

# Coproduction of Property Rights: The Management of Watercourses in Pre-modern Bohemia

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## Abstract

The structure of ownership is recognized as a key factor for economic and social development. The traditional approach suggests that new property rights emerge when it becomes profitable to invest in their production. I extend this idea by arguing that simply defining new property rules is not enough for new rights to develop effectively, and that enforcement of those rules is just as important. Identifying and implementing an optimal combination of definition and enforcement activities then becomes the central issue in the development of property rights. I illustrate the application of this theory with a detailed study of the evolution of water rights in pre-modern Bohemia.

*Keywords:* Property rights, Coproduction, Water rights

*JEL:* K11, N53, P48, Q25, Q34

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<sup>1</sup>I would like to thank Giovanni Ramello, an anonymous referee and participants at a graduate workshop at the University of Turin for their criticism and helpful comments. I am also very grateful to Martina Maříková from the Prague City Archives, who provided me with her extensive notes regarding the primary sources used in this article. Without her help, this work would not have been possible. I also wish to thank the Institute for Humane Studies for their financial support.

## 1. Introduction

The structure of ownership is recognized as a key factor for economic and social development. All the problems of overexploitation or under-provision associated with scarce resources stem from a lack of well-defined and well-enforced property rights, whether private, public or common (e.g. Coase, 1960; Hardin, 1968; Cheung, 1970; Pejovich, 1972; Anderson and Hill, 1975, 1983; Sutinen and Andersen, 1985; Ostrom and Schlager, 1996; Libecap, 2007, 2008, 2009; Ostrom and Hess, 2010; Anderson and Parker, 2013). In the absence of any enforced distinction of who owns what, interacting agents tend to fail to take into an account the differences between the private net returns of their actions and the net returns to society as a whole. These differences result in uncompensated harmful or beneficial effects to others or ourselves, known in economics as externalities. The primary purpose of property rights is to overcome these associated inefficiencies by “guiding incentives to achieve a greater internalization of externalities” (Demsetz, 1967, p. 348).<sup>2</sup>

The basic premise is that when more property rights are given to a resource, there are fewer conflicts over it and it is used more efficiently. The question is then what determines the emergence of new property rights? The traditional approach suggests that whether new property rights are created or not depends on the relative cost and benefit of their creation.

However, this picture omits an important aspect of the development of property rights: its internal production process. What kind of production factors matter in the development of new property rights? Who provides these inputs, and how? Who pays for them? How are production factors related to each other and to the internalization of externalities? What affects their relative roles? Answering these questions is important for a better understanding of the evolution of property rights and institutional context that surrounds them.

The purpose of this paper is to extend the neo-classical theory of property rights evolution. I argue that the level of internalization is not only conditioned on the cost-benefit of investment in property rights production but also on the relationship between its input activities as performed by different agents such as owners, judges, legislators or policemen. To incorporate the internal relationship into the property rights production process, I develop a

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<sup>2</sup>For the general role of property rights in managing side effects, see also Demsetz (1964, 1966); Furubotn and Pejovich (1972).

theory of the coproduction of property rights.

The evolution of property rights is an example of a coproduction process. Like any production process, a coproduction process relates an output to a variety of inputs. What is specific to the coproduction of property rights is that the inputs are generally provided by multiple agents from different organizations who act across time. The process starts with an agency that defines a set of rules for a scarce resource. To be effective, the newly established property rules require subsequent monitoring and policing, in other words enforcement, which is subsequently performed by other agencies. The result is that definition and enforcement are input activities that are provided by different agents, affect each other and are necessary in the production process, which makes their relationship an important part of the analysis. Understanding the role of each input and what variables affect that role becomes a central issue in the evolution of property rights.

I illustrate my theory in the context of water rights as they developed in pre-modern Bohemia.<sup>3</sup> The gradual expansion of water mills in the medieval period led to problems associated with the overexploitation and degradation of the commonly shared watercourses. The absence of well defined and enforced water rights became costly both to the users themselves and to their rulers. The establishment of a new institution, namely the Sworn Millers, followed. Its purpose was to define and enforce individual rights to the use of water resources. Understanding the production process yields insights not only into the development of water rights in Central Europe but also into other institutions involved in the production of property rights.

## 2. A Theory of Property Rights Coproduction

This article extends the neo-classical theory of rights evolution. In his pioneering work, Demsetz (1967, p. 350) formulates the thesis that “property rights develop to internalize externalities when the gains of internalization become larger than the cost of internalization”. Furthermore, Anderson and Hill (1975, p. 165) state that “establishing and protecting property rights is very much a productive activity toward which resources can be devoted.

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<sup>3</sup>For a similar approach with respect to property rights, see, for example, Demsetz (1967); Alchian and Demsetz (1973); Anderson and Hill (1975, 1983); Umbeck (1977); North (1987, 1990); Eggertsson (1992); Haddock and Kiesling (2002); Epstein (2004); Wyman (2005); Libecap (2007).

But, like any other activity, the amount of this investment will depend upon the marginal benefits and costs to investors of allocating resources to these endeavors.” Overall, economic theory suggests that property rights decisions are investment decisions. Property rights are simply economic goods and as such they will be produced once the benefits of doing so exceed the costs.<sup>4</sup>

However, none of these authors have explicitly explained how property rights production decisions are made. Whether an investment in new property rights is successful or not must depend on where, how and to whom that investment is allocated. My theory addresses these aspects.

### *2.1. Coproduction*

Setting and maintaining property rights requires resources. In other words, property rights are not free. In property rights production, decision makers such as the original appropriators, owners, claimants, resource users, communities or governments invest their valuable resources in order to establish laws, restrictions, regulations and social norms that aim to achieve greater internalization of beneficial and harmful effects. These decision makers are those who decide the mechanism by which the resources are to be allocated.

But property rights production to be successful must satisfy the following conditions: (1) the new property rules are well defined and (2) they are enforceable.<sup>5</sup>

Hence, the output is greater internalization of externalities and this is yielded by a combination of two distinguishable inputs: the definition of the new property rights and their enforcement. Here, definition is associated with establishing the set of economic and social relations that constrains one’s actions with respect to scarce resources and determines the punishment if damage occurs. Enforcement involves monitoring, policing and implementing these defined rules to scarce resources.<sup>6</sup>

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<sup>4</sup>See Demsetz (1967); Pejovich (1972); Anderson and Hill (1975); Umbeck (1977); Alston et al. (1995); Lueck and Miceli (2007).

<sup>5</sup>That these two condition are indeed crucial for the establishment of new property rights is well recognized in the literature (see Libecap, 1993; Williamson, 2000; Ostrom and Hess, 2010).

<sup>6</sup>To narrow down the analysis in this paper, I focus on definition and enforcement as the primary inputs in the evolution of property rights, but my argument is not limited to these two inputs only and can easily be extended to other activities.

Decomposing the production of property rights into definition and enforcement activities reveals several specific features of the production process. First, definition and enforcement are distinct inputs. Definition is not the same as enforcement. Each of these activities is generally performed at a different time and administrated by different agents. The process moves from defining property rights to enforcing them. Before any property right can be implemented, the rules of the game need to be defined. For example, a collective assembly such as a parliament or a single agent such as an absolutist ruler decides who owns what and what the means of enforcing that ownership will be. But enforcement itself has no place in this initial stage. Only after the property rule has been fully defined can its effects come into force. From that moment onwards, supervision and enforcement take place. A policing agency, judges or the subjects themselves supervise implementation of and compliance with the newly established set of rules.<sup>7</sup>

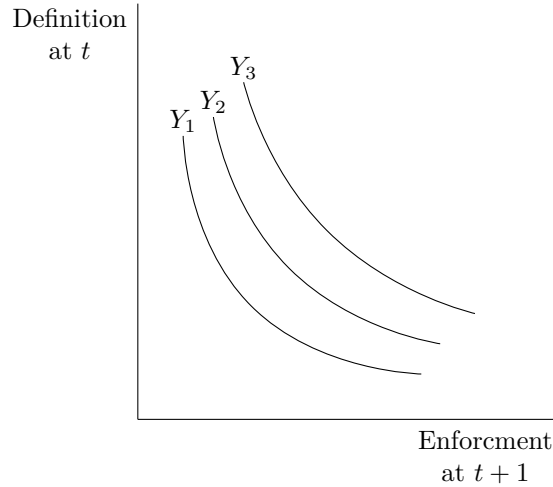
Second, definition and enforcement are interdependent. Although definition and enforcement are managed by different agents across time, they are dependent on each other. Definition must include “the degree to which the owner or the community is allowed to enforce the right” (Demsetz, 1964, p. 19) as well as consider available enforcement and monitoring techniques if property rights are to be enforced effectively. In the production process, this means that the optimal amount of one input affects the optimal amount of the other input. The relative roles of each input and the degree to which they influence each other then depends on the particular shapes of the production functions.

Third, definition and enforcement are indispensable inputs in property rights production. Neither definition nor enforcement can be neglected in the property rights production. In fact, both input activities are necessary for functioning property rights to be established. If property rights are perfectly defined but lack enforcement, the proposed rules will face implementation challenges. Under these conditions, the society runs the risk that the rules of the game will no longer be binding, since interacting individuals have no incentives to follow the specified property rules. The defined rights thus become ineffective. Whereas if property rights are enforced despite not being

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<sup>7</sup>Note that a property right can be a cultural norm. In this case, formal definition of the right may not take place at all, or only after a long period of time, but the right may still be enforceable once it is acknowledged by the society, for example through social ostracism.

Figure 1: Different levels of property rights



well defined, many external effects remain in place that are not captured by those rights, and thus externalities that were to be avoided persist.

The specific character of the property rights production process is similar to what Ostrom (1996) calls coproduction and Alchian and Demsetz (1972) call team production—a process that combines at least two inputs from different sources and these inputs are in a complementary relationship with respect to the output. In economic terms, the total output of internalization is not simply a sum of defining and enforcing activities, it is yielded by their joint production or coproduction.

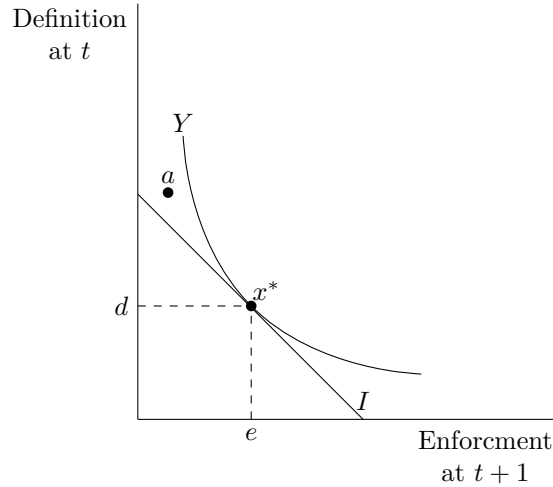
Figure 1 illustrates hypothetical levels of property rights  $Y_1$ ,  $Y_2$  and  $Y_3$  resulting from the trade-off between inputs of definition and enforcement.<sup>8</sup> The vertical axis represents the number of units of definition activity provided at time  $t$  whereas the horizontal axis represents the number of units of enforcement activity provided at time  $t + 1$ . The level of internalization remains the same along the curve while it increases when moving from  $Y_1$  to  $Y_3$ .

The maximum technically achievable level of internalization depends on constraints imposed on both definition and enforcement. As in any other production process, the amount of output is limited by the amount of avail-

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<sup>8</sup>The convex form of coproduction is standard in the literature (see Parks et al., 1981; Ostrom, 1996; Aligica and Tarko, 2013).

Figure 2: The optimal level of property rights



able resources. Line  $I$  in Figure 2 represents the maximum amount of resources available for investment in property rights production, or the budget constraint. Note that different points along the budget lead to the different output levels. So the question is how the available resources may be allocated between the two key activities in the most efficient way.

The greatest benefit from property rights is the highest level of the output-line  $Y$  subject to the given constraint  $I$ . In Figure 2, this is satisfied at point  $x^*$ , at which  $d$  units of definition and  $e$  units of enforcement are provided. Note that any other distribution of resources within the budget constraint  $I$  always leads to an inferior output level compared to  $x^*$  as it is below  $Y$ . Perhaps counter-intuitively, combinations of inputs that exceed the available resources  $I$  while between lines  $Q$  and  $I$  will also result in inferior outputs. For example, an alternative distribution of resources at point  $a$  is more expensive than  $x^*$  as it lies above  $I$  and still it leads to lower level of output as it lies below  $Y$ . Hence, greater investment in property rights production does not automatically generate more output. It matters where and how that investment is allocated. Now, the important question is what explains the particular level of property rights?

## 2.2. The Evolution of Property Rights

The structure of ownership is not constant over time and across places. When and how much communities invest in property rights production de-

depends on the goals and capacities of those who make these decisions as well as the processes and institutions through which they are made (Banner, 2002; Wyman, 2005; Fitzpatrick, 2006; Ostrom and Hess, 2010; Qiao and Upham, 2015).

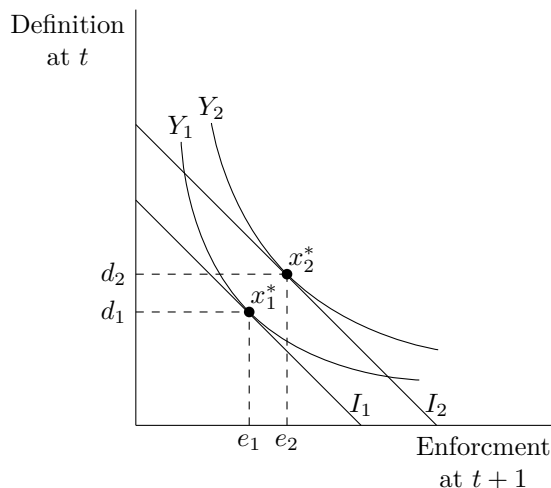
In coproduction, the decision maker compares the relevant gains from the expected internalization of externalities with the costs of definition and enforcement. At this point, those benefits and costs and changes to them matter only to the extent that they influence the decision maker. Different people can have different preferences regarding property rights regimes (Rose, 1990; Huang, 2000) and those preferences can change or be changed over time. Some decision makers may invest in the production of property rights for the sake of the whole society while others may do so only for their own benefit. It may be the case that a government invests in property rights to increase social welfare or to attract bribes from interest groups. Some decision makers will prefer private ownership, where others prefer collective rights. And so on. Therefore, recognizing who the decision maker is and what benefits and costs he derives from the rights is essential in order to be able to explain the evolution of property rights at a particular place and time.

The benefit reflects the value the decision maker attaches to the property rights' capacity to internalize harmful and beneficial effects. An increase in the perceived value of internalization increases the decision maker's willingness to increase the inputs into the production of property rights, and therefore increases the potential level of property rights produced. The logic is simple. The larger the perceived externalities, the greater the returns from additional rights and thus the greater the willingness to invest in their production. For example, sudden growth in the probability of losing ownership of a certain property results in greater value being placed in its protection. Rapid depletion of an environmental resource also affects the community's willingness to protect it by establishing clear rights in relation to its usage. Shifts in social, political and cultural attitudes as well as personal beliefs concerning the protection of property rights have the same effect—a greater willingness to invest in property rights. Negotiations with different stakeholders play a role as well. It may be not the decision maker's personal preference to invest in the production of property rights but a decision to do so may reflect the preferences of certain interest groups who may lobby for, and sometimes pay for the expansion of rights. In all these cases, the demand for property rights increases.

In Figure 3, an increase in the decision maker's desire to invest more in



Figure 3: Increase in demand for property rights

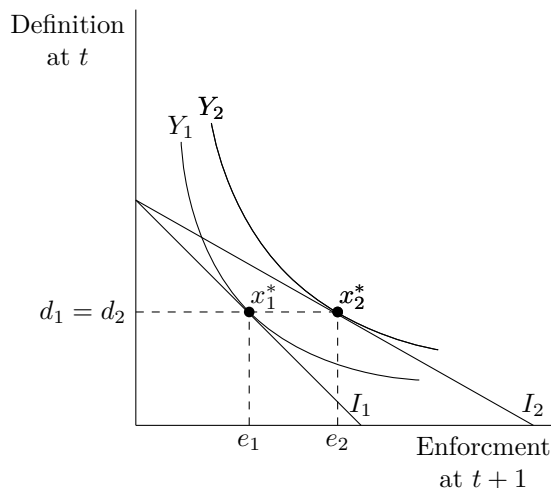


property rights is shown by the shift of the constraint from  $I_1$  to  $I_2$ . More property rights are expected to be produced as reflected by the increase in the potential level of the property rights from  $x_1^*$  to  $x_2^*$ . Both enforcement and definition activities must increase, from  $d_1$  to  $d_2$  and from  $e_1$  to  $e_2$ , in order to achieve this new potential level of property rights at  $x_2^*$ .

The cost, on the other hand, depends on the relative value of investment in property rights production and the prices of definition and enforcement. Changes in the opportunity cost or the amount of inputs necessary for production reflect this value. On the one hand, an increase in the endowment or a fall in alternative investment opportunities drives more resources towards the production of property rights. This situation is analytically the same as the previous case. The constraints move upwards, the potential level of internalization demands that more resources are invested in both definition and enforcement activities. On the other hand, a loss of income or growth in alternative investment opportunities drives resources away from property rights production. The constraint moves downwards, decreasing the level of internalization.

A change in the price of either definition or enforcement also alters the constraint. Any decline in the cost of defining property rights turns the constraint in favor of such definition activity, whereas any decline in the price of enforcing property rights turns the constraint in favor of enforcement activity. Differences in technology or the institutional settings in a society may

Figure 4: Decrease in price of enforcement



explain different production costs of enforcing and defining property rights. For example, inventions such as barbed wire are likely to decrease the cost of enforcing property rights. Similarly, the emergence of a new provider of enforcement activity increases competition between different providers and hence decreases the cost of enforcement. The process through which property rights are established also matters for the prices of definition and enforcement. For example, it is likely to be less expensive to define a set of rules in a society ruled by an autocrat than in a society governed by a direct democracy. This because the act of defining rules with a large group of people may be complex. However, property rules imposed by a single ruler may be more expensive to enforce compared to rules agreed upon by the majority.

Figure 4 shows an example of a new technology making enforcement cheaper.  $I_1$  shifts to  $I_2$  increasing the property rights output from  $x_1^*$  to  $x_2^*$ . Because inventions such as barbed wire make enforcement cheaper, more resources are invested into this activity, moving from  $e_1$  to  $e_2$ .

The above analysis provides a useful tool for explaining the potential level of property rights at a given time and place and how this level changes with changes in preferences, technologies or the availability of resources. It connects the evolution of property rights with the decision to invest in their definition and enforcement, using the coproduction model. However, the coproduction approach presents a challenge in managing inputs in a such way as to achieve a technically available level of property rights.

### 2.3. Issues with Coproduction

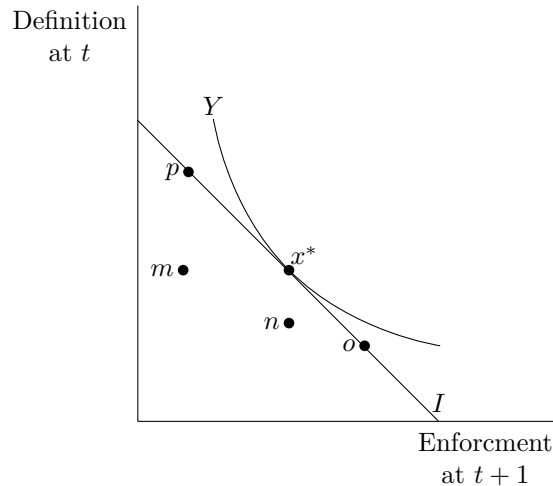
The coproduction process brings with it two problems that can occur in the production of property rights: misallocation of resources and insufficient effort.

The first problem occurs when the actual distribution of resources between definition and enforcement differs from the optimal distribution. This is primarily due to time inconsistency between the enforcement activity and the definition activity. Because rights are defined before they are enforced, it becomes difficult for the decision maker to decide how available resources  $I$  should be distributed between these input activities. Under this condition, the present definition may not fit the future enforcement and the future enforcement may not fit the present definition. The decision maker is not able to estimate the optimal level of definition and enforcement precisely and therefore a non-optimal combination of inputs is employed, resulting in the misallocation of resources. The larger the time gap between the two input activities, the greater room for error.

The second problem arises when the agents responsible for either definition or enforcement make less effort than is optimal. This is because of the principal-agent problem in the coproduction. The total output of internalization naturally relies upon the performance of those who provide definition and enforcement. This depends on their marginal contributions to the total output. Since inputs are interdependent in the production process, the marginal products of definition and enforcement are not precisely and separably observable. Thus, it is difficult for the decision maker to match the marginal contributions of the inputs to their costs. This creates space for the agents performing these tasks to shirk. Each agent tends to prefer leisure over work, therefore he will adjust his performance at work according to the ability of the producer to detect his relaxation in effort. As Alchian and Demsetz (1972, p 780) express it: “Only enough efforts will be made to equate the marginal gains of detection activity with the marginal costs of detection; and that implies a lower rate of productive effort and more shirking than in a costless monitoring, or measuring, world.”

Figure 5 provides illustrations of these fundamental problems. The optimal level of internalization for a given combination of inputs is shown as  $x^*$ , however misallocation and shirking result in this level not being achieved. If the agents providing the enforcement are shirking, the output is for example at  $m$ . If the agents providing definition are shirking, the output is for example at point  $n$ . Misallocation is shown, for example, at point  $o$ , at which the

Figure 5: Misallocation and shirking



decision maker underestimates the cost of definition or overestimates the cost of enforcement; and at point  $p$ , at which the decision maker underestimates the costs of enforcement or overestimates the cost of definition. Whether misallocation, insufficient effort or both are effective, the result is a lower level of output than could potentially be reached.

In such situations, enhancing productivity is the priority. Strategies to address shirking include methods of motivating agents to provide sufficient effort: employee benefits and internal audits may serve this function and shift production closer to  $x^*$ . Overcoming time inconsistency requires different strategies. Regularly re-evaluating the rules of the game and the budget distribution according to the current situation may be a solution that would bring production closer to  $x^*$ . The actual set of strategies will depend on a variety of factors including culture, technology, governance and knowledge.

### 3. Water Rights in Pre-modern Bohemia

In the above section, I argued that the structure of ownership is a complex institution consisting of necessary and interdependent activities. Adding the relationship between the definition activity and the enforcement activity into the production process can explain variance in property rights and their capacity to internalize externalities. This section employs that theory of the coproduction of property rights to explain the development of water rights

in pre-modern Bohemia.

### *3.1. Externality in the Absence of Water Rights*

The reason for establishing water rights is to internalize external effects that are associated with the use of water resources. This section explains how and why the question of establishing a comprehensive system of water rights became important during the Middle Ages in the Kingdom of Bohemia.

The early governance of rivers, streams and ponds was straightforward. Bohemian rulers had the sovereign privilege of ownership of all watercourses and were entitled to royalties from water-related commercial activities, known as ‘the water regal’ (*vodní regal*). Part of this royal privilege was the right to milling, which was the right to build and operate water-powered machinery on streams, including the right to construct water regulating barriers, the right to fishery and the right to navigation. But the rulers did not run mills themselves, or fish or sail; instead, they bestowed or granted these rights to interested users. Often, they did so in return for a promise of payment or as collateral. As a result of this process of bargaining with the feudal authorities, commercial activities on rivers, streams and ponds eventually came under the supervision of the owners of local estates (Jičínský, 1870, pp. 68-69; Čížek, 1886, p. 7-9).

This system of bargaining could only work if the local rulers guaranteed legal rights to the water resources they sold. If the users could not manifest their rights to watercourses, they would not pay for them and hence the rulers would not receive any royalties. Therefore it was in the authorities’ best interests to prevent any conflicts over water rights. Hence, the Bohemian rulers were the principal decision-makers guaranteeing a system of water rights in the kingdom.<sup>9</sup>

Initially, rivers and streams were considered part of the public domain. Once an individual had obtained the rights to commercial use of the river—fishing, transporting goods or building a mill—there were no additional rules governing their actions with respect to the common resource (Kult, 2014). In this early period, there was enough space for all users and conflicts over individual rights were rather sporadic. There was no need for a comprehensive system of water rights. Disputes were mostly limited to fishery and

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<sup>9</sup>Protection of property rights was a particularly important factor for the development of mills in Europe (see van Bavel et al., 2017).

navigability, which were under the supervision of royal or delegated local authorities. Limited evidence on this issue shows that if a conflict between stream users arose or harm was done, the litigants could approach magistrates (*smírčí soudce*), who functioned as judges and law enforcers in local matters on behalf of the feudal authorities. These magistrates reviewed the disputes and provided judgments on the parties' further use of the common watercourses (Maříková, 2012).

However, this initial situation changed with the introduction of large scale milling in the Late Middle Ages. The expansion of milling technology and its wide adoption had three immediate consequences. First, it invoked new harmful effects to which medieval society had not previously been accustomed: the expansion of milling technology spurred the construction of hydro-power dams or weirs, which were artificial barriers built across rivers and streams in order to alter their flow and level. Their primary purpose was to operate millwheels.<sup>10</sup> The principle was simple. The hydro-power dams created a waterfall, which was a source of power used to drive water-mills (or any other waterwheel-operated machinery). The higher the dam was, the greater the rate of water flow at the base or top of the millwheel, and hence the greater the mill's production capacities. Furthermore, a higher dam meant a larger capacity in the reservoir behind the dam, enabling millers to operate the mills even in unfavorable weather conditions (for an overview, see Reynolds, 2002, p. 62).

However, building high dams had undesirable consequences in terms of the external costs imposed on other river users and society in general. The rate of water flow at a given millwheel was not only affected by the height of its own dam but also by the height of other dams downstream from it. In economic terms, the downstream miller imposes an externality on the upstream miller. If the downstream millers built their dams too high, the level of water upstream would increase and the waterfall from the upstream dam would become smaller and therefore upstream millers would be left without sufficient power to drive their mills. From an analytic point of view, high dams led to suboptimal levels of production in mills and other water facilities. Furthermore, high dams did not only steal water from upstream millers

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<sup>10</sup>Mill dams also created artificial barriers that blocked the movement of migratory fish species and by doing so offered seasonal opportunities for fishers, see Hoffmann (1996, 2000).

but often caused additional damage to third parties or undermined other uses of the rivers and streams. The reservoirs created behind dams could cause flooding in neighboring pastures and estates. The presence of high water barriers could also limit fishery access along streams by preventing fish migration, and could disrupt water transit and trade.<sup>11</sup> All these problems pointed to a new externality problem.

Second, as new milling technology was widely adopted, the number of stakeholders increased and thus externality problems became more likely to occur. The first mills emerged in Bohemia in the 10th century and from the 13th century water mills could be found across the whole country (Maříková, 2005; Kotyza, 2014).<sup>12</sup> The milling boom followed during the 14th century. The use of water wheels became widespread, not only for grinding grain but also for processing and manufacturing of a whole range of products including timber, bark, woollen cloth, oil, leather, iron tools, iron, glass, ore minerals, paper, beer, sugar, coins and so on.<sup>13</sup> Winter (1909, pp. 643) estimates that by the end of the 16th century, each rural town and its neighborhood had on average 4–7 mills, and even more could be found in large cities. The towns of Prague had together 12 groups of mills, each of them with up to 10 individual mills, and other mills in the close neighborhood.<sup>14</sup>

Third, the number of disputes over individual water rights increased during the Late Middle Ages. Historical evidence shows that increasing utilization of watercourses in the 13th century led to a variety of conflicts between

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<sup>11</sup>For the problems associated with water mills in Bohemia, see Maříková (2012); Klimek (2015). These problems were common across Europe, see for example, Gimpel (1977, pp. 18-22) for Toulouse, Blair (2007) for the Thames or Schenk (2010) for Florence.

<sup>12</sup>Even though the Chronicle of Václav Hájek z Libočan (1541, chap. VIII and XXIII) dated the first Bohemian mills to the 8th century, there is no historical evidence to support this observation.

<sup>13</sup>For the application of water wheels, see in general Gies and Gies (1995, p. 265); Gimpel (1977, pp. 1-27); Lewis et al. (2014); Munro (2003); Lucas (2005, 2006); Smil, 1994, pp. 103-112; Smil (2004); Reynolds (2002, pp. 69-97). For Bohemia in particular, see Štěpán and Křivanová (2000, pp. 123-150).

<sup>14</sup>The groups of mills in Prague were as follows (with their approximate numbers of mills): Šitkovské (5), Na horních lodkách (5-9), Šerlinské (3-4), Staroměstské (10), Nové (unknown), Na dolních lodkách (10), Helmovy (10), Na Kameni (1), Kartouzské (2-3), Na huti v Čertovce (1), Velkopřevorský (1), Mlýny Sovovy (1). In addition to these twelve groups of mills Soukup (1905, pp. 12-43) also mentions other groups of mills, which did not survive over time. For Prague mills, see Soukup (1905, pp. 12-43); Winter (1909, p. 640); Klempera (2001b).

or with owners of mills (e.g. Šebánek and Dušková, 1962, pp. 94-95, 140-142; Šebánek and Dušková, 1974, pp. 106-107, 136-137; Šebánek and Dušková, 1981, pp. 481-482, 611-612). The most frequent causes of these disputes were changes in the water level. Millers were often blamed for stealing water from upstream users. Some were also accused of flooding local estates, disrupting navigability or causing damage to fishermen. At the heart of all these disputes were the mill weirs built by millers to increase the productivity of their mills.<sup>15</sup>

All these consequences increased the significance of the externality problem associated with common watercourses. With an increasing number of conflicts over the use of the watercourses, the system based on local courts was an insufficient solution, especially since the magistrates were not experts in milling and water-usage and were only able to resolve conflicts *ex post*. Thus, a new comprehensive system of water rights was necessary “if mutual harming of various users of rivers and endangering of public welfare should be prevented” (Maříková, 2012, p. 20).

### *3.2. The Water Rights Evolution*

My theory predicts that as the potential benefits of overcoming the externality problem increase, investment in the production of property rights increases as well. The evidence from the Bohemian millers supports this prediction.

To effectively regulate the use of the common watercourses, the ruler delegated the authority to define water rights, and later also enforce them, to the institution of the Sworn Millers. This institution originally administered mills located in the area of Prague, where water disputes were the most severe. Its foundation was initiated by Charles, the Margrave of Moravia (later Holy Roman Emperor Charles IV), who in 1340 ordered the representatives of the Old Town of Prague to immediately establish a universal height–*unam mensuram communem*–for Prague weirs (Emler, 1882, p. 309, n. 782). In the same year, the Old Town appointed eight officials under oath as experts in matters of water law–the Sworn Millers–half of whom were city representatives and half of whom were professional millers; they were tasked with setting standards for all Prague mills (Emler, 1882, p. 327, n. 839).<sup>16</sup>

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<sup>15</sup>For early conflicts with millers in general, see Maříková (2005, 2012); Klimek (2015).

<sup>16</sup>The establishment of the office of the Sworn Millers was confirmed later in 1340 by the king of Bohemia, John of Luxemburg, see Emler (1882, p. 330, n. 846).



As water mills spread across the region in the centuries that followed, the influence of the Sworn Millers and the official scope of their activities expanded beyond the borders of Prague. By the end of the 16th century, the Sworn Millers had become the primary authority in matters of water rights in Bohemia, and in place of their original 8 members there were now 24 (PCA, SR, s. 3012). During this time the development of the institution stabilized, and it remained unchanged until the Josephine reforms in the 18th century.

The primary function of the Sworn Millers was to conduct inspections regarding the use of watercourses and the operation of mills, with an emphasis placed on the observance of the heights of hydro-power dams. In the inspected area, the Sworn Millers specified the rules of usage of the common watercourses, which they recorded in memorial books. Hence, these inspections became the core of a new system of water rights in the Kingdom of Bohemia.

Table 1 and Table 2 depict the expansion of the Sworn Millers' influence. Table 1 reflects the frequency and variation of larger inspections conducted by the Sworn Millers from their establishment until the end of the 16th century. While in the office's early years (in the 14th century) only a few such inspections were recorded, in the next century the number of inspections doubled, and by the end of the 16th century inspections by sworn millers were conducted on a regular basis. With the increasing frequency of inspections, the scope of the inspections also increased. The Sworn Millers aimed to regulate and supervising the heights of weirs, which were the main source of disputes between users of watercourses. But that was not all they did: by the end of the 16th century, the official agenda of the Sworn Millers further included giving expert opinions on mill construction and reconstruction, water facility supervision, river navigability, milling law and river pollution.

Not only did the frequency and variation of inspections increase over time, but so did their geographical variance. This is shown in Table 2. At first the Sworn Millers only conducted inspections in the towns of Prague, but as the number of mills across the region increased, their services began to be required in other locations as well. In the 16th century, the Sworn Millers were regularly sent to inspect weirs and other water facilities in all parts of Bohemia.

My theory predicts that the activities associated with the production of water rights will be the strongest in regions where harmful effects are most likely to occur. The variation in the locations of the inspections allows us to test this. Table 3 combines the frequency of inspections for the 16th century

Table 1: Recorded inspections by the Sworn Millers 1340–1600 according to the main object

| Time Interval | Weirs |      | Non-weirs |     | Total |
|---------------|-------|------|-----------|-----|-------|
|               | No.   | %    | No.       | %   |       |
| <1400         | 2     | 100% | 0         | 0%  | 2     |
| 1460-1480     | 3     | 100% | 0         | 0%  | 3     |
| 1481-1500     | 1     | 50%  | 1         | 50% | 2     |
| 1501-1520     | 2     | 67%  | 1         | 33% | 3     |
| 1521-1540     | 7     | 86%  | 2         | 14% | 7     |
| 1541-1560     | 8     | 100% | 0         | 0%  | 8     |
| 1561-1580     | 12    | 67%  | 6         | 33% | 18    |
| 1581-1600     | 24    | 63%  | 14        | 37% | 38    |

There are no values for 1400-1460 due to a lack of written sources, probably as a result of the Hussite Wars.

Sources: PCA, SR, s. 60; PCA, SR, s. 101; PCA, SR, s. 993; PCA, SR, s. 1831; PCA, SR, s. 1833; PCA, SR, s. 2068; PCA, SR, s. 2133; PCA, SR, s. 2134; PCA, SR, s. 2141; PCA, SR, s. 3010; PCA, SR, s. 3012; PCA, SR, s. 3469; PCA, SR, s. 7802; PCA, SR, s. 8365; PCA, MHMP I., Hlavní spisovna, oddělení B (1822–1826), s. B 34/2, karton 963a and Emler (1882, p. 327, n. 839).

with the approximate number of mills in the location. The evidence suggests that the frequency of inspections did indeed increase in locations with more mills. Inspections were conducted more often in towns with large numbers of mills, like Prague, Tábor and Hradec Králové, than in regions with smaller numbers of mills. The demand for water law seems to have been higher in places where externality problems were likely to be more severe.

In line with my theory, the development of water law in pre-modern Bohemia was a response to the new externality problems associated with the expansion of milling technology in the medieval and early modern period. Increasing utilization of watercourses increased the benefits of property rights production and thus the local rulers' willingness to further invest in water rights. This is identical to the case in Figure 2: the budget constraint moves upwards and more property rights can be produced. In order to achieve a greater internalization of the externalities on Bohemian streams, rivers and ponds, the process of establishing of new water rights had to be addressed.

Table 2: Recorded inspections by the Sworn Millers 1340–1600 by frequency and location

| Time Interval | Prague |      | Non-Prague |     | Total |
|---------------|--------|------|------------|-----|-------|
|               | No.    | %    | No.        | %   |       |
| <1400         | 2      | 100% | 0          | 0%  | 2     |
| 1460-1480     | 2      | 67%  | 1          | 33% | 3     |
| 1481-1500     | 2      | 100% | 0          | 0%  | 2     |
| 1501-1520     | 2      | 67%  | 1          | 33% | 3     |
| 1521-1540     | 1      | 14%  | 6          | 86% | 7     |
| 1541-1560     | 1      | 13%  | 7          | 88% | 8     |
| 1561-1580     | 8      | 44%  | 10         | 56% | 18    |
| 1581-1600     | 17     | 45%  | 21         | 55% | 38    |

There are no values for 1400-1460 due to lack of written sources probably as a result of the Hussite Wars.

Sources: PCA, SR, s. 60; PCA, SR, s. 101; PCA, SR, s. 993; PCA, SR, s. 1831; PCA, SR, s. 1833; PCA, SR, s. 2068; PCA, SR, s. 2133; PCA, SR, s. 2134; PCA, SR, s. 2141; PCA, SR, s. 3010; PCA, SR, s. 3012; PCA, SR, s. 3469; PCA, SR, s. 7802; PCA, SR, s. 8365; PCA, MHMP I., Hlavní spisovna, oddělení B (1822–1826), s. B 34/2, karton 963a and Emler (1882, p. 327, n. 839).

### 3.3. *The Definition and Enforcement of Water Rights*

According to my theory, the development of new property rights as a response to the emergence of new harmful effects must be accompanied by the expansion of definition and enforcement activities. The history of the Sworn Millers' activities supports this prediction.

At the heart of the externality problems on Bohemian rivers was the millers' overexploitation of water flow at the expense of other river users. Water flow was not traditionally a resource to which ownership could be easily established. Unlike the mills themselves, which were linked with the land, the water that operated them was moving from upstream to downstream neighbourhoods. To prevent millers from exploiting the water flow, the Sworn Millers invented and supervised a system of water marks that addressed the source of the problem—the height of the mill weirs.

A water mark (*vodní cejch*) was an official mark, generally on wooden pole or sometimes on a stone, floodgate, mill or other convenient place, to determine the maximum water level behind the mill dams. The mark simply set an upper limit for the water level. The level of water at the dam could be freely regulated up to the water mark. However, millers who allowed the

Table 3: The frequency of recorded inspections by the Sworn Millers and the number of mills in the inspected location 1500-1600

| Number of inspections | Number of mills |         |         | Locations |
|-----------------------|-----------------|---------|---------|-----------|
|                       | Minimum         | Maximum | Average |           |
| 1                     | 1               | 7       | 2.42    | 12        |
| 2-3                   | 4               | 8       | 7       | 3         |
| 4-6                   | 8               | 12      | 10      | 2         |
| 29 (Prague)           | -               | -       | over 50 | 1         |

For discussion about the number of mills in Prague, see Footnote 14. Several locations were excluded because of the lack of sources regarding the number of mills.

Sources: PCA, SR, s. 101; PCA, SR, s. 1833; PCA, SR, s. 2068; PCA, SR, s. 2133; PCA, SR, s. 2134; PCA, SR, s. 2141; PCA, SR, s. 3010; PCA, SR, s. 3012; PCA, SR, s. 3469; PCA, SR, s. 7802; PCA, SR, s. 8365; Klempera (2000b,a, 2001b,a, 2002, 2003b,a,c, 2005); Soukup (1905, pp. 12-43).

level of water at their dam to rise above the water mark exposed themselves to financial or manorial punishment.

The historical evidence shows that setting water marks was one of the Sworn Millers' main responsibilities from their early days (Emler, 1882, p. 309, n. 782; PCA, SR, s. 993, p. 66.). The marking procedure took place during mill inspections of two kinds. Firstly, general inspections took place with the purpose of setting up water marks at all mills in the region (e.g. PCA, SR, s. 3012, ff. 238v, 255v–256r; PCA, SR, s. 3469, ff. 75v-76v, 77r; PCA, SR, s. 7802, ff. 1r–2r, 3r–5v.). For example, in 1581 the Sworn Millers recorded an inspection in the town of Stříbro whose purpose was to “set and mark mills, weirs and thresholds, so that each single mill would follow the marking for the future and present time under the fine” (PCA, SR, s. 7802, ff. 1r). Secondly, water marks were set during mill inspections that took place when a mill was reconstructed or newly opened (e.g. PCA, SR, s. 7802, ff. 15v–16r, 17r–18v). Winter (1905, p. 160) illustrates a typical procedure during the opening of mills in the 15th century with the example of Lukášovic Mills in Poříčí. The opening was a ceremony during which the Sworn Millers set the water mark, which was “honestly made according to the rights of other mills” so that “no harm would be made to the community, especially to the estates (mills) upstream as well as downstream”.

As the theory explains, this investment in the definition of water rights was not sufficient: enforcement had to follow. The founding documents of

the Sworn Millers from 1340 suggest that the representatives of the Old Town of Prague were originally responsible for this activity. Any contravention of water marks was to be forwarded to a reeve and the elders of the Old Town of Prague, who sent millers to inspect the location in question. If the claim was valid, the offender was punished on behalf of the city with a fine of 10 shocks of groschen the first time, 20 shocks the second time, and 30 shocks the third time combined with a prohibition from milling for a year (Emler, 1882, p. 327, n. 839). In the 1440s, the Old Town council fortified their position. They reserved the right to resolve disputes among millers with the help of the Sworn Millers: “Item no miller shall hold more water than that marked by the town councilors with the Sworn Millers; if any one holds more, he shall pay 10 shocks of groschen to the masters [city representatives]” (Janáček, 1983, p. 129). Furthermore, the Old Town expressed that “no one shall judge mills and weirs other than Prague councilors” (Schranil, 1916, p. 71).

The Old Town authorities were not specialists in water resource management. Their knowledge about mills and hydro-power dams was extremely limited. Therefore, to make a valid decision, the city representatives requested the assistance of professional millers (Emler, 1882, p. 327, n. 839). This, however, was inefficient. It prolonged the enforcement process and increased its cost. Furthermore, as the office extended its jurisdiction across Bohemia by the beginning of the 16th century (see Table 2), it became extremely inconvenient to resolve disputes by means of this process involving councilors from the Old Town of Prague.

Hence, the competence needed to resolve conflicts over defined water rights had changed. No later than the beginning of 16th century, the enforcement activity moved from the Old Town councilors to the Sworn Millers. In 1534, Holy Roman Emperor Ferdinand I clearly stated that the Sworn Millers were responsible for mills, weirs and water levels and if any problems arose among millers they “shall secure it, inspect it, and implement the solution” and “what they assess shall be taken up by both mills [disputants]” (PCA, SR, s. 1833, f. 66r). To supplement the coercive authority of the Old Town, the Sworn Millers’ decisions were guaranteed by local authorities, usually by a portreeve and town councilors (e.g. PCA, SR, s. 7802, ff. 29r–31v) or a local governor (e.g. PCA, SR, s. 7802, ff. 7v–8v). So by the early modern period, the Sworn Millers did not only define a variety of water rights, they also monitored these rights, resolved conflicts over them and decided upon sanctions when they were broken. They became responsible for both definition and enforcement.

Extending the agenda of the Sworn Millers to enforcement was an effective way to reduce the costs of water rights production and eliminate shirking. As construction engineers and experts in milling, the Sworn Millers were in the best position to resolve disputes over water rights and to determine an adequate fine or other sort of punishment. In the coproduction model, this strategy corresponds to increasing the available budget (shifting the constraint upwards) and hence increasing the production of property rights. Furthermore, since the same office was then responsible for the entire production process, shirking was likely to be reduced.

Furthermore, to make their decisions more reliable, a single Sworn Miller never decided any case alone: all cases were decided collectively to avoid any harm to their reputation, as their ordinances required (PCA, SR, s. 3012, ff. 239r-246r). This was secured by the revision of the case after the millers returned to Prague after an inspection, where they could raise the matter with their colleagues and decide on its outcome together (e.g. PCA, SR, s. 3012, ff. 48r-51r, 176v-177r).

Another strategy to reduce the cost of producing water rights was to combine definition and enforcement. Many inspections were carried out with the primary purpose of resolving an immediate problem among the water users, but while doing so the Sworn Millers also updated or established new water marks. During an inspection in the town of Tábor in 1567, the Sworn Millers resolved disputes among local millers over their water marks and also set up a new water mark at the local drapers' mill (PCA, SR, s. 101, f. 264rv). Similarly, in 1600 the Sworn Millers were invited to Rokycany to decide disputes among the local millers there and set new water marks at the local mills (PCA, SR, s. 7802, ff. 37r-39v). Because the same people were responsible for defining and enforcing the water rights, they could combine these two activities into one and therefore shift the budget constraint even further upwards, increasing property rights production.

A specific case of combining enforcement and definition activities in a single inspection was the general inspection. This was a large inspection in all three towns of Prague, accompanied by government representatives, during which all mills, weirs and water marks were inspected. It was conducted regularly, as the situation on the river Vltava and smaller streams changed over time. These general inspections took place in 1340, 1364, 1479, 1517, 1530, 1581 and 1594 (PCA, SR, s. 993, p. 66; PCA, SR, s. 2133, ff. 382v-383v., 513rv, 384r-386r; PCA, SR, s. 7802, ff. 3r-5v, 29r-31v; Emler, 1882, p. 327, n. 839). During these inspections the existing water rights

were reviewed and if necessary updated to fit the new circumstances. The Sworn Millers defined new water marks, renewed or updated old ones, checked riverbank pollution and assessed fines for noncomplying individuals.

Conducting regular inspections was a way of reducing the costs of the entire system. They enabled a more effective allocation of resources between definition activity and enforcement activity and hence shifted water rights production closer to its potential. Though this strategy provided a means of solving time inconsistency, it potentially generated uncertainty for stream users as their rights could frequently be altered. In order to avoid potential problems, water rights holders were always present at the inspections and were allowed to challenge the Sworn Millers' decisions. Furthermore, longer intervals between the general inspections reduced potential instability.

The initiating practice had a specific role in the production process. Before the Sworn Millers could inspect water rights in any location, they had to be invited by the local authorities or by a private entity who wanted to resolve a conflict or needed some sort of assistance. This initiator was then responsible for covering the cost of the inspection (e.g. PCA, SR, s. 3012, ff. 29v-30r, 228r-229v). This initiating practice helped to overcome the principal-agent problem. The initiator became an investor or decision-maker in the particular water rights dispute and as such he had the best incentives to supervise the Sworn Millers in their task. In fact local authorities, citizens and disputants accompanied and hence oversaw these inspections (e.g. PCA, SR, s. 8365, ff. 70v-72r; PCA, SR, s. 2133, f. 395rv).

Moreover, the Sworn Millers were themselves motivated to provide a good service because they could be substituted. Rather than approaching the Sworn Millers, locals could choose to resolve their problems themselves or with the help of a local court. Even though there is no systematic evidence of the prices charged by these different justice providers, there were certainly several options available for resolving water rights disputes. This motivated the Sworn Millers to maintain their reputation. If the Sworn Millers had a bad name, they would receive no more invitations to carry out inspections. As a result, the threat of losing their reputation together with supervision by local initiators motivated the Sworn Millers to provide high quality service. In terms of the coproduction model, competition among different providers of water rights definition and enforcement reduced the price of the input activities and hence increased the output of the production process.

#### 4. Conclusion

My analysis makes the allocation of resources an important factor in property rights production. Adding the coproduction relationship into the evolution of property rights can be useful for explaining the problems associated with a lack of property rights in several respects.

First, investment in property rights production is an economic activity and as such it has to be profitable for the investor: the benefits must exceed the costs. The degree of the enforcement and definition activity is affected on one side by demand for internalization and on the other by the relative value of the invested resources necessary for production. As shown, an increase in perceived externalities and the expansion of the available budget will both increase the property rights production.

Second, property rights production consists of two activities that are necessary and interdependent. Simply defining property rights is not sufficient to achieve the internalization of externalities. Where property rules are defined they must also be enforced. If we focus only on one activity, the internalization will be inconsiderable. That is why in reality we observe that successful systems of property rights consist of both definition and enforcement activities.

Third, the coproduction nature of property rights production creates opportunities for misallocation of resources and insufficient effort. Because property rights are first defined and then enforced, the producers may underestimate or overestimate the importance of each of these activities and hence misallocate their resources. Moreover, the agents responsible for these activities may shirk their work responsibilities since their marginal contribution to the output is hardly observable. That is why the reputation mechanism, regular monitoring and other specific strategies are employed in the successful production of property rights.



## **Appendix**

Primary sources are from the Prague City Archives located at Archivní 6, 149 00 Praha 4, Czech Republic. The abbreviations by which these sources are referred to are as follows: PCA (the Prague City Archives), SR (fond Sbírka rukopisů), MHMP I (fond Magistrát hlavního města Prahy I.), s. (signatura).

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