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Between commons and anticommons: a nested common-private interface framework

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The collapse of the former Soviet Union signaled failure of large-scale experiment in communitarian property. Privatization reform consequently was taken as the start point to transfer the planned economy to a market economy by the post socialist countries. This also occurred in economic transition countries such as China. However, in overcoming the tragedy of the commons privatization might create anticommons problems. Here we develop a nested common-private interface framework from the perspective of resource system and resource units and apply this framework to explain reforms of rangeland property in China and Kyrgyzstan. We confirmed that the root of the dilemma, either caused by commons or anticommons, can be attributed to the interface mismatch between individual elements and common elements. Trying to overcome the dilemma by changing property arrangements alone cannot eliminate the incentive mismatch caused by the common-private interface. Institutions aimed at alleviating the mismatch are accordingly required. Theoretically, this framework converts Ostrom's concept of commons into liberal commons that the members have options to exit, which is becoming increasingly common in the current global context of marketization. In the real world, this framework can serve to understand the property reform progress of transition countries, and may enlighten future property reforms.

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Introduction

Taking the communal apartments and the empty Moscow storefronts in the post- Soviet Union as examples, Heller (1998) developed the notion of "anticommons" originally coined by Michelman (1982). Heller (2008) argued that the transition from Marx's communitarian property to capitalist private property may lead to the tragedy of anticommons, that is, the inefficient use or even inaccessibility of resources. Anticmmons can be understood as the mirror image of commons property (Buchanan and Yoon, 2000). In case of commons, all the members are endowed with the privilege to use the resource, and no one has the right to exclude another. If these owners are not able to develop their own institutions to achieve collective actions for ensuring their commons long-term use, the resource is overused, which leads to the tragedy of the commons. While in the case of anticommons, "multiple owners are each endowed with the right to exclude others from a scarce resource, and no one has an effective privilege of use." (Heller, 1998: 622). If too many owners hold such exclusive rights, the resource tends to be underuse or inefficiency use, which leads to tragedy of the anticommons. For example, the share chopper dilemma that Native American families face, and the BANANA (build absolutely nothing anywhere near anyone) republic that reflects the dilemma of consolidating fractionized lands reported by Heller (2008: 108–109), as well as the problems of fragmented rangelands studied in this article.

The disintegration of socialism in the former Union of Soviet Socialist Republics (USSR) and Eastern Europe has been considered as the end of a 70-year-long real social practice, and the communitarian property system seemed to have verifiably failed (Brada, 1993; Murrell, 1993; Wegren, 1998). This explained why privatization reform was the first policy that all the post-socialist countries sought for regime transition after the USSR collapse (Havrylyshyn and McGettigan, 2000; Lerman et al. 2004; Roberts, 1992; Slider, 1994). Ironically, however, as Heller (1998) observed, privatization might solve the tragedy of commons by creating the problems of anticommons. The property regime seems to be stuck in a dilemma.

In fact, the predicament observed by Heller (1998) is not unusual in the post-socialist countries. Particularly, the dilemma generally exists in the realm of natural resources, such as rangelands in Eurasia (Galvin et al., 2008; Robinson et al., 2017). After 1991, following the privatization policies for arable farmlands (O'Brien and Wegren, 2002; Prishchepov et al., 2012), some governments in Central and Inner Asian countries started a pastureland privatization process (Robinson et al., 2017). Nevertheless, after decades of practice, it has been observed that the uneven use of pastures due to privatization is leading to overgrazing near the settlements while undergrazing in the remote pastures (Fernández-Giménez, 2002; Gunya et al., 2019; Kerven et al., 2012; Kerven et al., 2021; Sneath, 2000; Watanabe and Shirasaka, 2018). In addition to the empirical evidence from Central Asia, research on global pastoralism, particularly Africa (Behnke, 1994; Mwangi and Dohrn, 2008; Niamir-Fuller, 1999; Scoones, 1994), has also shown that land fragmentation caused by privatization is the main institutional cause of degradation, because livestock mobility is hindered or even has to be abandoned (Galvin et al., 2008; Humphrey and Sneath, 1999).

China is no exception. That is, adopting the private property approach to overcome the dilemma of commons leads to the problems of anticommons. In 1978, China began to transition from a planned economy to a market economy, starting with the reform of rural land tenure by implementing the household responsibility contract policy. The arable lands were contracted by the state to individual households, forming de facto privatization of land use rights. Privatization of use rights followed for other landed natural resources, including pastures and forests. After more than 40 years of land tenure reform, along with rapid economic growth, China has gradually recognized the problems of fragmentation caused by land division, including the inefficiency of agricultural production resulting from diseconomies of scale (Long et al., 2019), as well as negative impacts on the ecological environment, especially the degradation of rangelands (Gongbuzeren et al., 2015; Li et al., 2017; Li and Huntsinger, 2011; Sun et al., 2021; Zhang et al. 2019). In recent years, the Chinese government has been trying to re-integrate the fragmented lands by encouraging land lease and cooperatives (Zhou et al., 2020).

How to understand the dilemma caused by property rights transformation from commons to anticommons? And how to overcome the dilemma? We will address these two questions in this article. Both China and Kyrgyzstan have implemented diverse land tenure arrangements over the past decades, which provide a natural experiment in answering these questions. In this paper, taking rangelands as an example, we develop a nested common-private interface (NCPI) framework from the perspective of resource system and resource units. We apply this framework to analyze China and Kyrgyzstan reform of rangeland property system. We confirmed that the root of the dilemma, either caused by "commons" or "anti-commons", can be attributed to the interface mismatch between individual property and common property. Trying to overcome the dilemma by changing property arrangements alone cannot eliminate the incentive mismatch caused by the interface, but instead only moves the interface boundary between the common and private elements. The interface always exists no matter what kind of property regimes are operating. To remedy this situation, institutions aimed to alleviate the mismatch are therefore required to be designed and applied for all the different property regimes, including rangelands, where both individual and common property rights pertain.

Our intention is to consider the implications of property rights as well as common pool resource governance theory founded by Elinor Ostrom (1990). In the commons governing theory, the NCPI framework converts Ostrom's commons to liberal commons that the members have options to exit, which is becoming increasingly common in natural resource governance in the context of marketization. In the real world, the framework can serve to understand the property reforms of post-socialist countries as well as economic transition countries such as China, and may enlighten the future property reforms.

Commons and anti-commons: interface between common and private

The cause of the tragedy of the commons (Hardin, 1968) has been widely attributed to unclear ownership, which makes herders fall into the Prisoner's Dilemma driven by the incentives of maximizing their own interests thus resulting in resource overuse. In fact, however, as Fennell (2011) pointed out, the typical tragedy of the commons was not due to the shared property, but to the incentive misalignment caused by the interface between common elements (such as pastures) and individual elements (such as cattle). Common-private interface mismatch means that the property rights on the two sides of the interface are not same. For example, livestock is private, but the forage that livestock graze is shared by the community, and when private livestock graze on common pasture, property mismatch occurs. Interface mismatch leads to environmental externalities, i.e., each herder has an incentive to increase the number of cattle raised, because the benefit from each additional animal goes to the individual herder, but the cost of pasture degradation due to overgrazing is borne by

all members in the community. That is, the cost caused by individual actions cannot be fully internalized and borne by the individual. Therefore, from this perspective, the tragedy of Hardin's commons can be attributed to the mismatch of property rights at the public-private interface.

Fennell (2011) drew a vertical line to describe metaphorically the interface between common and private property. To solve this interface mismatch problem, one direction of adjustment may be to share the cattle to match the common pastures, so as to eliminate the interface between the private cattle and common pastures. This is obviously the property regime which was adopted by socialist countries, which had been proved to be economically inefficient and as the main cause for the eventual disintegration of the former Soviets (Roberts, 1992; Wegren, 1998). The property solution could only move the common-private interface in one direction or another, but did not eliminate this interface. That is, the problems caused by the interface where private and common elements border did not disappear. When cattle became collectively owned to match the shared pastures, though the previous mismatch between private cattle and common land ownership was eliminated, it however led to a new interface between private and communal elements. Because one key input to cattle raising, such as human labor, is personally owned, shirking would occur, as individuals declined to contribute their labor to a commonly-held resource, and overgrazing would be replaced by a lack of dedication to take care of cattle (Alchian and Demsetz, 1973; Krier, 2009).

The other direction of adjustment may be to privatize pastures so that they can be matched with the privately owned cattle. The philosophy behind is that if individual-owned cattle were raised on the individual-owned pastures, the external cost of grazing would be internalized to the same herder who received the benefits. Obviously, this is the logic behind the property privatization reforms in those post-socialist countries and China. However, the solution of privatizing land to overcome the dilemma of commons brought about the dilemma of anti-commons. In contrast to the dilemma of commons attributed to communitarian property, the dilemma of anticommons is thought to be caused by excessive fragmentation of property (Fennell, 2004; Heller, 1998, 2008). The privatization of pastures can solve the previous mismatch between shared pastures and herder' private cattle, but the privatized pastures are still adjacent to the larger public water resources and ecosystems, thus creating a new private-public interface. This new interface may result in the underuse of the resources because each plot of land is too small to be used for any purpose if the owner can not extend her small land into the larger neighboring space, such as the share chopper dilemma that Native American families face (Heller, 2008:108–109). Specifically, this interface may also lead to the excessive depletion of resources though the mechanism is different from the tragedy of commons. As observed in China's rangeland degradation after the pasture household contract was implemented, excessive fragmentation leads to the fact that the resources, including forage and water resources, within the small piece of individual rangelands cannot meet the basic needs of grazing for one household; thus the individual households have to buy extra resources from a larger spatial scale through market transactions. The result thereby dramatically increases production costs, consequently more livestock need to be raised to pay for these costs, resulting in severe overgrazing of rangelands as a whole (Li and Li, 2021; Lu et al., 2022).

Therefore, either the tragedy of commons or anti-commons can be both attributed to the misalignment between the private elements and common elements (Fennell, 2011). A new common-private interface is generated when the old property arrangements are altered. Addressing the problems of anticommons through collectivization of property will lead to the dilemma of commons. Similarly, adopting privatization of property to solve the dilemma of commons will lead to the problems of anticommons.

Nested liberal commons

A property solution is not the only way to avoid the tragic ending. Regarding the governance of common pool resources (CPR), the Bloomington School founded by the Nobel laureate Elinor Ostrom (1990) proposed a non-property approach; that is, governing the commons by collective action based on community self-governance. The distinction between resource system and resource units is the starting point of Ostrom's CPR governance theory. In her seminal book *Governing the Commons* (Ostrom, 1990), she pointed out that the tragedy of the commons usually starts with the over-appropriation of resource units. Ostrom, her colleagues and followers have constantly worked to make invaluable contributions to the CPR governance proposition in the aspect of property right (Agrawal, 2001; Araral, 2013a, 2013b, 2014; Grafton et al., 2000; Ostrom, 2010; Schlager and Ostrom, 1992). However, few scholars have specifically paid attention to the property regime of CPR governance from the perspective of resource system-units, except Araral (2014) who pointed out that all those cases of failure reported by Ostrom (1990) might be attributed to the difficulty of exclusion to the resource system and units. However, he did not distinguish the objects of the "exclusion" between resource system and unit.

From the perspective of resource system and resource unit, Qi and Li (2021) developed the nested property system by taking rangeland as an example. Theoretically, the *resource system* (pasture) can be used by multiple individuals at the same time, while the *resource units* (forage) "are not subject to joint use or appropriation" (Ostrom, 1990. p. 31). Because the biomass of forage as the *resource units* is divisible, this means the resource units of the rangelands, i.e. the forage production, can be privatized to the individual households according to the measurement of their livestock number - that is called grazing quota - while the resource system, i.e. the pasture, can remain in common use so to prevent fragmentation. Based on a study in China's pastoral areas, Qi and Li (2021) argued that the resource units (forage) can be privatized by allocating the grazing quota to each individual household, while the resource system (pasture) remains in common ownership among the group. Moreover, the private elements (forage) are embedded in the public elements (pasture), rather than the juxtaposition with a vertical line as interface, as illustrated above by Fennell (2011). The nested property model demonstrates that the resource units (such as production of forage and fish) as flows can be privatized, while the resource systems (such as rangeland and water ecosystems) as stocks can be remained common, thus forming a nested property regime with private property (resource units) embedded in the common property (resource system). The nested property model therefore can be expected to solve the long-standing wicked problems: how to maintain the ecological integrity of the resource system while using resource units economically efficiently, that is, avoiding the dilemma of anticommons while overcoming the tragedy of the commons.

However, the nested property system (Qi and Li, 2021) did not develop an in-depth discussion of the interface between common and private property, which we apply in this article to explain the tragedy of anti-commons caused by the fragmentation of property rights. We further discuss how to overcome the problem of commons and anti-commons. In particular, the nested property system did not involve the question of whether the grazing quota based on the resource units is alienable, let alone the issue of whether the members have the option to exit from the group.

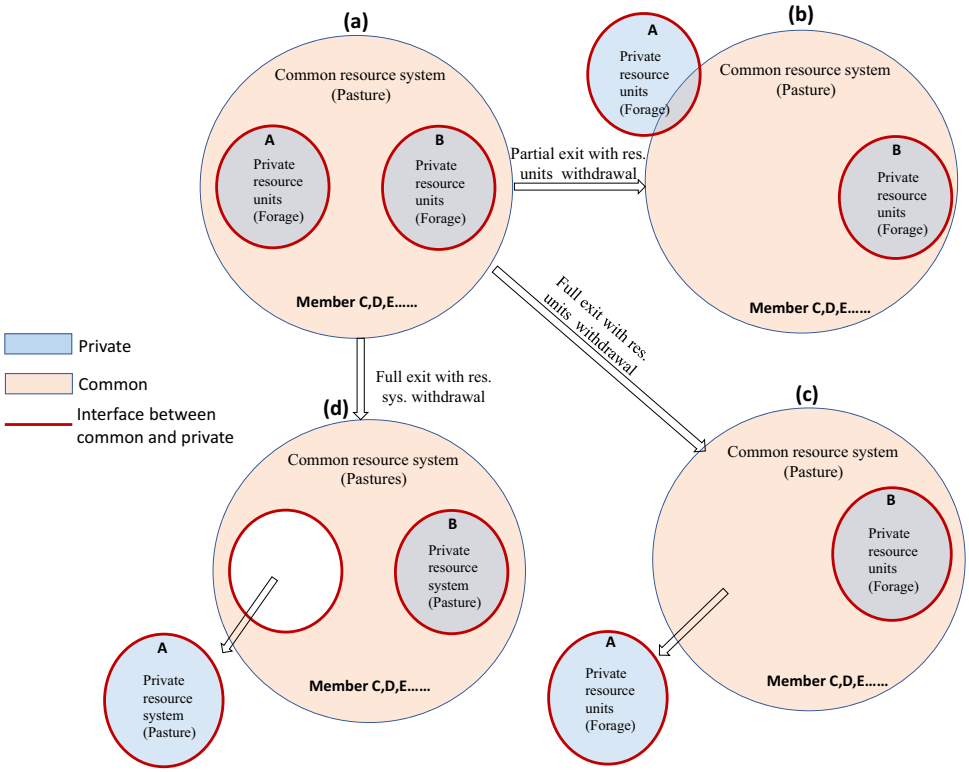

Fig. 1 Nested liberal commons. For the communities that have been keeping the pastures in common use (**a**), there are two types of exits with resource units withdrawal: partial exit (**b**) and full exit (**c**). These two types of exits would not lead to the further fragmentation of rangeland. While for those communities where the use rights of pastures were privatized, a member's exit action means he withdraws his piece of pasture from the cooperative collective rangeland (**d**).

In the current world with the development of marketization, the demand of claiming individual rights has been increasingly strengthened and valued, and the alienability of rights is becoming a mainstream narrative in the context of a market economy. With this background, governance of the commons is facing the challenges as members increasingly demand clarity on individual transferable rights. Meanwhile, if the rights are tradable, it means the members would have options to exit the group by selling their rights, which Dagan and Heller (2001) called as "liberal commons". In a crowded world, people want or need to cooperate in order to promote the efficient economic and social use of scarce resources, but at the same time they are afraid of being taken advantage by others. To solve this problem, a liberal common system may be one possible solution as argued by Dagan and Heller (2001).

The act of exiting itself is a kind of threat, and is often a significant mechanism for constraining social organization and optimizing the use of shared resources, as Green (1998:171) mentioned "The possibility of exit may itself make the group responsive to the interests of its members". And, in turn, exit can motivate members to work better together within their groups. Therefore, exit has a protective function in this sense.

Combining the concept of liberal commons and nested property system, we propose a framework that we call nested liberal commons (Fig. 1), to understand the liberal commons and the mechanism to overcome the tragedy of commons/anti-commons.

For the community that has been keeping the pasture in common use, there are two types of exits: partial exit (Fig. 1b), and full exit (Fig. 1c). If a member decides to sell part of his use right, e.g. grazing quota, so he can input more labor to the non-pastoral livelihoods, this can be called partial exit (Fig. 1b); if a member decides to quit animal husbandry so sells out all his grazing quota to cash in, this is called full exit (Fig. 1c). These two types of exits would not lead to the further fragmentation of rangeland because the exit members only withdraw their shares of resource units rather than the resource system. In this case, a herder's choice to fully exit to cash in does not mean that he can withdraw an area of real land for personal use. This is why the liberal commons can overcome the problem of land fragmentation by guaranteeing individual rights. While for those communities where the rangelands were already contracted to individual households and are trying to reintegrate their fragmented pastures by forming cooperatives, for example, a member's exit action means he withdraws his piece of pasture from the cooperative collective rangeland (Fig. 1d). In this case, if more members choose to exit, it means the failure of efforts by the cooperative to reintegrate fractionized pastures.

Nested common-private interface framework

Based on the above analysis, here we develop a nested common-private interface (NCPI) framework (Fig. 2), to reveal the characteristics and problems of different property regimes applied to overcome the problems of commons/anti-commons.

Figure 2a shows Hardin's commons, where the common shared pastures and privately owned livestock forms a common-private property mismatch interface (the red circle), resulting in the so-called "the tragedy of the commons". To overcome the tragedy caused by this mismatch, there are often three property solutions adopted in the real world. First, making cattle commonly shared, therefore moving the interface toward the inner circle, that is the socialist property regime as shown in Fig. 2b. Second, privatizing the pastures, so moving the interface toward the outer circle, that is the post-socialist or private property as

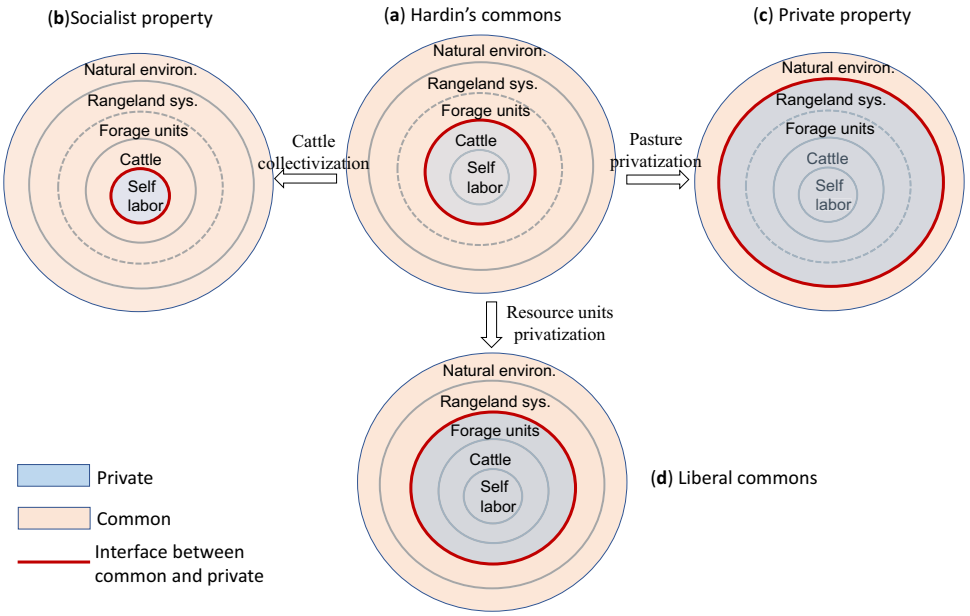

Fig. 2 Nested common-private interface framework: property solutions to Hardin's tragedy of the commons. a Shows Hardin's commons, where the common shared pastures and privately owned livestock forms a common-private property mismatch interface (the red circle), resulting in the so-called "the tragedy of the commons". To overcome the tragedy, there are often three property solutions adopted in the real world. First, making cattle commonly shared, therefore moving the interface toward the inner circle, that is the socialist property regime (**b**). Second, privatizing the pastures, so moving the interface toward the outer circle, that is the post-socialist or private property (**c**). Third, applying the nested property system by privatizing the resource units and keeping the resource system commonly shared, as shown in (**d**). However, by all these solutions, a new common-private misalignment interface is generated while "the tragedy of the commons" overcome; see the red circle in (**b**–**d**).

shown in Fig. 2c. Third, applying the nested property system by privatizing the resource units and keeping the resource system commonly shared, as shown in Fig. 2d.

However, a new common-private misalignment interface is generated while "the tragedy of the commons" overcome; see the red circle in Fig. 2b–d. Therefore, institutions are accordingly required to remedy the mismatch. When a socialist property regime was applied for example in China (Fig. 2b), in order to avoid labor underinvestment, an income distribution institution "work-point system" was designed and implemented to encourage the collective members to input more work to get more income (URHMCRD, 1990). Under the private property regime (Fig. 2c), the governments need to regulate land markets to facilitate the assembly of fragmented land (Heller and Hills, 2008) to overcome the diseconomies of scale. In addition, the governments often apply financial transfer payments, e.g. payments for ecosystem services, to control overuse and thus prevent degradation of the larger natural environment as in China (Li et al., 2015) and America (Worster, 1982). Lastly, under the liberal commons (Fig. 2d), the delimitation of private rights needs to be accompanied by Ostrom's CPR governance principles (Ostrom, 1990) to prevent the overuse of common resource system by collective action. In addition, under liberal commons, the herders have options to exit if their individual use rights are alienable, see Fig. 1.

Framework application

China. Applying the NCPI framework (Fig. 2), we explore the characteristics and the problems that arise at each stage, and the corresponding remedies taken by institutions in the process of property reforms in China's rangelands (Fig. 3).

During Phase I (1949–1979), after the founding of the People's Republic of China in 1949 until the end of the 1970s when China began reforms and opening up, the socialist communitarian property system had been applied. Both the livestock and pastures were owned by the village collectives after 1958, which formed an interface between the private labor of members and collective livestock and pastures. As we already know, this system led to low production efficiency because of lack of care for raising livestock due to insufficient labor inputs. At this stage, the collectives faced a series of problems to solve labor underinvestment, e.g., the difficulties of accurately dividing the production process, fine-tuning allocation of labors, accurately defining production responsibilities, identifying labor quality, and evaluating performance. In response to these problems, the remedy called "Four Settings and One Award" (Si Ding Yi Jiang) was designed by the communes and implemented in the production brigades. "Four Settings" (Si Ding) included "setting production targets, setting investment scale, setting the annual product amount to submit, and setting production increase measures". "One Award" (Yi Jiang) meant an award to those who exceeded production targets. For the individual members, the "Workpoint System" was applied to distribute the benefits (Kung, 1994), under the principle of "more work more reward".

In Phase II (1980s–1990s), with the early transition from planned economy to market economy, the previously collective livestock were privatized and distributed to households, while the majority of pastures were still shared by communities or groups. As a result, the interface between shared pastures and private livestock has been formed, which led to the typical "tragedy of the commons" due to overgrazing (Li and Zhang, 2009). In that decade, there were no institutions for governing the common rangelands. In fact, that decade was in an institutional vacuum. On one hand, the government administration as a formal system was abruptly withdrawn; on the other hand, the traditional social relations and networks were almost completely lost after about 30 years of top-down government administration, while the informal community-based system of natural resource management was not built yet.

In Phase III (after 1990s), because the rangelands were rapidly becoming seriously degraded, the governments began to widely

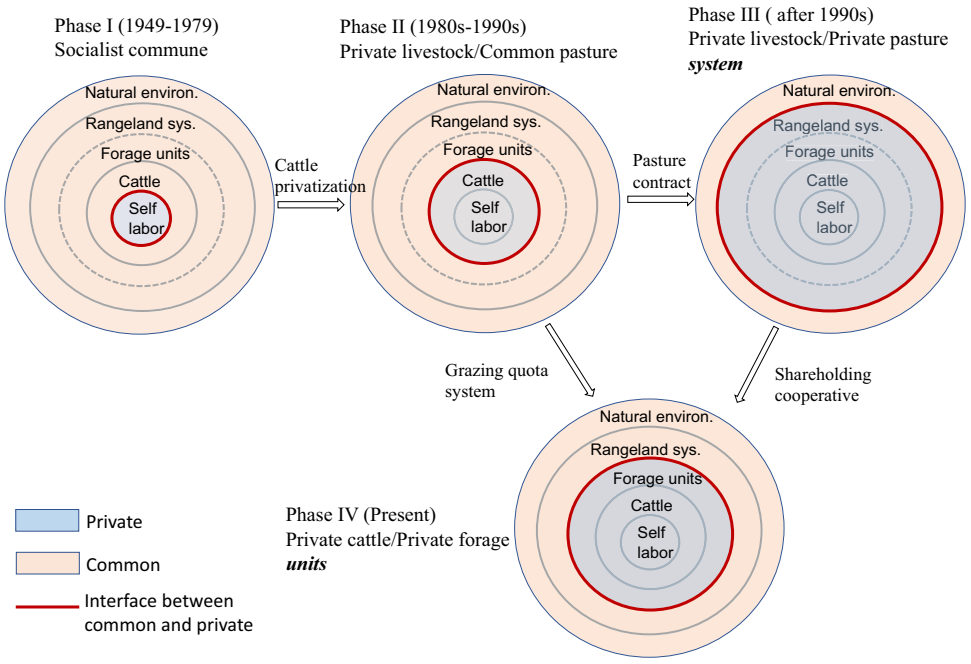

Fig. 3 Nested common-private interface framework application: China's rangeland property reform.

implement the rangeland household contract policy (although the policy was initiated as early as the 1980s and widely promoted in the cropland regions), by contracting the use rights to each household (Li and Huntsinger, 2011). The logic behind was that privatizing the pastures so as to match with the private cattle would solve "the tragedy of the commons". However, contrary to the policy expectations, the degradation trend was not controlled, due to the anticommons dilemma caused by the fragmented use of rangeland (Li and Huntsinger, 2011). The government has had to adopt a series of remedial measures: applying financial transfer payments to try to control the degradation, including the policy of "grassland-livestock balance"; "retire livestock to restore grasslands", and "grassland ecological award and compensation" (Gongbuzeren et al., 2015). Meanwhile, currently there are still many pastoral areas retaining traditional pasture common use, particularly on the Qinghai-Tibetan Plateau (Cao et al., 2011; Gongbuzeren et al., 2016), that is, keeping the previous property regime as in the second phase of the 1980s to 1990s. Many of these communities develop their own institutions to manage their common pastures, i.e. a quota system, which we will elaborate below in the Phase IV of Fig. 3.

To deal with the problems caused by fragmentation of the rangelands, a new round of property reform has been initiated since 2017, that is, "Separation of Three Rights"(Li et al., 2018). Here the "three rights" refer to the ownership right, contract right and use right. Under this policy, the village's collective ownership right is re-claimed and warranted by issuing an ownership certificate, and the previous household's contract right plus use right that was previously claimed in a single certificate is further separated as contract right and use right, respectively, by issuing two corresponding certificates to each household (Chasu et al., 2023). In this way, the village households can establish cooperatives by transferring their use rights or by offering the use rights as shares to join the cooperatives, so that the fragmented rangeland can be reintegrated (Zhou et al., 2020). Integrating the fragmented pastures by establishing herders' cooperatives is becoming the reform characteristics of the current stage, see Phase IV of Fig. 3. Meanwhile, those communities that still maintain traditional shared use of pastures, for example on the Qinghai-Tibetan Plateau, have begun to explore their own innovative ways through self-governance, such as grazing quota system (Phase IV of Fig. 3), by delineating individual use rights while maintaining ecosystem integrity (Qi and Li, 2021).

We can see that at this stage, the common-private interface is generated between the pasture resource system owned by the collective or cooperative and the resource units owned by the individual members. Under the NCPI framework, individual property rights are delineated and tradable, which means the members can exit from the group when they feel their interests are damaged, see Fig. 1b, c. For those communities that still keep the pastures in common use, the grazing quota system is applied to delineate the individual use rights. In most cases, the grazing quota is alienable, which offer a mechanism for exit in terms of labor input in animal husbandry. There are two types of exits of members, partial exit (Fig. 1b) and complete exit (Fig. 1c). If a herder does not want to devote all his labor to animal husbandry, he can choose to sell part of his quota to other members, so that he can have more time to engage in other non-pastoral employments, which can be called partial exit. If a herder already has a stable source of livelihood in the urban area, he may choose to sell all the household's quota to the collective, thus quitting animal husbandry, which is called complete exit.

For those villages where the rangelands were already contracted to individual households and trying to reintegrate their pastures by cooperatives, the individual property access is delineated by the capital shareholdings assessed according to the pastures and livestock that the households would offer when joining the cooperatives. In China, the Law of Farmers' Professional Cooperatives (Amended in 2017) stipulates that the farmers' cooperatives are voluntarily joined by members of village collectives and the members have the freedom to exit. In this case, if a member of the cooperative decides to exit from the cooperatives, he can withdraw his piece of pastures (Fig. 1c). Therefore, if more members choose to exit, it means the failure of land consolidation by the path of cooperatives, which actually has been taking place frequently in the past decade in China (Hu et al., 2023). It still takes time to evaluate the effectiveness of the cooperative approach for re-integrating the fractionized lands.

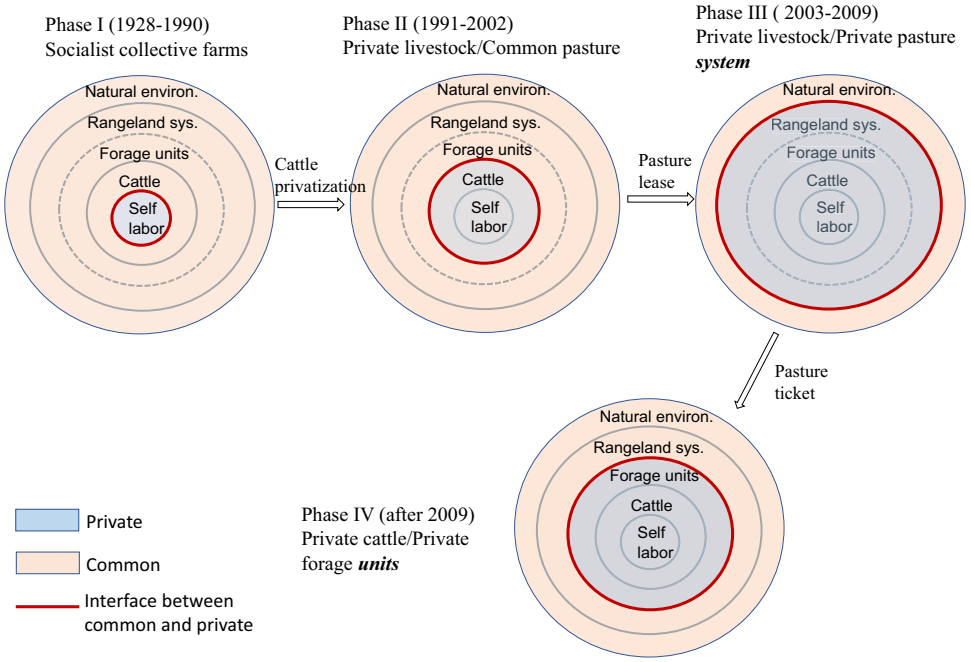

Fig. 4 Nested common-private interface framework application: Kyrgyzstan's rangeland property reform.

Similarly, in dealing with the new interface, the nested property regime also needs to be arranged accordingly with the remedial institutions, that is, Ostrom's CPR governance principles. However, the commons situation of China in phase IV is different from Ostrom's depiction of CPR in terms of the individual rights. In this sense, the cooperatives of Phase IV are neither same as Ostrom's CPRs nor the former socialist commune in China.

Kyrgyzstan. Over the past century, Kyrgyzstan's pasture management practices and institutional arrangements have undergone drastic changes, with a variety of property system attempts, which provide practical experiences and lessons for the study of natural resource property in transition countries. Before the Soviet Union, Kyrgyz pastoralists migrated seasonally in a vertical transhumance system between valleys and mountains. Tribal sultans and khans assigned access rights to winter and summer pastures to clan leaders under their control, and pastures were grazed in common by clan group members (Jacquesson, 2010). Imperial Russian administration from the 1840s to 1918 sought to reorganize the tribal and clan nomadic power structure, but did not succeed in changing the seasonally mobile pasture use arrangements.

In the Soviet period (1918–1990), after about 1928 livestock production was managed through collective farms and state farms, and grazing land was allocated to the state farms by local soviets (councils) (Farrington, 2005). In order to maximize the output of pastoral production, livestock mobility on a larger spatial scale than previously was achieved through extensive transportation improvement and livestock-raising infrastructure including watering wells and barns in the more remote pastures (Van Veen, 1995).

In the post-Soviet period, the collective state farms were dissolved from 1991 and with the support of international financial and development institutions such as the World Bank and the International Monetary Fund, Kyrgyzstan's pasture management legislation underwent two major changes. Firstly, the 2003 "Government Resolution 360" introduced privatization of agricultural land including pastures, but was perceived as unjust and caused conflict between pasture users (Undeland et al. 2010; Mogilevskii et al. 2017). Following the 2009 new law "On Pastures" changed the pasture land from state ownership to common property, and the herders were then required to seasonally rent distant pastures from the village community instead of the state (Dörre, 2015; Robinson et al., 2017; Shigaeva et al., 2016). Particularly and innovatively, the "pasture ticket" system was adopted, with the seasonal pasture rent was paid according to the number of livestock required to be pastured rather than the area of pasture regulated by the previous 2003 legislation.

For animal husbandry, in the Soviet period, the number of livestock began to increase in 1941 and peaked in 1990 when Kyrgyzstan declared independence (Wilson, 1997). Since 1990, livestock had decreased significantly until 1997, then began to gradually recover. By 2017, the number of cattle and horses had exceeded the 1990 level, with the number of cattle increasing by 74% and horses by 62.7%. Sheep and goats, although increasing year by year, had only recovered to 62% of what they were in 1990 (Kyrgyzstan Statistics, cited from: Datkaiym, 2020).

We can apply the NCPI framework to explain the changes of rangeland property systems at different stages and the corresponding remedial institutions (Fig. 4).

In phase I (1928–1990), the Soviet socialist period, all livestock, pastures and means of production belonged to either collective farms or state farms. Therefore, the common-private interface was generated between private labor and the collective livestock as well as pastures.

During the Soviet period, continuing the traditional mobile grazing method, a scientific grazing system was established based on geobotany and meteorological sciences, coupled with construction of many watering wells, so that many remote "waste" pastures could be used. However, as СЛУЖНЕВ (1955:33) reported: "*The experience of many state farms and collective farms had shown that the achievements of livestock production,* i.e. *higher production efficiency with increasing young animal survival rates and eradication of livestock mortality, is largely relied on the well organization and correct remuneration of labor forces. Where*

there are no responsible cadres and no responsibility for managing livestock, but egalitarianism in labor remuneration, the livestock production efficiency and the survival rate of young animals must below, and the loss of young animals due to death must be large".

The system of remuneration for labor was based on the quantity and quality of the labor inputs. The farm workers were paid according to the product outputs (milk, meat, wool), the survival of young animals born, as well as the adult animals' health conditions and fertility. In addition, extra renumeration was paid as awards to those workers when they exceeded the production targets. Generally, because the oversight costs were too high, this led to inefficiency of production. This was not different than China's phase I of collectivization (Fig. 3).

In Phase II (1991–2002), after the collapse of the Soviet Union, livestock were privatized and the pastures remained state-owned (although arable lands were immediately privatized). The public-private interface was thus generated between the private livestock and shared pastures. Similar as in China (1980s-1990s), such a mismatch interface led to " the tragedy of the commons." However, unlike the general widespread degradation of shared pastures in China at this stage due to a large increase in livestock numbers, in Kyrgyzstan where livestock numbers dropped dramatically after 1991, the severe degradation took place around the settlements, while pastures in the remote mountain areas were under-grazed or even abandoned (Farrington, 2005; Van Veen, 1995).

In the first decade following independence, the number of livestock in Kyrgyzstan had experienced a drastic decline, falling by about 50–70% (Robinson, 2016). Since 1997, the total meat and milk production has gradually recovered. By 2020, the total production has exceeded the level of 1991 (Robinson and Petrick, 2021). However, due to the lack of maintenance of transportation and barn infrastructure that was constructed in the former Soviet Union, most individual herders could not bear the cost of long-distance transportation, so the mobility of livestock declined, resulting in an increase in the input cost of animal husbandry, mainly reflected in the input of winter animal feeding. Even if a few large households were able to move, the cost of transportation for single-family operations has risen sharply, plus many of the pre-Soviet watering points have fallen into disrepair, so many remote pastures lacked access to watering. Thus, despite the drastic decline in the number of livestock, the immobility of livestock led to the degradation of pastures around the settlements and the abandonment of remote pastures. In fact, in the post-Soviet period, the phenomenon of uneven use of pastures was not limited to Kyrgyzstan, but widespread in Central Asia (Gunya et al., 2019; Kerven et al., 2012; Kerven et al., 2021; Watanabe and Shirasaka, 2018).

The undergrazing in remote mountain pastures is the result of decline in livestock mobility, since individual pastoralists were not able to afford the high transportation costs. If the private livestock herds can be combined together in a cooperative way, e.g. among several households, the transportation costs can be shared, and this dilemma may be overcome, as the cooperatives that are being encouraged and practiced in China's Phase IV. According to the logic of the NCPI framework, this cooperative way means that the interface between private livestock and common pastures can be eliminated at a certain scale (among the cooperative members), resulting in economies of scale.

In Phase III (2003–2009), the use rights of pastures were privatized through a leasing system. After the collapse of the Soviet Union, Kyrgyzstan was the first country in Central Asia to privatize arable land (Dekker, 2018; Delehanty and Rasmussen, 1995), which was considered highly successful (Asian Development Bank, 2008). In this context, the government believed that pasture tenure reform should be followed up. The first decree on pasture leasing came into force in 1999, which provided individual households pasture use rights by leasing (Kasymov and Thiel, 2019). Based on this decree, in 2003 the government formally enacted law (Government Resolution 360) governing pasture management. However, due to the complexity of the pasture leasing system, only about 14% of Kyrgyz pastures had been officially leased by 2007, the most of pastures thus became de facto open accessed (Dörre, 2015). Moreover, this system did not overcome the previous problems that livestock were not able to move, but even further hindered the movement of livestock, as rents levied according to the pasture area further increased the cost of movement (Crewett, 2012; Kerven et al., 2012; Robinson and Petrick, 2021). The results were that:

> "*rights to such land had to be allocated through competitively awarded leases, pastures near villages remained in common use while the more distant so-called intensive and remote pastures were leased out. A non-transparent process of awarding leases led to negative equity consequences whereby the best pasture land was often leased by big farmers or well-connected businessmen who then entered into sub-leases with shepherds and villagers. This implied that the majority of small livestock holders had no access to good quality pastures, prompting them to graze their animals on the communal areas in villages' immediate proximity, leading to a dramatic degradation of this type of land*" (Undeland et al. 2010: 11).

Thus, at this stage, the tragedy of the anti-commons and the tragedy of the commons actually co-existed.

In phase III, the interface between private livestock and open access pastures, and the interface between leased pastures and larger pasture ecosystems, both coexisted. There was no effective correction mechanism, resulting in rangeland degradation.

After the promulgation of the new law"On Pastures"in 2009, Kyrgyzstan entered the fourth stage of rangeland property reform (Phase IV of Fig. 4). The biggest change was that the new law abolished the area-based lease system of the previous law, and replaced it with the pasture ticket system. The pasture tickets were priced according to the number of livestock rather than the pasture area (Dörre, 2015; Shigaeva et al., 2016). From the perspective of resource system and resource units, the pasture ticket system can essentially be understood as an individual grazing right according to measurement of the number of the individual's livestock, while keeping the resource system (pasture) in shared use.

For rangeland management, a community-level Pasture Users Associations (PUA) was established, and the government transferred administrative authority for pasture management to the Pasture Committee, which is the executive body of the PUA. The Pasture Committee is composed of representatives of pasture users, local communities, leaders of pasture department of local government, and experts, usually veterinarians and land use experts, who also often work in local government administrations. All herders join the PUA of their rural municipalities (village units) and acquire pasture use rights through the purchase of seasonal use pasture tickets. The cost of a pasture ticket is determined according to the type and number of livestock owned by the herders. While collecting fees the herders paid for the pasture tickets, the Pasture Committee recorded the personal information of pasture users; the name, location, and area of the corresponding leasing pastures; and clarified the carrying capacity with the type and number of livestock allowed to graze, and the temporal and spatial migration plan.

The Kyrgyz 2009 "On Pastures" (revised in 2011) was the first law in Central Asia to claim rangelands as a common property right, and empowered pasture management to local communities.

Especially, the payment of pasture fees based on the livestock numbers rather than the pasture area as before, can overcome the fragmentation of pasture, thus avoiding the problems of anti-commons. Theoretically, this realignment of governance system can match the highly environmental variability of mountain and valley areas and can also meet the needs of herders to cope with the varying resources through mobility (Crewett, 2012; Jacquesson, 2010; Rahimon, 2012).

Of course, the problems faced at this stage are no different from those encountered in Ostrom's CPR governance, that is, how to prevent the overuse of commons through designed regulations, such as rule-making, monitoring, and sanctions (Dörre, 2015; Kurmanalieva and Crewett, 2019). For the pasture ticket system, the majority of problems are mostly reflected in the following two aspects. First, the unfair use of shared pastures. The relatively wealthy and socially well-connected households can afford to build sheds in winter or spring/autumn pastures, so they can actually use a large area of common pasture exclusively. Consequently, the pastures that poorer households can use are relatively small in size, which lead to greater grazing pressure on these unclaimed pastures (Kerven et al., 2012). Second, in terms of institutional support, there may exist the problem of the second-order dilemma of governing commons proposed by Ostrom (1990). The community-based pasture management system was introduced by international financial and development agencies from outside, which technically seems simple and credible, but in the face of actual power and wealth asymmetry, it is unwise to believe that respected members of the community are immune to local power struggles (Earle, 2005). This also answers the question on why funding from international aid agencies is still needed years after the pasture law has been implemented (e.g. IBRD, 2013; Shigaeva et al., 2016).

The implementation and effects of the pasture ticket system at this stage still needs time for in-depth observation in the future.

Discussion

The nested common-private interface (NCPI) framework developed in this article reveals the characteristics and problems of different property regimes applied to overcome the problems of commons/anti-commons. The contributions of the NCPI framework is reflected in three aspects. First, the delineation and protection of individual rights may be the premise to achieve endured collective action of governing commons. Further, the NCPI framework converts Ostrom's commons to liberal commons that the members have options to exit, which is becoming increasingly common in natural resource governance in the context of marketization. Finally, we highlight that there is no so-called optimal property regime in the world because the common-private interface mismatch always exists, and all property regimes need to be supplemented by remedial institutions to correct the interface mismatch. We elaborate these three points below.

Individual rights vs. collective action. The NCPI framework presents a different perspective to understand property systems of natural resources. The resource system is stock, such as rangeland and water ecosystems, which provides public welfare, i.e., ecosystem services such as functioning as carbon sinks, conserving biodiversity and sustaining aquifer. Obviously, ecosystem services are hard to be privatized. Maintaining the spatial and functional integrity of the resource system is conducive to maximizing the value of ecosystem services. Nevertheless, the resource units are flow, such as production of forage and fish, and their function is reflected in the economic output of resource use. Delimitation and protection of individual rights and interests will be conducive to improving economic efficiency. That is, privatization of resource units is better to be applied to achieve the economically efficient use in the market economy. In order to promote the efficient use of resource units while keeping the integrity of the resource system, people want to cooperate, or need to cooperate, but at the same time they worry about being taken advantage of, which leads to Prisoner's Dilemma. Aimed to solve this dilemma, the NCPI framework is developed from the idea that different property rights can be assigned for the resource system and resource units, respectively. In the fourth and current stage of both countries, China's grazing quota system and Kyrgyzstan's grassland ticket present one common feature, that is, they both reflect the clarity and protection of individual rights without fractionizing the rangelands.

Ignoring the rights of individuals in the governance of common resources is often the root cause of "tragedy of the commons". Only when individual rights are delineated and protected, can collective action endure. Most of the CPR literature emphasizes the members' collective action, while not paying attention to the individual member rights. Although the eight design principles of CPR sustainable governance that Ostrom (1990) concluded were mostly related to the resource units' appropriation (i.e. the principle #2-#6) and related to define and secure the de facto rights of individual members, we consider that Ostrom showed some negative attitudes to the privatization of resource units (see e.g. Ostrom, 1990: 135–136; Ostrom and Hess, 2010: 70–71). However, as shown in Fig. 2, the dilemma of commons has always been related to the conflict between private elements (based on the resource units) and common elements (resource systems).

Therefore, the challenges faced by CPR governance can largely come down to how to deal with the "interface" between the individual and collective interests, and how to adjust the interface mismatch accordingly. The NCPI framework is aimed to address these challenges.

Ostrom's commons vs. nested liberal commons. The resources under the NCPI framework are the commons with delineated individual use rights. If the rights are tradable, it means the members would have options to exit the group by selling their rights, which Dagan and Heller (2001) called as "liberal commons". Liberal commons are different from Ostrom's commons because the latter did not take the exit as a variable when studying collective action (Kurrild-Klitgarrd, 2010). While for liberal commons, when members believe that their interests are not guaranteed, they can choose to exit from the commons cooperation.

Indeed, tradable use rights are not new in commons governance, such as the wide application of tradable fishing quotas (Costello et al. 2008; Copes and Charles, 2004), and the Swiss grazing commons (Stevenson, 1991: 89). However, previous studies, including the trading of grazing rights in the Swiss Alpine pastures, have not considered that the right alienation may give members the option to exit, either partially or fully exit. In addition to securing the individual's rights, in the long run, the option to exit would also help alleviate the pressures on resources due to population growth, which is particularly important for transitional countries.

Hirschman (1970) defined the exit as "voluntarily leaving the effective jurisdiction of the group". Exit represents the right to withdraw, the ability to dissociate, and the ability to cut oneself off from others. Exit can provide a function of self-preservation, as Green (1998: 165) pointed out "If the group harms the interests of the member as the member sees them, then leaving is a form of a self-defense." In addition to protecting the interests of members,

exit also has the function of promoting cooperation. The threat of exit is often an effective mechanism for optimizing the use of common resources. If there are possibilities that members may exit, it will promote the group to be more responsible for the interests of its members, and in turn promote better cooperation among members.

In countries with economies in transition, this exit mechanism has positive implications both for protecting the rights of individual herders and protecting the rangeland ecosystem. In China, with the rapid development of urbanization and industrialization, a large number of herders have found alternative livelihoods in urban areas. Therefore, on one hand, individual herders themselves have incentives to quit animal husbandry. On the other hand, at the national level, herders who choose to withdraw from animal husbandry can alleviate the long-term degradation of rangeland ecosystem caused by over-grazing. In China, currently both partial exit (Fig. 1b) and complete exit (Fig. 1c, d) are taking place in pastoral areas. In many villages which still keep the rangeland in common use, mostly on the Qinghai Tibetan Plateau, more and more of the population is moving out and living in the townships (Zhang et al., 2023). Many of these households choose to sell their grazing quotas to the other members, and cash in, i.e., quit animal husbandry, though they still legally have a share of the common pastures (Gongbuzeren et al., 2021).

In Kyrgyzstan, the pasture ticket system applied since 2009 can be understood as an individual grazing right depending on the number of the indivdual's livestock, with the premise of keeping the resource system (pasture) under shared use. At present, Kyrgyz's pasture ticket is only traded between herders and local Pasture User Associations (PUAs), and it seems that they are not tradable between herders. Therefore, the pasture ticket is closer to the liability rule (Calabresi and Melamed, 1972), i.e., it is the PUA which sets the price of pasture tickets rather than herders themselves, and herders must pay the PUA's price in order to obtain the right to use the pasture. Meanwhile China's quota system is closer to the property rule (Calabresi and Melamed, 1972), i.e., herders can set the price by bargaining with each other. The basic difference between the two systems may be attributed to the point that China's quota system is a privilege that each member has endorsed, while the Kyrgyz pasture ticket is more like a contract between individuals and a committee rather than a property right at this stage (for more details about the difference between contract and property, see Rose, 1997). Thus, the Kyrgyz pasture ticket system is at the stage (a) of Fig. 1, with no option to exit.

Ostrom's theory of CPR governance did not consider the exit. This may be attributed to the thinking that all the members have no incentives to exit. Given the collective ownership of the resources, exit means voluntarily giving up common ownership if the individual rights are not delineated. At the same time, most of the cases reported in those long-enduring CPR governance (Ostrom, 1990) did not consider the markets for the purchase, lease or exchange of resources. Rights are limited to specific and qualified group members and cannot be transferred to outside persons without the collective consent. Further, Ostrom even seemed to take exit as problematic. Taking migration as an example, Ostrom (2000: 153) stated this point: "*Major migration (out of or into an area) is always a threat that may or may not be countered effectively. Out-migration may change the economic viability of a regime due to loss of those who contribute needed resources.*" As one scholar of Bloomington School, Araral (2014: 21) critically pointed that: "Ostrom (1990) *is justified for her critique of the Leviathan solution to the tragedy of commons but a rethinking is needed of her critique of private property rights and markets*".

In the context of market-oriented globalization, however, such CPR governance based on the boundedness of traditional communities is increasingly facing challenges. The liberal commons are becoming general in the current real world, and the NCPI framework may provide a new type of property regime to manage liberal commons. Around the world, pastoral communities are losing the labor of their younger members due to out-migration for wage-employment, rendering livestock management increasingly problematic, regardless of land rights (Singh and Kerven, 2023; Scoones, 2021). Weakened local cultural institutions and rising social inequality are encouraging external interests to gain control over the rangelands, as commercial markets for land develop within communally-held rangeland (Ykhanbai et al., 2014). Innovations of weaving communal access into private or state-owned rangeland property, using formal rentals and informal access arrangements, have arisen in east and southern African pastoral rangelands (Jeppesen and Hassan, 2022; Bollig, 2016). These bear some resemblance to the pathways now emerging in China's rangelands.

Everything has two sides. Although the exit option may protect the rights and interests of individual members, if there are no corresponding regulations, exit options may also have negative impacts on cooperation. When some members exit, those who choose to stay may fear that the departing members will take advantage of them, thus leading to either excessive appropriation of common resources or unwillingness to contribute to common resources. This topic deserves future in-depth study in the CPR field.

Implications and limitations. Because the common-private interface mismatch always exists, there is no so-called optimal property regime in the world. An appropriate property regime is related to the optimal scale of resource utilization, while the optimal scale of natural resource use varies with time and goals of each particular society and period, including both economic efficiency and ecological benefits. Since the economic efficiency is derived from resource units, while the ecological benefits are the outcome from resource systems, the optimal scale for economic efficiency and ecological benefits may differ, which creates scale mismatch. When the scale of resource unit utilization matches the labor input, economic efficiency is achieved; while for ecological benefits provided by the resource systems, generally the larger the spatial scale, the higher the ecological benefits provided. Therefore, there is no one-size-fits-all property system, and all property regimes need to be supplemented by remedial institutions to correct the interface mismatch.

This analysis has particular implications for future property reforms in economic transition countries, though also applicable in the other countries beyond the context of former Soviet Union. Compared with the developed countries with mature market economies, the characteristics of transition countries were/are resource-intensive and labor-intensive, and inhabitants are changing from subsistence to commercial livelihoods. Therefore, the appropriate property regime determined by the scale of effective use of resources is not fixed, but a dynamic evolutionary process. Privatization of natural resources is not the panacea necessary to the transition from a planned to a market economy.

Although the NCPI proposed in this article is based on the problems that emerged from the transformation of the property rights system after the collapse of the former Soviet Union, the anticommmons and its dilemma caused by the excessive fragmentation of property rights do not only exist in economic transitional countries, but are also in countries with relatively complete market economy and property rights systems. For example, the share chopper dilemma that Native American families have been facing, and the BANANA (*build absolutely nothing anywhere near anyone*) republic that reflects the dilemma

of consolidating fractionized lands, reported by Heller (2008: 108–109). Therefore, the NCPI framework would be of interest to those who study common property governance beyond the specific context of transition countries.

Although the NCPI framework we proposed is originated from our long-term rangeland studies and observations, it also can be applicable to the other renewable ecological resources, including forests, oceans, lakes and rivers and other water bodies, etc. All these resources consist of the resource units with flow characteristics and the resource system with the stock characteristic. The excessive appropriation of the resource units will lead to the degradation and even depletion of the resource system. Here the relation between the resource units and resource system is based on their functionality. Therefore, if we consider their relation from the perspective of function utilities as well as spatial scale, for example, the joint apartments of Moscow (Heller, 1998), taking each room as the resource units and the entire apartment as the resource system, the NCPI framework may be also applicable. This is worth being studied in-depth in the future.

Data availability

Data sharing is not applicable to this research as no data were generated or analyzed.

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