$$\Delta > \tilde{\Delta}(\theta) = \frac{2(c - \gamma\pi(1 - \theta))}{(2\gamma - \theta)}.$$

Notice that $\tilde{\Delta}(\theta) > 0$ when θ and γ are large enough; moreover, $\frac{d\tilde{\Delta}(\theta)}{d\theta} > 0$, which implies that the propensity to patent reduces with the strength of the statutes.

Let us focus now on the case of innovation by a non-guild member. In this case, patent opposition is profitable for a guild member when

$$\frac{2\theta(\pi + \Delta)}{2} - \kappa > \frac{\theta\pi}{2} + \frac{(1 - \gamma)}{2}(\pi + \Delta - \theta\pi) + \frac{\theta(\pi + \Delta)}{3}$$

By accommodating the patent, in the first period, a guild member obtains its status-quo profits plus half of $(1 - \gamma)(\pi + \Delta - \theta\pi)$. Therefore, a guild member chooses to oppose a patent by an external if

$$\Delta > \hat{\Delta}_E(\theta) = \frac{3c - \pi(3\gamma(1 - \theta) - \theta + 2\theta^2)}{(3\gamma - \theta + 2\theta^2)}.$$

It can be easily verified that $\frac{d\hat{\Delta}_E(\theta)}{d\theta} < 0$ which implies that the larger θ the more likely is guild members opposition to patents of external innovators.

In turn, for $\Delta \leq \hat{\Delta}_E(\theta)$, patenting is optimal for the external innovator if

$$\gamma(\pi + \Delta - \theta\pi) + \frac{\theta(\pi + \Delta)}{3} - c > (1 - \theta)\frac{2\theta(\pi + \Delta)}{3},$$

or

$$\Delta > \tilde{\Delta}_E(\theta) = \frac{3c - \pi(3\gamma(1 - \theta) - \theta + 2\theta^2)}{(3\gamma - \theta + 2\theta^2)}.$$

From the above expression it follows that $\tilde{\Delta}_E(\theta) < 0$ if $\gamma > \frac{3c + \pi\theta(1 - 2\theta)}{3\pi(1 - \theta)}$; hence, the external innovator always prefers to patent provided that γ is large enough.

Settling patent opposition

The patent opposition process described in Section 3 leads to an important inefficiency: patents with large Δ are opposed and, therefore, inventors refrain from patenting their innovations. This fact reduces the overall surplus generated by the innovation at $t = 1$ from $\pi + \Delta$ to $\theta(\pi + \Delta)$. Since we are considering a game of complete information, one may wonder whether our results are still valid when we allow for efficient negotiations about the opposition decision. To address this issue, in this Appendix we assume that, once the patent is granted, the innovator and the guild member/s negotiate over the opposition decision. Specifically, we assume that the innovator makes a take-it-or-leave-it offer about how to share the two-period overall surplus. If the proposal is accepted, then the patent is not opposed; otherwise, opposition takes place.²⁴

Suppose that the innovator is a guild member. In this case, during the negotiations the innovator offers to the other guild member an overall payoff equal to $\theta(\pi + \Delta)/2 + \theta(\pi + \Delta)/2 - \kappa$,

²⁴In the analysis, we assume that, in case of rejection, patent opposition is profitable. If this is not the case, then the analysis of the patenting decision coincides with that presented in the baseline model when $\Delta \leq \hat{\Delta}(\theta)$ (internal innovator) or $\Delta \leq \hat{\Delta}_E(\theta)$ (external innovator).

i.e. the payoff that the latter would obtain in the case of opposition; clearly, such a proposal is accepted. Hence, by choosing to patent the invention, the innovator obtains $\pi + \Delta + \theta(\pi + \Delta) - c - \theta(\pi + \Delta)/2 - \theta(\pi + \Delta)/2 + \kappa = \pi + \Delta - c + \kappa$, a payoff which does not depend on θ . By contrast, by not patenting, the innovator obtains $\theta(\pi + \Delta)/2 + \theta(\pi + \Delta)/2$, a payoff which increases with θ . Comparing the two payoffs, patenting is optimal when

$$(1 - \theta)(\pi + \Delta) - c + \kappa > 0$$

which decreases in θ . Therefore, also if we allow for negotiations over patent opposition, when the innovator is a guild member patenting becomes less likely as θ gets larger.

Suppose now that the innovator is an outsider. During the negotiations the innovator offers the two guild members an overall payoff equal to $2(\theta(\pi + \Delta)/2 + \theta(\pi + \Delta)/2) - \kappa$, i.e. the payoff they would obtain jointly if one of them were to oppose the patent. By patenting the innovator obtains a payoff $\pi + \Delta + \theta(\pi + \Delta) - c - 2(\theta(\pi + \Delta)/2 + \theta(\pi + \Delta)/2) + \kappa$, that is $(\pi + \Delta)(1 - \theta) + \kappa - c$. By contrast, when choosing not to patent, the innovator obtains $(1 - \theta)\frac{2\theta(\pi + \Delta)}{3}$. Comparing the two payoffs, patenting is optimal when

$$(1 - \theta)\frac{(\pi + \Delta)(3 - 2\theta)}{3} - c + \kappa > 0$$

a condition which is less likely to hold as θ grows larger. Therefore, also in the case of external innovator, patenting is decreasing in θ .

Figure 1. Venetian State Boundary



Map 3.1. Venice's Terraferma.

(Source: Knapton, 2013)

Table 1. Summary statistics

	Obs.	Mean	Std. Dev.	Min	Max
Patents	340	1.47	5.10	0	42
Strong internal regulation	340	0.21	0.40	0	1
Distance	340	59.90	77.67	0	422.10
Trade guild	340	0.46	0.49	0	1
Guild members	169	164.06	392.27	2	3390

Main Cities

Venice	161
Verona	54
Padua	39
Brescia	31
Treviso	16
Udine	13
Others	26

NOTES: Unit of observation is a guild i located in city j . Patents is the total number of patents granted from 1474 to 1550 in the technology sector of the guild. Distance= distance from Venice in Km. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. Trade guild =1 if the guild is not involved in manufacturing. Guild members = number of registered members as reported in the "Istituzioni Cooperative" data.

Table 2 . Guild internal regulation and patenting

	(1)	(2)	(3)	(4)
Dependent Variable	Patents	Patents	Patents	Patents
Strong internal regulation	-0.750*** (0.151)	-0.995*** (0.103)	-1.133*** (0.439)	-1.717*** (0.610)
log(Distance)		0.224*** (0.026)		
log (Guild members)				0.256 (0.191)
Trade guild	-4.535*** (0.710)	-4.357*** (0.708)	-4.355*** (0.848)	-5.268*** (1.042)
City Effects	No	No	Yes	Yes
Observations	340	340	340	169

NOTES: Poisson estimation with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. Distance= distance from Venice in Km. Guild members = number of registered members as reported in the "Istituzioni Cooperative" data. Trade guild =1 if the guild is not involved in manufacturing.

Table 3. Inventors' origin and alternative patent data

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Patents Local	Patents Local	Patents Foreigners	Patents Foreigners	Patents Mandich	Patents Mandich
Strong internal regulation	-0.960*** (0.098)	-1.098** (0.429)	-0.029** (0.012)	-0.034* (0.020)	-1.372*** (0.317)	-1.266** (0.616)
log(Distance)	0.218*** (0.025)		0.006*** (0.001)		0.168*** (0.037)	
City Effects	No	Yes	No	Yes	No	Yes
Observations	340	340	340	340	340	340

NOTES: Poisson estimation with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. All regressions include a dummy for Trade guilds. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. Distance= distance from Venice in Km. Patents local= patents granted to Italian inventors. Patents foreigners= patents granted to non-Italian inventors. Columns 1-4 exploit patent data from Berveglieri (1995, 1999) columns 5-6 exploit patent data from Mandich (1936).

Table 4. Religious confraternities and guild internal strength

	(1)	(2)	(3)	(4)
Dependent Variable	Strong guild	Patents	Patents	Patents
Estimation	OLS	OLS	2SLS	2SLS
Religious confraternity	0.150*** (0.045)			
Strong internal regulation		-1.958** (0.861)	-4.183* (2.720)	-4.387** (2.191)
City Effects	Yes	Yes	Yes	Yes
Observations	340	340	340	340
First stage F-test			7.85	13.21
Instrument			Religious confraternity	Probit regression

NOTES: OLS estimation with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. All regressions include a dummy for Trade guilds. Religious confraternity =1 if guild is linked to a religious institution. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. In column 4 IV is predicted value from probit regression as in Wooldrige (2002).

Table 5. Noble families and patenting

	(1)	(2)	(3)	(4)
Dependent Variable	Patents	Patents	Patents	Patents
Strong internal regulation	-1.123*** (0.121)	-1.199*** (0.124)	-1.280*** (0.128)	-1.111*** (0.116)
log(Distance)	0.299*** (0.034)	0.318*** (0.020)	0.255** (0.115)	0.393*** (0.061)
log(Noble Families)	0.092*** (0.031)	0.470*** (0.094)	0.495*** (0.097)	0.639*** (0.219)
log(Population ₁₅₀₀)	0.102 (0.126)	-0.066 (0.070)	0.001 (0.139)	-0.353 (0.295)
Politically Connected Families		-1.595*** (0.361)	-1.700*** (0.375)	-2.168*** (0.822)
log(Books)				0.146 (0.102)
City Effects	No	No	No	No
Drop Venice	No	No	Yes	No
Observations	334	334	173	334

NOTES: Poisson estimation with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. All regressions include a dummy for Trade guilds. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. Distance= distance from Venice in Km. Noble families = number of noble families in the city as registered by Schroeder (1830). Population= inhabitants in 1500 as estimated by Malanima (1998). Politically connected families=1 if there is at least one family in the city which belongs to the Great Council or is linked through marriages to a family in the Great Council. Books= number of printed books in the city in 1500, information from "Incunabula Short Title Catalogue".

**Table A1. Patents by technology sector
1474-1550**

Mills	
cereals	42
metals	6
textiles	9
wood saws	6
multiple usage	22
Fabrics	8
Paint	4
Bread and food	1
Pottery and Porcelain Vases	1
Agricultural machines	4
Drainage, mud removal	20
Hydraulic pumps	11
Guns	7
Arsenal	3
Mining	3
Perpetual Motion	3
Miscellaneous	19
Total	169

Source: Berveglieri (1995)

Table A2. Robustness

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Patents	Patents	Patents 1474-1600	Patents	Patents	Patents
Strong internal regulation	-1.010*** (0.098)	-0.948** (0.431)	-0.728** (0.318)	-0.837** (0.359)		-1.307*** (0.486)
Placebo					0.282 (0.394)	
log(Distance)	0.259*** (0.068)					
log (Population ₁₅₀₀)	-0.013 (0.476)					
log (Population ₁₄₀₀)	0.176 (0.769)					
log(Population ₁₃₀₀)	-0.054 (0.383)					
Apprenticeship		0.120 (0.307)				
log(Age)		0.047 (0.164)				
Mills				2.044*** (0.325)		
City effects	No	Yes	Yes	Yes	Yes	Yes
Industry effects	No	Yes	No	No	No	No
Drop guilds with change in statute	No	No	No	No	No	Yes
Observations	340	340	340	340	340	275

NOTES: Poisson estimation with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. Regressions include dummy for Trade guilds. Strong internal regulation =1 if guild has internal rules which restrict competition, grant privileges to sons of members, and restrict rights of foreign members. Placebo=1 if the statute includes: (i) a list of manufacturing activities precluded to women, (ii) the name of the guild's patron saint and (iii) a description of the hierarchical structure of the guild. Distance= distance from Venice in Km. Population data are from Malanima (1998). Apprenticeship=1 if the "Istituzioni Corporative" database documents an apprenticeship requirement. Age= age of the guild in 1600. Mills=1 if guild activities involve the use of mills. Industry effects are dummies for guilds in agriculture, textile and construction. Column (6) drops guilds with changes in statutes in the period 1474-1550.

Table A3. Exogeneity of religious origin

	(1)	(2)	(3)	(4)
Dependent Variable	Religious confraternity	Religious confraternity	Religious confraternity	Religious confraternity
Age	0.001 (0.001)			0.001 (0.001)
Age ²	-0.001 (0.001)			-0.001 (0.001)
Apprenticeship		0.046 (0.042)		0.055 (0.042)
Number of statutory changes 1474-1550			0.022 (0.044)	0.041 (0.045)
Textiles				-0.062 (0.045)
Construction				-0.096 (0.120)
Agriculture				0.032 (0.055)

NOTES: OLS regression with robust standard errors. * significant at 10 percent, ** significant at 5 percent and *** significant at 1 percent. The dependent variable is filtered with city effects and a dummy for trade guilds. Apprenticeship=1 if the "Istituzioni Corporative" database documents an apprenticeship requirement. Age= age of the guild in 1600. Number of statutory changes 1474-1550 = number of times the statute of the guild changed during the period 1474-1550, as reported in the "Istituzioni Cooperative" data. Textile, Construction and Agriculture are industry dummies.