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RESEARCH ARTICLE

Shared Patterns in Long-Term Dynamics of Commons as Institutions for Collective Action

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We present an analysis of regulatory activities in historical commons offering a unique picture of their long-term institutional dynamics. The analysis took into account almost 3,800 regulatory activities in eighteen European commons in two countries across seven centuries. Despite differences in time and space, we found a shared pattern where an initial, highly-dynamic institutional-definition phase was followed by a relatively long period of stability and a final burst of activities, possibly in an attempt to respond to new challenges. In addition, most of the initial regulatory activities focused on resource use, while towards the end other activities prevailed. Our approach allows for a better understanding of institutional dynamics and our findings also provide important insights about how to regulate the use of current natural resources.

Keywords: historical commons; shared patterns; ADICO framework; institutional evolution; rule change

1 Introduction

Commons are governance regimes set-up to coordinate the exploitation of natural or man-made resources shared among different users (Ostrom 1990, 2005). Understanding commons is important as the underlying social dilemma situation may lead to resource overuse and ultimately depletion if not appropriately managed (Hardin 1968). However, long-term processes of rule-making (which we refer to as ‘regulatory activities’) in commons as institutions for collective action are poorly understood (Ostrom 2014; De Moor 2015; Boyd et al. 2018). We present a quantitative analysis of eighteen European commons in two countries across seven centuries offering a unique picture of long-term institutional dynamics. The analysis relies on the database recently built as part of the Common Rules Project (De Moor et al. 2016). This database includes detailed formal rules that were developed and registered to facilitate the functioning of commons, including their changes across several centuries. Despite the differences in time and space, we found a shared pattern where an initial, highly-dynamic institutional-definition phase is followed by a relatively long period of stability and a final burst of new regulatory activity, possibly in an attempt to respond to internal or external factors menacing the survival of the commons. Our findings not only challenge some elements of the current view on institutional dynamics (North 2005; Ostrom 2005) but also provide important insights on the management of natural resources worldwide and how commons being formed today may be expected to evolve (Dietz et al. 2003).

The expression ‘common-pool resources’ (CPRs) formalises the broader concept of commons and refers to a class of goods defined by two characteristics: a difficult exclusion of potential beneficiaries and a high degree of subtractability, i.e., rivalry of consumption (Ostrom 1990). These characteristics complicate the management of CPRs: as in the private good case, the subtraction of resource units from the commons (e.g., timber from a forest, water from a basin, etc.) by one user reduces the total quantity available to others. As

in the public good case, it is difficult to force users to contribute to the commons-maintenance activities (e.g., repairing common irrigation infrastructures). This led Hardin in his famous ‘Tragedy of the Commons’ article to depict the problem by means of a model akin to a n -player version of the prisoner’s dilemma (Hardin 1968). Under this framework, as users have no rational incentive to limit their consumption or to provide labour for the commons maintenance, the possibilities to avoid the resource degradation or destruction are extremely limited. More generally, CPR-use implies a social dilemma – i.e., a condition where the maximization of individual self-interest yields outcomes leaving all participants worse off than feasible alternatives (Ostrom 1998). This depends on the structure of the situation faced by the commoners, and holds quite independently of the physical nature of the shared good. The CPR concept can indeed be extended to non-natural and even to non-material resources, such as knowledge (Anderies and Janssen 2013).

Independently of the nature of the shared good, research suggested that institutions – i.e., systems of rules and enforcement mechanisms – are the key to overcome the tragedy of the commons (North 1990; Ostrom 1990, 2005). Rules indeed represent the main instruments used by humans to overcome selfish temptations in social dilemmas and achieve collectively beneficial outcomes (Ostrom 1998, 2000). Empirical research based on multiple methods has shown how commoners themselves can coordinate their actions around certain sets of rules in order to increase both their welfare and the sustainability of the resource use (Dietz et al. 2003; Bravo and De Moor 2008; Poteete et al. 2010). The resulting self-governed regimes often exhibited high levels of resilience, and were able to survive for centuries in front of internal changes and external shocks (Ostrom 2005; De Moor 2015). However, the process of rule change underlying this institutional longevity is poorly understood (Ostrom 2014). Past contributions to the analysis of institutional change typically oscillated between sophisticated theoretical exercises and the in-depth analysis of a small number of case studies under limited time, almost always ignoring their long-term development. In other words, the field lacks a serious longitudinal perspective, whereas now only a static picture of the functioning of institutions is usually provided. Only recently, attempts have been made to empirically understand the dynamics of institutional change within a commons setting in the longer run (De Moor 2015; De Moor et al. 2016).

Overall, understanding how institutions changed over time is one of the most challenging research areas for social scientists and increasingly also for humanities scholars. In the latter field, in particular the area of economic history has provided new insights, amongst others by the works of by Douglass North (2005), Avner Greif (2006) or Daron Acemoglu and James Robinson (2010). In terms of historical, longitudinal analysis of in particular institutions for collective action, there is however very little empirically based research. Elinor Ostrom (1990), Jean Emsminger (1996), and Tobias Haller (2013) have all provided theories about how institutions for collective action evolve over time but the amount of empirical evidence provided to substantiate their specific claims is small. Moreover, in their studies they look into only fairly short time periods, whereas commons are typically capable – as our data show as well – of reaching very high ‘ages’, even when confronted with multiple crises along the way (Laborda Pemán 2017). We intend to contribute to this body of literature With our new approach to the empirically grounded-research on institutional dynamics with our new approach to empirically grounded and longitudinal research on institutional dynamics.

2 Methods

2.1 Data

To improve our understanding of these long-term dynamics, we analysed the data collected as part of the Commons Rules Project. During the lifetime of the institutions that were recorded, some spanning more than six hundred years, groups of commoners regularly created new rules or adapted existing rules on the use, governance and management of resources (henceforth, ‘regulatory activities’). The database contains background information on all of the Dutch, English, Spanish, Italian and Belgian cases that were studied, a literal transcription of all the regulatory activities as taken from the original archival sources, and a translation into modern English for all these activities.

Moreover, an extensive coding system was used to allow in-depth analysis of the regulatory activities and accompanying sanctioning (De Moor et al. 2016). Having transcribed and scrutinized the available written sources, text parts containing actual decisions and/or rules were distilled from the text and translated into modern-day English. To be able to analyse rules on specific topics properly, these rules (qualified as ‘Original Rules’) were split up into several ‘Individual Rules’ in case the text contained more than one decision within the same sentence (e.g. in a rule of the marke Exel from 1634, in one and the same sentence both a standing prohibition on digging and transporting peat was prolonged, as well exemptions mentioned for

specific commoners and purposes). The Individual Rules-level formed the basis for the actual data analysis. In the next step of the coding process, for each Individual Rule it was determined which domain the rule referred to: whether the rule concerned primarily the use of resources, the access to the common and its resources, the management system of the common, the governance structure, or other domains. Next, it was determined per Individual Rule whether its nature was permissive, prohibitive, creating an obligation, a rejection of a proposed rule, or of a more general nature. Also, by comparison with previous rules in the same source, it was determined whether the rule was introduced for the first time ('first mentioning'), an adjustment of a previously existing rule, or a repetition of a previously existing rule. To be able to do this, the coding per source needed to be performed preferably by one and the same coder, as this coder was most aware of the rules previously coded. After coding all rules, the status of rules that were initially mentioned as first mentioning but did not have any related petition or adjustment within the source, was changed to 'singular mentioning'. In the last stage of qualifying the Individual Rules, it was determined to whom the rule referred: to all commoners, just to the management of the common, or to specific (groups of) commoners. At the next level, it was identified which sanctions were mentioned within the regulations for disobeying the recorded rules. These sanctions were also coded for nature of the sanction (e.g. monetary, physical), the person(s) affected by the disobedience, and the type of sanctioning (per case/measure). Special attention was paid whether the sanction concerned graduated sanctioning, i.e. a sanction that became more severe if the trespasser repeated his trespass. To avoid multiple interpretations of the same source, all individual sources were coded by the same coder. By comparing coding samples with other coders consistency within the coding group was checked and preserved.

For our present analysis, we selected the commons with an extensive and reliable documentation of regulatory activities (see the supplementary method in the Appendix), in order to identify the dynamics within the organisation. All selected cases had records that lasted for at least two hundred years. The resources shared by the commoners were land use for pasture and/or land peat extraction. As our goal was to look into the institutional dynamics, we focused on regulatory activities. The resulting dataset included 3,775 regulatory activities for ten commons in the Netherlands and eight in the United Kingdom across six centuries: from the fourteenth to the early twentieth century in the Netherlands and from the early sixteenth to the mid-nineteenth century in England. More specifically, the earliest record in the data was (approximately) dated 1300 and the latest recorded regulatory activity 1904. On average, commons lasted for 245 years and had 210 regulatory activities during that time, although with considerable variation among the different cases (**Figure 1**).

In some cases, several regulatory activities were included within the same sentence (e.g., a commoner is not allowed to have more than two cows, but was permitted to have one pig); both aspects were then recorded as separate regulatory activities in the database. Subsequently, an analysis was made on the nature, goal, and focus of the regulatory activity. In particular, changes of a permissive or prohibitive nature often also included a sanction for those infringing a rule. The sanctions related to these regulatory activities were also recorded in the Sanctioning-part of the database and linked to the regulatory activity they belonged to (De Moor et al. 2016).

Following Ostrom's work (Crawford and Ostrom 1995; Ostrom 2005), the regulatory activities were recoded into categories linked to their generic deontic (prohibition, permission or obligation) and aim

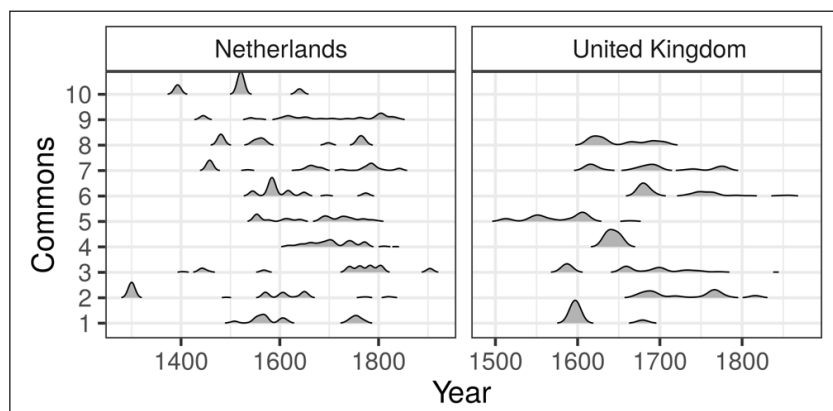


Figure 1: Overview of regulatory activities in the dataset. The figure shows the density of regulatory activities per year and commons.

(resource use or commons administration) (De Moor et al. 2016). For instance, a record such as “No one will be allowed to use horses or yokes coming from outside of the mark in order to collect peat [...]” (marke Exel, Netherlands, 1772) was categorised as prohibition/resource, while one such as “Since the annual leases were too small to pay for the yearly expenses, the esteemed gentleman had foreseen this by increasing the tenancy fees [...]” (Millom, England, 1594) as obligation/administration (for an overview of the coding system see De Moor et al. 2016).

2.2 Details on the commons

The Dutch commons included were all known as *marken*, a type of common that could be found in particular in the eastern and northern part of the Northern Netherlands (Beekman and Commissie voor den Geschiedkundigen atlas van Nederland 1913; Van Zanden 1999), which was highly self-governed. Although uncultivated, this land was owned by either private landowners (free farmers, but also local noblemen) or by institutions (e.g., the nearby town or village, or by the church) (Slicher van Bath 1957). Entitlement to use the common was predominantly linked to being a legal inhabitant of the area the common belonged to and/or the possession of land or real estate in the area concerned. Decisions about the daily use and governance of these commons were taken by the commoners power at the general assembly (*markevergadering* or *holtink*), in general held annually, but also held ad-hoc in urgent matters. Voting rights in this assembly were mostly directly linked to the ownership of specific farms and estates within the area, the so-called ‘*gewaarde erven*’ (Van Zanden 1999); when an owner sold this estate, his voting rights were transferred to the new owner. The rules established at these meetings were laid down in writing in specific registers (*markeboeken*), of which the oldest examples date back to the fifteenth century; some of these *markeboeken* included copied texts from even considerably older documents, like the *markeboek* of the *marke Berkum* from 1648, which started off with a 1648 copy of a (lost) set of rules dating from c. 1300 (*Marke Berkum* 1648). Formulation, adaptation, and repetition of these rules was performed by the assembly of commoners without interference by regional formal authorities. The task of surveying the implementation of these rules and the sanctioning of trespasses was also primarily up to the commoners themselves; to this purpose, specific commoners were appointed as guardsmen (*schutters*, literally ‘enclosers’, referring to the main task of enclosing animals found wandering astray or animals confiscated from trespassers) that brought trespassers to justice, in cooperation with the chairman of the assembly of commoners (*markerichter*; this position was either obtained via election (*gekozen* or *gekoren markerichter*) or related to the possession of the estate the chairmanship was linked to (*erfmarkerichter*)).

The first archival sources of the majority of the *marken* in the Northern Netherlands date back to the late Middle Ages or early modern times, as was the case in the selected Dutch *marken* included in our research (De Moor et al. 2016). It is suspected however that the first rules laid down for such a common often already existed among the commoners, but that an increasing population and hence increasing pressure on resources were incentives for laying down these rules in writing. Examples from other types of commons elsewhere in Europe, such as the *gemene weiden* in Flanders (northern part of Belgium), seem to support this idea: the oldest written rules of the commoners of the *Gemene and Loweiden* in *Assebroek* (near Bruges), for example, state explicitly that the rules laid down back then were based on rules agreed upon ‘from immemorial times’ (De Moor 2003).

The first *marken* emerged in the current province of Overijssel, close to small rivers that provided both good pasture land and a relatively small risk of flooding, in the 8th and 9th centuries (Slicher van Bath et al. 1970). Throughout the following centuries, the spread of *marken* extended all over the current provinces of Gelderland and Overijssel; although *marken* in the current province of Drenthe also already existed in the thirteenth century (Van Zanden 1999), an increase of *markegenootschappen* in that area coincided with the start of extensive commercial exploitation of the extensive peat bogs present there. Although the *marken* were located in the less populated areas of the Northern Netherlands (Slicher van Bath et al. 1970; Van Zanden 1999), the soil conditions and availability of resources could vary per common. For example, in most of our cases peat was available in a limited amount and hence a scarce resource of which harvesting should be regulated strictly, whereas in the Drenthe *marken* peat was available in abundance, but good pasture land was a scarce good.

Nine out of our ten Dutch commons were located in or just outside the current province of Overijssel. The geographical outlier in our dataset is the *marke Het Gooi*, which was located near Hilversum, in the far southeast corner of the current province of North-Holland. All were located on sandy, sometimes silted soil in a predominant rural area; only the *marken Berkum* and *Coevorden* were located within the vicinity of larger towns, i.e. Zwolle and Coevorden. Only a small part of the land was suitable for growing crops and

pasture land. The major part of the areas the Dutch commons concerned uncultivated land, mostly grown with heath, sods, or covered by extensive sand drifts. Until fertilizers were introduced in agriculture emerged in the course of the nineteenth century, the sandy soil was mixed with sods harvested from the uncultivated land, that were fertilized with the manure from the grazing cattle. As fertilizing one area of land required the use of sods of twenty equivalent plots of uncultivated land, the area of land used for agriculture increased at a very slow pace, leaving most of the land uncultivated and used as common land (Slicher van Bath et al. 1970).

Although the lifespan of *marken* varied per case, most commons survived for at least several centuries. For our study we selected cases that all had a lifespan of over two hundred years, in order to make sure we were focussing on examples of successful commons. We defined the beginning and the end of a commons' 'life' by the first and the last regulatory activity, being the first or the last rule that was noted in the archival documents. The start of a common is often hard to identify exactly as the archival records do not always go back to the very beginning, forcing us to rely on references to the first mentioning of a rule. The year of dissolution, to the contrary is usually much clearer, as this was often the consequence of an official enclosure procedure which could also be found in other official records kept by local and national governments. Towards the nineteenth century, increasing industrialization, agricultural use of artificial fertilizer, and increasing population pressure were incentives for the national government to attempt to dissolve the commons. Legislative measures issued before 1810, exempting newly cultivated land from land tax and assigning ownership to individual commoners, initially did not have much effect. Legislation issued in 1837 and 1848 made it possible for single commoners to start the process of formal dissolution of the common (Demoed 1982). Combined with the strongly increased possibilities for extensive cultivation of formerly uncultivated land by the use of artificial fertilizer, these led to a 'wave of dissolutions' among the *markegenootschappen*: between 1830 and 1880 all but a handful of them were dissolved (with just a handful of them surviving until the twentieth century, among which one of the selected cases, i.e. the common *Het Gooi*).

The English commons selected for this article shared similar characteristics: located in the northern regions of England (Lake District, Pennine area), they all were located in a predominant rural area without neither large rivers nor large towns close by. All belonged to larger manorial territories and were located in hilly terrain.

As was the case in the Netherlands, English commons also varied in soil and location. All commons however had in common that they were located in areas that were less suitable for agriculture: wooded lands, rocky terrains, sand drifts, etc. The institutional situation of the English commons however differed essentially from the Dutch commons. Whereas the Dutch commons were self-governed by the respective assemblies of commoners (*markegenootschappen*), the English commons had always been formed as part of manorial land, governed and managed by the lord of the manor. The English commons therefore had the status of 'manorial waste', that is, waste land belonging to a manor or landed estate, ownership of which had been vested in the lord of the manor since 1235. On these commons, the rule-making process and sanctioning was conducted through the manorial court, a seigniorial court with a jurisdiction limited to the boundaries of the manor: in contrast to the Dutch cases, which were independent institutions, each governed by an organization especially created for the purpose of the management of the collective resources and solely responsible for that, the regulation of the local common was part of the governance of the manor to which it belonged. Notwithstanding these differences in the rulemaking procedure, commons as resource governance regimes did go through similar phases (De Moor et al. 2016). The difference in legal context may however explain the difference in the role of sanctioning that was found between the Dutch and English cases (see above). With commoners having less control over their rules and the making thereof, as was the case in England, they may have found less opportunities to meet and discuss the need for specific restrictions of their resource use and other measures taken. This may have affected the degree to which the commoners 'internalised' the rules and realised why they should not freeride. With a lesser involvement of commoners in the actual management of the commons, as in England, there may have been a higher need for sanctioning, in order to prevent freeriding.

The difference in legal status of the commons between England and the Netherlands also explains the survival rate of commons throughout the course of time. In the Netherlands, nowadays only a single common has survived until today, notwithstanding present-day efforts to reinstate some characteristics of the commons (De Moor 2019). In England, the main threat to the commons already existed earlier because of the practice of enclosure, in use from the thirteenth century onward, where pieces of open land, open to common use by all entitled users, were enclosed by fences and subsequently befell to the private use of the

person who enclosed that part of land. This use was promoted by consecutive governmental Inclosure Acts between 1773 and 1882 (Slater 1907). The status of the land as part of the manorial land however prevented complete dissolution of all commons. Although significantly smaller in surface (Winchester 2015), there are numerous commons still 'alive' in England.

The difference in legislative status between the English and Dutch commons also shows in the way the regulations were recorded. In the Dutch cases, the oldest regulations preserved often concern a list of basic rules regarding the management of the commons and the use and governance of its natural resources; in some cases it was made clear that these already pre-existed before they were noted down in the registers that were kept by the chairman of the marke assembly. Decisions about new rules or adaptation of existing rules made at subsequent meetings were noted down in the same registers, either explicitly stated as new rule, or implicitly included in the minutes of the meetings. Sometimes a new list of rules was drawn up, integrating the prior regulation with the adaptations that were made throughout the previous years; in other cases however, the commoners apparently were satisfied with only noting down the decisions without composing a revised list of rules.

The initial rules of the English commons consisted of rules laid down by the manorial courts. These lists, known as 'pain lists', were far more concise and more focused on the sanctioning part (hence their name) than the Dutch *markeboeken*. These pain lists were often drawn up as a single document that stayed in force for a considerable amount of time. Adaptations were made far less frequently than in the Dutch regulations; changes were often included in new pain lists being drawn up (De Moor et al. 2016).

3 Results

The R statistical platform (R Core Team 2018) was used to analyse the data. Details are provided in the Appendix. To better visualise the trends in institutions that lasted for different time spans, we rescaled the life span of each common into "standardised time" units such that, for all commons, 0 always represents the year with the first recorded regulatory activity and 100 the one with the last recorded regulatory activity for each institution (see the Supplementary method appendix). **Figure 2** shows how regulatory activities were distributed across the life span of the commons, highlighting a clear dynamic in both the Netherlands and the UK with the strongest activity in the first quarter and towards the end of a commons' life span and a less intense period in between.

To formalize the U-shaped dynamic, we estimated a mixed-effects regression model with the number of regulatory activities per year as outcome. Because the number of regulatory activities is a count variable,

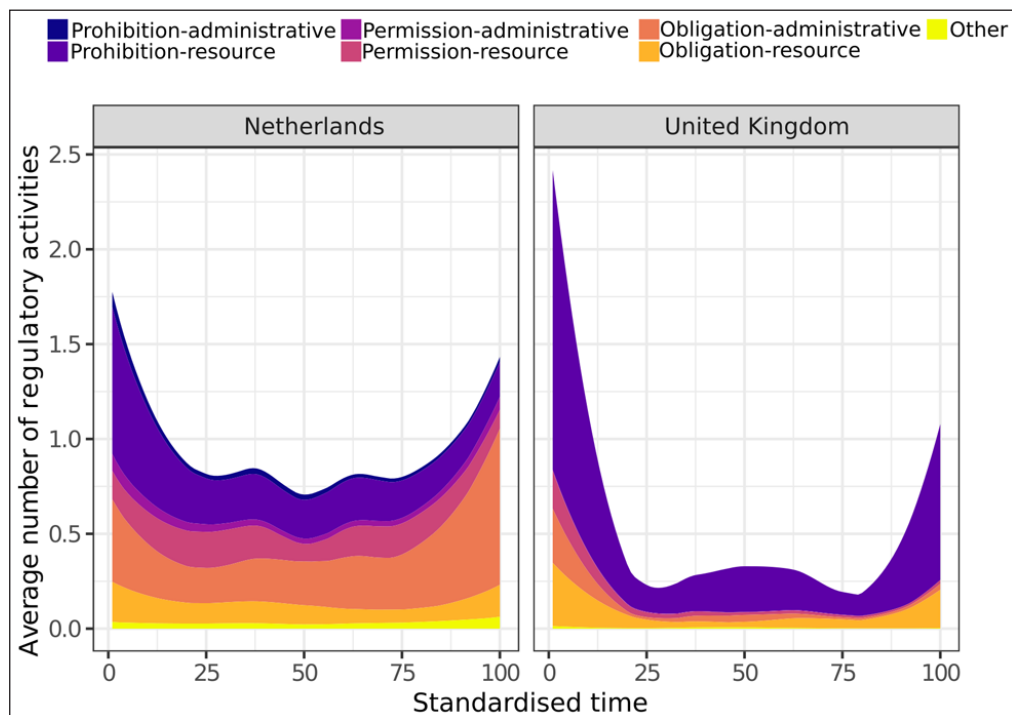


Figure 2: Smoothed estimates of regulatory activities during the existence of a common by category (deontic and aim).

we used a generalized linear regression model assuming a Poisson distribution. As a U-shape corresponds to a polynomial of degree 2, the model included both a fixed-effect for *year* and *year*². To check whether the U-shape was similar across countries, the model also included two interaction effects between *year* and a country dummy, and between *year*² and a country dummy, respectively. Finally, having multiple observations over time for each common, the model also included a random effect for this variable (see Appendix). **Table 1** summarizes the results of the generalized mixed-effects model, confirming the U-shape dynamic, with a negative and significant effect for *year* and a positive and significant effect for *year*². In addition, the estimates for the interactions suggested no significant differences between countries with respect to the declining number of rule changes over time, though the U-shape seems to be slightly weaker for the UK than The Netherlands. The same result held independently of whether the standardised time was used as predictor instead of the actual year.

Additionally, we estimated separate models for the four most common types of regulatory activities shown in **Figure 2** (together they account for 85 percent of all rule changes). A similar U-shape as the one found for regulatory activities in general could be found for all sub-types but 'Permission-Resources'. The regression tables for these models can be found in the Appendix.

Figure 2 also suggested that over a commons' life span the focus of activities increasingly shifted towards administrative issues and away from issues related to the use of the resource(s), with a clearer trend for the Netherlands. A linear mixed effects model was used to statistically evaluate this temporal trend, with the ratio of activities categorized as having a focus on administrative issues in a given year as outcome variable (here no quadratic term for the year was included as we had no reason to expect a non-linear time trend). In addition, we controlled for the total number of regulatory activities in the same year and the country. As before, the model included a random effect for each common. The model estimates confirmed the hypothesis of increasing focus on the commons administration, with a positive and highly significant effect for the year (**Table 2**). It is worth noting that, also in this case, no significant differences emerged across countries.

Another interesting aspect that emerged in the analysis concerned sanctioning. Following Ostrom's work, appropriate sanctioning represents a fundamental design principle for well-functioning institutions (Ostrom 1990, 2005). However, De Moor and Tukker argued that sanctioning was not a decisive factor to explain the longevity of several Dutch commons (De Moor and Tukker 2015). To better understand how sanctioning varied over time in our data, we estimated a third model using the ratio of regulatory activities dealing with sanctioning issues over the total number of regulatory activities as outcome. Fixed and random effects were kept as in the previous model (**Table 2**). The model estimates highlighted a general declining trend over time for sanctioning,

Table 1: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities as outcome. The model also includes random effects for commons. We present robustness checks in the Appendix.

	Estimate	SE	z	p
Intercept	1.05207	0.25737	4.085	0.000
year	-0.00989	0.00074	-13.295	0.000
year ²	0.00002	0.00000	14.993	0.000
UK	0.57616	1.27629	0.451	0.652
year × UK	0.00777	0.00645	1.204	0.229
year ² × UK	-0.00001	0.00000	-3.262	0.001

Table 2: Fixed effects estimates for the mixed effects model using the proportion of strictly administrative changes as outcome. The model also includes random effects for commons.

	Estimate	SE	t	p
Intercept	0.10055	0.08370	1.201	0.230
year	0.00114	0.00019	6.083	0.000
UK	-0.18116	0.21052	-0.861	0.389
N. of rule changes	-0.00094	0.00115	-0.819	0.413
year × UK	-0.00066	0.00052	-1.263	0.207

Table 3: Fixed effects estimates for the mixed effects model using the ratio of sanctioning rules as outcome. The model also includes random effects for commons.

	Estimate	SE	<i>t</i>	<i>p</i>
Intercept	0.74927	0.08984	8.340	0.000
year	−0.00115	0.00019	−6.185	0.000
UK	0.06184	0.22530	0.274	0.784
N. of rule changes	0.00099	0.00120	0.827	0.408
year × UK	0.00112	0.00055	2.049	0.040

confirming the De Moor and Tukker argument. However, in this case, significant country differences emerged, with the sanctioning ratio in the Netherlands showing a negative time trend, while the same was not true for England, as the positive interaction effect fully compensates the negative one for *year* (Table 3).

4 Discussion

The current work analysed rules and regulatory activities regarding these rules in Dutch and English commons across six centuries. A surprising result was that some basic trends were shared by most of the studied cases, suggesting a fairly similar pattern of institutional development among self-governing institutions regardless of their geographical location or period of development. Most notably, the time dynamics seemed to follow a common pattern where a first intense phase of rule creation and changing, often lasting for decades, was followed by a relatively calm period and finally by a second burst of activity in the period closer to the final observation for each commons. In addition, most of the initial regulatory activities focused on resource use, while towards the end administrative not directly linked to the resource prevailed in the rule making activity. Our analysis proved that this pattern was shared by both countries despite geographical, economic and political differences, and regardless the specific period in which the commons emerged and developed. The U-shape is in fact even more striking given the difference in legal context of common land in the UK and the Netherlands.

To better understand the different temporal developments of institutional change seen in Dutch and English commons, it is worth considering that the building of institutions for collective action can be considered as a kind of public good for the group of entitled resource users, as institutions help to solve the underlying social dilemma, and their provision hence represents a second-order social dilemma, although of a kind that is somewhat easier to solve than the resource one (Ostrom 1990, 1998; Singleton and Taylor 1992). This is also consistent with recent evidence that the initial provision of a public good leads to more cooperation within experimental groups than its subsequent maintenance (Gächter et al. 2017). The initial provision of an institution for collective action indeed seemed to produce a burst in regulatory activities (i.e., of cooperation in the second-order social dilemma) in most of the cases in our database. After this initial phase, fewer rules were changed either because of sustainable resource use or because lower cooperation in maintenance activities was achieved (Gächter et al. 2017). This may also explain why administrative rules increased over time, i.e., as an effort to sustain the institution on the face of lower interest from the commoners and, possibly, external challenges due to more general changes in the surrounding economy and society.

It is worth noting that the last recorded rule for most of the cases considered here occurred during the eighteenth or early nineteenth centuries. From this point of view, the second burst of institutional activity in our data could be related to commoners trying to deal with increasingly stringent top-down legislation which aimed at the dissolution of all forms of collective resource management (Brakensiek 2000; Demélas and Vivier 2003). At the same time, this period also went through an important demographic transition, with in large parts of Europe, a very rapid population growth, putting additional pressure on the commons (Allen 2003). This may actually be a special case of a more general rule where institutions facing internal or external challenges try to adapt in the period before their disappearance, hence more or less systematically producing the final activity burst recorded in the database. Further research on extended data will be needed to disentangle the degree to which internal turmoil or external pressure contribute to the increase in rule making.

Since the focus of this paper is on long-term dynamics in commons, the commons considered here are only those that managed to survive for at least two centuries. We do not claim that these commons are representative for commons in general and future research needs to investigate how long-lasting commons differ in their activity from more short-lived ones.

Besides increasing our understanding of the long-term dynamics of institutions, these results have potential policy relevance also for today's world, where commons are increasingly put forward to act as an alternative governance regime. In some regions, such as Europe, citizens refer to commons when creating energy cooperatives, care coops, urban agricultural collectives. In some countries, such as the Netherlands and Germany, these new forms of commons have developed rapidly since 2005 and are now reaching a stage of maturity (De Moor 2015). The 'lesson from the past' that can be derived from our work is that the (relatively easy) focus on building institutions for the governance of collectively held and used resources should be followed by a sustained period of rule tuning and change before reaching a steady state characterised by successful governance and stability. Moreover, our results show that sanctioning as a mechanism to prevent and punish freeriding may be less important than usually assumed, and that there are other ways to make sure commoners adhere to the rules.

There might also be lessons to be taken for resource governance on a global scale in order to offer alternatives for current climate change mitigation efforts, such as the Kyoto-protocol or the Paris agreement, which currently seem far from representing working solutions to limit climate change to an acceptable level (Rogelj et al. 2016; Mehling et al. 2018; Steffen et al. 2018). The knowledge that institutional building requires an initial sustained period of rule definition and fine-tuning should hence push governments and citizens to continue in this endeavour, trying to be as inclusive as possible (Nature Editorial 2016) and without looking for shortcuts which may backfire in the longer run, such as more authoritarian interventions (Stehr 2015).

A Appendix

A.1 Supplementary methods

The data used in our analysis as well as the *R* (R Core Team 2018) code used to generate figures, tables and statistics can be downloaded from the Harvard dataverse (<https://doi.org/10.7910/DVN/PCZMJ1>). Only commons that had regulatory activities occurring in at least 4 different years were selected for our analysis from the larger dataset of the *Commons Rules Project*. This resulted in 8 British commons and 10 from Netherlands.

We aggregated the number of regulatory activities per common per year, starting per common with the year that the first regulatory activity occurred and ending with the last year of activity. For years when there were no activities, all values were set to 0. To make interpretation of coefficients and intercepts in the regression easier, the first year during which a regulatory activity in the dataset occurred (1300) was recoded to 0 and 1300 was subtracted from all following years. Every regulatory activity was categorized as belonging to one of the categories shown in **Figure 1** (main text). This categorization is a simplified version of the categorization used in De Moor et al. (2016) in the fields *Rule Category* and *Rule Form*.

To graphically compare the trends in the commons (**Figure 1** main text), the year in which a given regulatory activity occurred was transformed into a standardised time $t_{c,a}$ using the following formula:

$$t_{c,a} = \frac{y_{c,a} - y_c^F}{y_c^L - y_c^F} * 100$$

For each rule change a and commons c , y_c^F refers to the year when the first record for the corresponding commons was reported and y_c^L to the one when the last record was reported.

A.2 Robustness check of the U-shape

The available data only included incomplete information with regard to the formal beginning and end of a common. As described in the main text, we defined the beginning and the end of a commons' "life" by the first and the last regulatory activity recorded, which may have led to an artificial construction of the U-shape. To check this, we added years with zero regulatory activities before and after the beginning and the end, respectively, of each commons' life and then re-estimated our regression models. This resulted in that the U-shape flattened and thus that the p -value for the $year^2$ estimate increased. We found that the estimate for $year^2$ remained significant below the 0.05-level for up to 10 years with added zeros to both sides (see **Table 4**).

To check to what extent the U-shape is driven by a few commons in our data, we re-estimated the regression models on all possible subsets with one of the commons excluded from the data. In all cases, the estimated coefficients remained qualitatively the same, as did their significances (all below 0.05).

Tables 5–8 show estimates for separate models of the four most common types of regulatory activities shown in **Figure 2** (together they account for 85 percent of all activities). A similar U-shape as the one found for regulatory activities in general could be found for all types but “Permission-Resources”.

Table 4: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities as outcome with added zeros to both ends of the life-span of a common. Random effects for commons were included in the model.

	Estimate	Std. Error	z	p
Intercept	0.54361	0.24	2.26	0.024
year	−0.00692	0.00	−9.39	0.000
year ²	0.00001	0.00	11.01	0.000
UK	−1.64529	1.15	−1.43	0.152
year × UK	0.01629	0.00	2.79	0.005
year ² × UK	−0.00001	0.00	−4.63	0.000

Table 5: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities classified as *Prohibition-Resources*.

	Estimate	Std. Error	z	p
Intercept	1.02093	0.35	2.88	0.004
year	−0.01600	0.00	−10.73	0.000
year ²	0.00002	0.00	9.63	0.000
UK	0.06915	1.55	0.04	0.964
year × UK	0.01316	0.01	1.66	0.097
year ² × UK	−0.00001	0.00	−2.85	0.004

Table 6: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities classified as *Obligation-Administrative*.

	Estimate	Std. Error	z	p
Intercept	−0.54581	0.36	−1.51	0.132
year	−0.01093	0.00	−7.48	0.000
year ²	0.00002	0.00	10.07	0.000
UK	−9.43220	5.58	−1.69	0.091
year × UK	0.04995	0.03	1.78	0.075
year ² × UK	−0.00008	0.00	−2.24	0.025

Table 7: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities classified as *Permission-Resources*.

	Estimate	Std. Error	z	p
Intercept	−3.60224	0.50	−7.26	0.000
year	0.00486	0.00	2.29	0.022
year ²	−0.00000	0.00	−1.27	0.205
UK	7.21401	4.08	1.77	0.077
year × UK	−0.03003	0.02	−1.38	0.167
year ² × UK	0.00002	0.00	0.63	0.529

Table 8: Fixed effects estimates for the generalized mixed effects model using the number of regulatory activities classified as *Obligation-Resources*.

	Estimate	Std. Error	z	p
Intercept	−0.34023	0.45	−0.75	0.451
year	−0.01592	0.00	−7.57	0.000
year ²	0.00002	0.00	7.59	0.000
UK	−1.93459	3.45	−0.56	0.575
year × UK	0.02962	0.02	1.59	0.112
year ² × UK	−0.00006	0.00	−2.51	0.012

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Competing Interests

The authors have no competing interests to declare.

Author Contribution

G.B., T.D.M. and A.G. developed the research concept. T.D.M. and R.V.W. provided the data. M.F. performed the data analysis in collaboration with G.B. and A.F. M.F. and G.B. drafted the manuscript and all other authors provided critical revisions and additions. All authors approved the final version of the manuscript for submission.

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