

Scarcity and the evolution of water rights in the nineteenth century: the role of climate and asset type

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The adoption of a hybrid approach to water rights known as the California doctrine in some western states of the United States (US) and Australia creates some doubt as to what factors drive scarcity and the evolution of property rights to water. In previous studies commentators have argued that climate is the only variable that drives water scarcity. This can explain why private rights (prior appropriation) were adopted in western states of the US during the nineteenth century. However, it cannot explain why the hybrid approach where common and private rights co-existed in nine of seventeen arid US states and two Australian colonies persisted. This paper shows that in addition to climate, the dominant type of asset investment impacts water scarcity via the mobility constraint. Asset investment can be deployable or non-deployable. When deployable assets dominate the mobility constraint is close to zero and not binding thereby reducing water scarcity because alternative production locations are available. Conversely when non-deployable assets dominate the mobility constraint is close to one and binding so that assets are unable to be moved to alternative production locations. We present a framework that combines climate and asset type in order to determine the net effects on water scarcity in order to predict when and where common and/or private water rights will evolve. Empirical evidence from several countries is used to verify the frameworks predicative capacity. The findings show the combination of these two variables is better able to explain the emergence and persistence of the hybrid California doctrine as well as the adoption of 'pure' private rights (the Colorado doctrine) in eight of seventeen US states than if we rely on climate alone.

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During the nineteenth century water rights in a number of western states of the United States (US) and Australia evolved so as to create a hybrid system that incorporated two very different types of property rights, common property (riparian law) and private property (appropriative law). This system is known as the 'California doctrine.' Economists and legal historians have extensively analysed the doctrines evolution and impacts particularly in the US (Milliman, 1959; Lauer, 1963; 1970; Schieber and McCurdy, 1975; McCurdy, 1976; Littleford, 1983; Freyfogal, 1985; Pisani, 1987; Rose, 1990; Kanazawa, 1998). Moreover, because the California doctrine was applied in arid areas, it's adoption runs directly counter to property rights theory where scarcity will influence a move to private rights. Scarcity will cause the evolution of property rights along a linear spectrum from open access to private property via its impact on asset values (Demsetz, 1967). Specifically, as scarcity rises for example, because of a larger number of competitors, asset values increase. In turn, the benefits of defining and enforcing rights at more margins start to outweigh the costs. In other words, actors will internalise a greater rental stream by expending their resources on definition and enforcement activities. Consequently, as asset values increase the returns from clear property rights also rise, encouraging the move toward private property, the most precise form of rights. In the context of water rights, previous studies have found that scarcity is determined by climate (Lauer, 1963; 1970; Anderson and Hill, 1975; McCurdy, 1976; Dunbar, 1983; Pisani, 1987; Kanazawa, 1998; Libecap, 2007). As a result, because southern Australia and states of the US beyond the 100th meridian are arid, high scarcity will prevail, and theoretically, private property rights to water should evolve. Nevertheless, during the nineteenth century, only a handful of arid US states (and no Australian states) exclusively applied private rights to water (the prior appropriation doctrine).¹ The remaining US states and Australian colonies, although arid, used the hybrid California doctrine.² The widespread adoption of this hybrid approach implies factors other than climate must influence scarcity in any given context. These factors will counteract scarcity brought about by an arid climate.

This paper shows, in addition to climate, water scarcity is influenced by asset investment. Considered individually both factors impact scarcity in different ways; combined, they provide a more concise explanation of water rights evolution by allowing us to determine their net effects on scarcity. This paper formulates a predictive framework that will show when and where common and private water rights will be applied. In doing so, the analysis will create a framework that provides a better understanding of water rights evolution in alternative historical contexts. Our expectations are that in arid climates with non-deployable asset investment private rights evolve; in arid climates with deployable asset investment common rights will evolve; in climates that are not arid with non-deployable asset investment common

¹ Exclusive adherence to prior appropriation is referred to as the 'Colorado doctrine.' States that apply this approach are: Colorado, Wyoming, Montana, Idaho, Nevada, Utah, Arizona, and New Mexico.

² The US states where: Washington, Oregon, California, Nebraska, North Dakota, South Dakota, Oklahoma, Kansas, and Texas. In Australia, New South Wales (NSW) and Victoria adopted the California doctrine.

rights will be adopted; and the same outcome will occur in the presence of climate that is not arid and deployable assets dominate. The empirical examples presented here conform to our expected outcomes given the alternative combinations of climate and asset type. Private rights did evolve in the presence of an arid climate with non-deployable asset investment in California and Colorado's gold mining and irrigation sectors, and the Australian gold mining sector. Common rights evolved in the presence of a rainfall abundant climate with non-deployable asset investment in the eastern US and England. Common rights also evolved where the climate was arid but deployable assets dominated in the Australian sheep grazing industry. These findings indicate that by adding investment type to climate and determining the net effects on scarcity we can provide a more complete story of water rights evolutions in different historical contexts.

The remainder of this paper is set out as follows: section two outlines the origins of both prior appropriation and riparian rights in the US and Australia. Section three presents a predictive framework that establishes how aridity and asset type interact to determine the type of water rights that will be applied in a given setting. Section four applies the framework developed in section three to several empirical examples to determine its predictive power. Section five discusses additional variables that may impact water scarcity and thereby the durability of the predictive framework. Section six offers some concluding remarks.

2. Prior Appropriation and Riparian Rights

Before outlining the predictive framework and testing this against the empirical evidence, the context in which prior appropriation and riparian rights evolved in both the US and Australia warrants some discussion. The application and subsequent codification of prior appropriation in the US is well known and has undergone extensive examination (Wiel, 1912; 1936; Milliman 1959; Lauer, 1963; 1970; Anderson and Hill, 1975; Schieber and McCurdy, 1975; McCurdy, 1976; Freyfogal, 1986; Littleford, 1983; Pisani, 1987; Rose, 1990; Lueke, 1992; Kanazawa, 1998; Libecap, 2007). Initially, miners applied the doctrine to allocate water on the gold fields during the late 1840s and early 1850s. Both courts and state legislators later endorsed these rights. Prior appropriation's basic premise was 'first in time is first in right.' In other words, water rights adhered to the principle of first possession. Several additional characteristics were also present: 1) seniority ruled so that, in the presence of a water shortage, later (junior) claimants would be required to reduce or cease using water to provide sufficient volumes for more senior claimants.³ This meant senior claimants had greater security of right; 2) non-use would lead to forfeiture and; 3) rights could be traded. Over time, the doctrine was refined to require appropriators to put water to beneficial use or lose their right. The application and subsequent formalisation of prior appropriation in southern Australia has received much less attention. In

³ Based on evidence from early Colorado mining codes Schoor (2005: 10-14) argues this idea of seniority is a misinterpretation of prior appropriation and in fact equity was the main aim of water allocation rules. A point that is discussed in more detail later.

fact, there have been no studies analysing the circumstances leading to its application in Australia despite the strikingly similar conditions under which the doctrine arose.

Like the US, appropriation in Australia evolved from water use on the goldfields in the 1850s. Appropriative rules to water use were sanctioned by government officials, Gold Fields Commissioners, appointed to manage and administer gold mining licences. The first recorded use of the doctrine took place on Victoria's Beechworth Goldfield in 1853. The doctrine was based on the premise of first possession so first in time was first in right; and many of the characteristics present in the US approach were applied in Australia, including seniority rule, forfeiture for non-use, and tradability.⁴ The main divergence apparent in the evolution of appropriation in these two countries was the mechanism by which these informal rules were transferred into formal rights. As noted, in the US this happened primarily via courts, in Australia via legislation.⁵ Australian colonies relied on legislation because the courts refused to sanction appropriative rights. There were two reasons for this: 1) it was considered that all diversions were illegal under gold mining regulations (Court Reporter, August 18, 1858); 2) Mining Courts found it impossible to deal with the idea of priority water rights because they believed such rights lacked legal foundation. On giving evidence at a Royal Commission into administration of the Victorian goldfields one judge plainly stated: "It is a thing unknown in law, a first right, a second right, or a third right, and I did not know how to deal with them" (Victorian Parliamentary Papers, 1862-63: 73). What is surprising about this interpretation by Australian courts is that prior appropriation had its origins in English common law.

The English appropriation doctrine, referred to as prior use, developed from the 1700s onward. This approach to water rights did not have its foundations in court rulings, rather it was espoused in legal treatise.⁶ Judges later cited these doctrines in their judgments as authoritative rules. In the late eighteenth century the eminent legal writer, Blackstone stated rights to flowing water should follow occupancy, or first possession (Rose, 1990; Getzler, 2004). Appropriation theory replaced the previous doctrines used to determine water rights disputes: ancient use and natural flow principles.⁷ The English appropriation rule resembled the appropriation doctrine subsequently adopted in the US and Australia in the nineteenth century including: 1) rights were conditional on any prior rights that existed for a given water source; 2)

⁴ However, there were a number of important differences in the doctrine's application on Australian goldfields, specifically: volumes claimed under appropriation were limited; and control over return water (referred to as tail water) was prohibited.

⁵ In NSW the legislation was, 'Act to amend the laws of the Gold Fields' (1857); and in Victoria it was the 'Gold Fields Act' (1855).

⁶ Getzler (2004) notes that many important aspects of eighteenth century land and water law were developed by treatise rather than judicial decision. Moreover, judges in leading cases cited Blackstone's treatise as a direct authority on questions of water law. For this reason, it is justifiable to claim that Blackstone in particular laid the foundations for nineteenth century land and water use.

⁷ Refer to Getzler (2004) chapter five for an excellent discussion of the move from natural use to appropriative use in the English common law over this period.

rights to the current were limited to the volumes originally utilised; 3) no rights could exist unless water was 'beneficially' used; and 4) non-use would result in forfeiture.

However, in England individuals could not assert claims to water rights based on appropriation unless they occupied land coming in contact with the watercourse (Getzler, 2004). This was the fundamental difference between the doctrine as it applied in that country compared with the US and Australia. Therefore, in England appropriation was a test applied to disputes *between* riparian owners who obtained water use rights by virtue of the position of their land.⁸ Specifically, the rule was used to determine what actions would be considered acceptable given the shared right of all riparians to make use of the resources on their land. Individuals occupying land that did not come into contact with the watercourse were unable to obtain water rights and therefore, they could not appropriate the resource. In turn, prior use did not alter *who* could obtain water rights; it merely dictated how disputes between group members would be settled. As a result, water use rights were obtained by a group of individuals based on their land occupancy. This group of right holders were permitted to make use of water to the exclusion of all others – a characteristic typically associated with common property. The appropriation rule assigned each group member a right to the *flow* of services from the asset. However, the flow did not have to be equally shared between users; rather the first user would be entitled to unencumbered use rights compared with subsequent users. For example, assume a river has two riparian owners A and B; and contains 100 megalitres of water. In period one A utilises 50 megalitres for her mill; in period two B begins to utilise 60 megalitres for his mill. Applying the appropriation rule a court would find A has a prior use right to 50 megalitres and therefore B can only 'appropriate' the volume not being exploited by A – 40 megalitres.⁹ By the nineteenth century, English courts (and those in the eastern states of the US) had replaced the appropriation rule with reasonable use. Reasonable use dictated that actions by water users were reasonable if and only if they did not devalue the common right held by all water right owners along the watercourse. This test became the foundation for the modern tenets of riparian law.

In both the US and Australia riparian law had its origins in English common law. Californian courts were bound by English common law after 1850 when the legislature passed "An Act adopting the common law." Kanazawa (1998) notes that it is unlikely early legislators recognised that adoption of English common law meant simultaneously accepting riparian law and the

⁸ Under common law when individuals occupy land bordering a river or stream the boundary of ownership extends to the bed of the river. In this way, individuals own land *ad medium filum aquae* (to the 'middle thread'). This gives them rights to use the water flowing over this land. These rights were the same type of property that existed in wild animals where title arose "by a man's *reclaiming* (original emphasis) and making them tame by art, industry, and education; or by so confining them within his immediate power, that they cannot escape and use their natural liberty...[this] property may be destroyed if they resume their ancient wildness, and are found at large" (Blackstone, Book 2, p. 393 quoted in Getzler, 2004: 176).

⁹ A court would find that B had infringed A's right under tort rules of trespass or negligence. The remedy would be either an injunction or damages.

reasonable use test.¹⁰ This decision gave rise to the California doctrine and created complications for courts determining riparian-appropriator conflicts that occurred with increasing frequency from the 1880s. Australia adopted British common law in 1827 under the “Australian Courts Act.” Section 24 explicitly granted colonial courts the right to diverge from established precedent stating English law applied:

That all Laws and Statutes in force within the Realm of England at the Time of the passing of this Act...shall be applied in the Administration of Justice in the Courts in New South Wales and Van Diemen’s Land respectively, so far as the same can be applied within the said Colonies; and as often as any Doubt shall arise as to the Application of any such Laws or Statutes in the said Colonies respectively, by and with the Advice of the Legislative Councils...by Ordinances to be by them for that Purpose made, to declare whether such Laws or Statutes *shall be deemed to extend to the Colonies, and to be in force within the same, or to make and establish such Limitations and Modifications of any such Laws and Statutes* (emphasis added) within the said Colonies respectively as may be deemed expedient on that Behalf...

By virtue of section 24, Australian courts could have refused to adopt or modified aspects of riparian law if they believed colonial circumstances warranted this deviation. Moreover, courts had deviated from English common law in other areas suggesting the flexibility granted under section 24 would be exercised where appropriate. For example, in *R v Farrell, Dingle and Woodward* (Court Reporter, 11 July, 1831, p.3) the court found applying English rules of evidence forbidding convicted criminals from giving testimony was unworkable in a penal colony.¹¹ Nevertheless, despite the obvious climatic deviations between Australia and England combined with the relative flexibility given to Australian courts, several decisions led to the application of the reasonable use test to determined riparian conflicts in the colonies.¹² As a result, common law riparian rights and reasonable use were applied alongside legislation supporting prior appropriation – thus, establishing the California doctrine.

What is unique to Australia is the very clear sectoral demarcation of the two water rights systems. Specifically, legislation applied prior appropriation only on the gold fields so that no water users outside this sector could assert or defend claims based on first possession. Riparian rights and reasonable use was applied in all other areas, including the largest sector of the colonial economies, the pastoral industry. This divergence from theory can be rationalised using the predictive framework from section three.

¹⁰ English common law adopted reasonable use in 1849 (*Wood v Waud*, 3 Exch. 748, 154 Eng. R. 1047). Application of reasonable use in the eastern states of the US preceded English courts by at least four decades (*Palmer v Mulligan*, 3 Caines R. 307 (1805), cited in Rose (1990)).

¹¹ Individual judges would also exercise flexibility under this rule, particularly when considering decisions of British courts of coordinate jurisdiction. Refer to Harris (2009) for a discussion of the relevant judges attitudes.

¹² Riparian rights and the reasonable use test were applied in several cases in NSW and Victoria during the nineteenth century. In NSW these cases were: *Cooper v Corporation of Sydney* (1 Legge 765 (NSW 1853)); *Hood v Corporation of Sydney* (2 Legge 1294 (NSW 1860)); *Pring v Marina* (5 NSW (L.) 390 (1866)); *Howell v Prince* (8 NSW (L.) 316 (1869)); *Lomax v Jarvis* (6 LR (NSW) 237, 1885). In Victoria the one case was *Newstead v Flannery* (8 ALT 178, 1887).

3. A predictive framework for water rights

Theoretically, scarcity leads property rights to evolve in a linear spectrum from open access to private property. Open access persists when there is little competition and therefore, scarcity is low. As competition intensifies, for example because factor price or technology changes increase returns to exploitation, scarcity rises. At this point, property rights will reduce the losses associated with racing that result in the familiar tragedy of the commons (Hardin, 1968). Initially, because the group of expropriators is relatively small and homogenous, common property rules can serve to limit the racing incentive, protect claims, and support productive investment. The creation of common property is dependent on organisation and exclusion costs. In the first instance, common property will arise only so long as the group can overcome the public good problem of collective action. Shared social norms provide a foundation for such organisation highlighting the importance of homogeneity in supporting the rise of such regimes. In the presence of cultural homogeneity where the costs of formal sanctions are high, for example at the frontier the supply of common property or *de facto* property rights will rely, in part, on norms. Norms lower the coordination costs by creating focal points that, prior to the play of the game, have mutual significance to players based on past experiences (Sugden, 1989; Zerbe and Anderson, 2001).¹³ This establishes an equilibrium all players expect increasing the likelihood of cooperation in a prisoners dilemma game. Individual members of a group monitor and enforce norms because it is in their interest to do so. This is because there are greater gains from cooperation than conflict. Internalising these gains relies on continuing the behavioural pattern established by shared norms. Actors will therefore have an explicit incentive to monitor and enforce norms because any breach is an indirect threat to them and the rental stream they derive from the collective good (Sugden, 1989). In other words, norms reduce organisational costs faced by a group. Once organisation costs are overcome, exclusion costs are ongoing requiring continued investment by group members to prevent encroachment. However, because each group member has an incentive to maintain exclusivity in order to maximise rents accruing to them, the marginal costs of defence per member are lower than in the absence of the common property arrangement. Internal governance costs also matter in these arrangements to prevent overexploitation by limiting free riding and restricting use. It can be assumed that where groups are small and homogenous, that is share social norms the costs of internal governance will be low.

Typically, the creation and maintenance of common property regimes means there exists margins on which rights go undefined because the costs of such definition outweigh the benefits. For example, rights of riparian owners were determined by the reasonable use test that was based on reference to a common right held by all riparians.¹⁴ An activity by one riparian owner would be deemed reasonable if and only if it did not devalue the common right.

¹³ Focal points include expectations about behaviour including, what is fair, and first possession rules that underpin the formation of property rights. Axelrod (1986); Sugden (1989); Ellikson, (1991); and Zerbe and Anderson (2001) all discuss the impact of norms on property rights and coordination costs.

¹⁴ *Ripa* means the banks of a water course that gives rise to the term riparian (Lauer, 1963). Only those individuals who owned land that came in contact with the water source could acquire riparian rights.

Similar imprecision may exist for other resources subject to common property regimes, for instance land where use of common pastures dictates only the number of animals each member can graze rather than their location on the pasture. By leaving the area on which animals owned by individual members can graze undefined, there is the potential for conflicts when common pastures are relatively large and have variations in feed quality. The probability of conflict can be reduced if rules requiring pooling of output are adopted to ensure returns to each member are equal regardless of individual animal production. Predominantly, common property prevails when it is too costly to divide the resource stock between individual owners (Lueke, 1995) for example, because the resource being exploited covers a large geographical area; and when there are net gains from assigning individual shares in the flow of services from the asset to group members (Eggertsson in Anderson and McChesney, 2003). Moreover, common property arrangements may be relatively stable and long lasting (Rose, 1990; Alston, Harris, and Mueller, 2009).

Under conditions of increasing scarcity, common property will give way to private property because scarcity creates higher costs of maintaining the former set of rights compared with the latter. Rising costs of common property enforcement are brought about by an increasing number of heterogeneous expropriators that lead to rising marginal costs of defence for incumbents. Once defence costs are prohibitively large, the common property system will collapse. For example, consider a case where output prices are rising for the product of a common pasture thereby increasing the returns from grazing. New entrants will have an incentive to move into the grazing sector to capture part of the growing rental stream available thereby increasing enforcement costs for common property owners. Once defence costs exceed the benefits of common property that is, the marginal costs of preventing encroachment outweigh the marginal benefits of group membership, economic pressures will encourage a move to private property.¹⁵ Alternatively, consider a case where technological change reduces the costs of dividing the stock of a commonly owned resource between owners. In the first period, the cost of dividing the stock is high because the technology does not exist for low cost enforcement of individual rights. For example, during the early settlement of the US Great Plains the absence of low priced fencing materials increased the costs of enforcing private rights to large land claims required for cattle grazing. However, returns from enforcing land rights for a small group of ranchers were high. In this case ranchers formed associations with each member having a right to the flow of services from the asset, that is land. In period two there is an exogenous technological shock with the introduction of barbed wire. Barbed wire, a low cost fencing technology, decreases the costs of enforcing individual rights to the stock of land. As a result, land owned in common in period one will now be divided among ranchers transforming parcels into private property. Technological innovation altered relative values of the resource under different ownership arrangements causing the shift to private property.

¹⁵ The form that private rights take depends on the interaction between norms, politics, and economics (Alston, Harris, Mueller, 2009). Further, extant common property owners may not have their rights legitimised so that the prevailing private rights may allocate goods to other actors.

In line with the more general property rights literature, empirical studies analysing water rights evolution highlight the vital role of scarcity in moving from open access to private rights. These studies argue that climate alone determines scarcity and therefore the type of water rights that evolve in a given setting. Climate acts to affect scarcity in the following ways: assume competition exists but remains constant in the short-run, in rainfall abundant climates, scarcity is low and; in rainfall constrained that is, arid climates scarcity is high. Therefore, *ceteris paribus*, in rainfall constrained climates, water rights evolution would tend toward private rights; while in rainfall abundant climates common rights will prevail.¹⁶ The gap between the theoretical expectations and empirical work lies in the fact that climate cannot adequately explain why the California doctrine persisted in both the US and Australia. Moreover, commentators pay limited attention to the fact that at any time the legislature in either country could have acted to remove riparian rights in favour of appropriation. Alternatively, courts could have abolished riparian rights in favour of exclusive reliance on prior appropriation as Colorado had done from the 1870s.¹⁷ This oversight is surprising, particularly in the California context, given the general contention that these courts were particularly innovative and undertook doctrinal change given the unique climatic conditions that prevailed (Wiel, 1912; Lauer, 1963; 1970; Schieber and McCurdy, 1975; McCurdy, 1976; Pisani, 1987). Court codification of informal miners' rules including prior appropriation is a case in point.¹⁸ Further, no study offers a framework by which to rationalise the broader application of the California doctrine in arid climates such as Australia. As a result, aridity as the main driver of scarcity loses its explanatory power. In order to provide a more comprehensive framework by which to make sense of these empirical outcomes, careful re-examination of factors that affect scarcity is critical. It is the contention of this paper that in addition to climate, the type of asset investment that dominates different sectors affects water scarcity and therefore, the water rights that evolve in a given setting. Like climate, asset investment influences scarcity in specific ways. Further, by combining asset investment and climate, we are able to better predict where and when common and/or private rights will prevail.

Asset investment in productive facilities will be either deployable or non-deployable. Deployable assets can be moved at little or no cost that is, they are mobile, for example, sheep or cattle. Non-deployable assets are unable to be moved from one location to another at low cost because their physical features make them costly to install, remove, and relocate (Burnham, Chavas, and Coomes, 1998) for example, a channel to move water to a gold mine. First, putting aside climate, consider the impacts of asset investment on scarcity. Assume

¹⁶ The timing of these events is ignored, but it is recognised that this evolution may happen over varying time frames given different contexts.

¹⁷ The two important cases in Colorado were: *Yonker v Nicholas* (1 Colo. 551, 1872) and *Coffin v Left Hand Ditch Company* 6 Colo. 443 (1882) cited in Frefoygal, 1983.

¹⁸ *Irwin v Phillips* (5 Cal 140 (1855)) was the first case in which the California Supreme Court recognised the right of first possession and diversion. Recognition of first possession was at the core of the prior appropriation doctrine that was repeatedly upheld in later cases.

competition exists but remains constant in the short-run, asset investment affects scarcity in the following way: where deployable assets are the main form of investment, scarcity is low; conversely, where non-deployable asset investment prevails, scarcity is high. The mechanism by which asset investment influences scarcity is through the mobility constraint. For simplicity, assume the mobility constraint is either zero or one.¹⁹

At zero, the asset is fully mobile that is, the mobility constraint does not bind and movement costs are also zero; conversely, at one the mobility constraint binds and movement costs are equal to one. If the mobility constraint is zero in any period, it is not binding and assets are fully deployable increasing the availability of alternative productive locations, therefore scarcity is low. For example, in the face of district drought, sheep or cattle are not confined to one site; they can be moved at relatively low costs to alternative production locations where inputs are unaffected. The costs of moving these assets are positively related to the distance travelled where a greater distance increases relocation costs by causing the death of smaller animals and a reduction in wool and/or meat quality of the flock or herd.²⁰ However, assume that in any one period distance travelled is small therefore, movement costs approach zero (costs are positive but at very low levels). As a result, the costs of mobility are not so high as to decrease the returns from movement to zero. Further complementing a non-binding mobility constraint for livestock is the ability to slaughter animals in the face of region or state wide drought. Drought limits the availability of both feed and water for existing flocks or herds. Slaughtering acts to reduced competition for all inputs. In other words, marginal adjustments to animal numbers could be made given climatic variations experienced over time. Once a drought had broken, natural increases in numbers could be relied upon to rebuild flocks or herds to pre-drought levels. Nevertheless, at some point, slaughtering costs would approach one for example, where flock or herd numbers were reduced to such a point so that only key breeding animals remained. At this point, the cost of slaughtering would be outweighed by the costs of replacing animals that is, the cost of going to market to buy new stock. As a result, there is diminishing marginal returns to slaughtering because at some point the costs of continued slaughter will be higher than the benefits.

There may be cases were the mobility constraint is non-binding, that is, close to zero but returns to movement are zero, for example if relocation could cause the death of an entire flock or herd. Under these conditions, asset mobility is associated with prohibitively high costs so actors will not relocate under any conditions. As a result, while these assets would be considered deployable in the first instance, deployment costs are approaching or equal to one so that in fact non-deployable characteristics dominate. This will increase water scarcity. When the mobility constraint is equal to one in any period, it is binding so movement costs are

¹⁹ Of course, the mobility constraint may have a value anywhere between zero and one and this will in turn affect the costs of relocation accordingly.

²⁰ One could easily assume that relocation costs are a function of transportation costs for instance, the costs of hiring labour and a truck suitable for asset redeployment. However, this would not alter the outcome of the analysis because transportation costs are also positively related to distance.

prohibitively high, assets are non-deployable, and scarcity is high. To summarise, the effects of asset investment type is: *ceteris paribus*, when investment in deployable assets dominates, water rights evolution will tend toward common rights; and *ceteris paribus* when non-deployable asset investment dominates, water rights evolution will tend toward private rights. By combining climate and asset investment, we can predict when and where to expect either common or private water rights to apply (table 1).

Table 1

		Asset type	
		<i>Non-Deployable</i>	<i>Deployable</i>
Climate	<i>Arid</i>	Private rights	Common rights
	<i>Not Arid</i>	Common rights	Common rights

Table one illustrates that in arid climates where investment is in non-deployable assets, scarcity is high, and private rights like prior appropriation will be applied.²¹ However, where climate is arid and investment is in deployable assets, scarcity is counteracted by a non-binding mobility constraint and common rights will be used to allocate water supplies. In a non-arid climate where non-deployable asset investment dominates, a relative abundance of rainfall will counteract the binding mobility constraint effects on scarcity leading to the adoption of common rights. When climate is not arid with investment in deployable assets, the combination of rainfall abundance and a non-binding mobility constraint will mean low scarcity prevails and common rights will be utilised. How does this predictive framework fit with empirical evidence?

4. Empirical Evidence

4.1 Australia

Before applying the predictive framework from section three, climate and asset investment in nineteenth century Australia need to be considered. Australia is arid, with much of NSW and Victoria receiving less than 200-300mm (eight-12 inches) annually, similar to the US Great Plains and far west. Australian economic development in the nineteenth century was underpinned by pastoral sector expansion and growth of the wool industry. By the 1830s, Australian wool producers were critical suppliers of the British textile industry; by 1865 total sheep numbers in NSW and Victoria were 16.5 million (Davidson in Vamplew, ed., 1987); and by the end of the century numbers exceeded 50 million (Davidson in Vamplew, ed., 1987). Pastoralists used water for two main activities: washing wool prior to transport to reduce its weight (Butlin, 1964); and for sheep to drink. During much of the nineteenth century pastoralists relied almost exclusively on surface water supplies to maintain sheep flocks. Substantial ground water

²¹ Literature suggests that reliance on common property arrangements for water in arid environments may be fleeting or skipped altogether as a result of climate constraints (Rose, 1990).

supplies were available, particularly in NSW below much of which lays the Great Artesian Basin one of the largest groundwater basins in the world, however until the 1880s pastoralists limited their use of groundwater (Butlin, 1964; Lloyd, 1988; Jarvis, 1952).²² From the 1880s, there was greater investment in locating potable groundwater in order to substitute for highly variable surface water supplies. Nevertheless, anecdotal evidence suggests graziers found locating groundwater supplies suffered from uncertainty and high cost. A government report summed up the situation in 1885 stating:

There are localities in which the existence of underground water has been discovered and turned to account by means of wells; but it has happened in many cases that, of two wells sunk within a few yards of each other, one, and the deeper of the two, has been perfectly dry, while the other has passed into a water-bearing drift...but in the absence of anything like determinate surface indications, the sinking of wells has been found to be a very costly, and for many an almost ruinous undertaking (Lyne, 1885: 29).

Therefore, NSW and Victorian graziers faced relatively high levels of water scarcity brought about by limited rainfall and an absence of low cost surface water substitutes. This was counteracted by a non-binding mobility constraint in the pastoral industry. Complimenting this, graziers scattered their land claims over large areas to lower the cost of district level drought.²³ Given these conditions, using the predictive framework in section two we would expect common rights to be adopted to govern water allocation in the pastoral sector during the nineteenth century– and in fact, this did occur. Common rights under the riparian doctrine had several advantages compared with prior appropriation when applied to wool production: 1) riparians did not lose their rights during periods of non-use.²⁴ Retention of water rights during non-use periods complimented grazing where optimal location for profit maximisation was subject to inherent seasonal variation and land claims were scattered over large areas to include summer and winter properties.²⁵ Retaining water rights even during non-use decreased monitoring and enforcement costs of water access. Further, it conferred on pastoralists the net gains from assigning individual shares to the flow of services from the resource to group members; 2) the riparian doctrine created a right of access rather than a right to a specific quantity of water. Shortages in any one location could be overcome by moving stock to alternative locations where supply was unaffected and water rights were retained by virtue of land claims. The non-binding mobility constraint therefore, counteracted scarcity brought about by aridity. During widespread drought reducing sheep numbers via slaughtering could combat

²² The Great Artesian Basin is estimated to contain close to 65 billion megalitres of water (*Australian Natural Resource Atlas*, 2003).

²³ On average graziers claimed 34,000 acres in NSW and 24,000 in Victoria (Roberts, 1935).

²⁴ Clause 41 in regulations under the Gold Fields Act of 1861 stated conditions under which water rights would be forfeited as: “Privileges not upheld and used for a period of 14 days in the case of alluvial mining and of a week in the case of river working shall be held to be forfeited, unless abandonment be explained to the satisfaction of the commissioner.” Under the 1869 Gold Field’s Act regulations the period of non-use before forfeiture was extended to one month for all use types. Both acts noted that non-use during periods of drought could not be grounds for forfeiture.

²⁵ In each district, land claims were enforced by a government appointed Crown Lands Commissioner appointed under the 1836 Squatting Act, and by the physical presence of employees.

supply constraints further reducing the costs of scarcity brought about by aridity and; 3) interpretation as to what constituted reasonable use was fluid across time and space. Therefore, when lack of rainfall reduced supply, courts could redefine reasonableness in order to limit the concentration of losses on one individual. In the absence of a water market when users have identical profit functions, Burness and Quirk (1979; 1980) show riparian rights have an allocative efficiency not attained by appropriative rights. In cases where heterogeneous profit functions exist, for example in mining because of ex ante information asymmetries regarding the productivity of a claim, appropriative rights retain their allocative efficiency.

As has been established, Australia is arid and nineteenth century pastoralists faced a non-binding mobility constraint. Now, consider asset investment on the goldfields in NSW and Victoria. Water was a critical input for mining primarily used to wash gold bearing gravel. Water use often took place at a distance from the water source. In order to convey the resource to the primary mine site various ditches and channels had to be constructed, in Australia, these were referred to as 'races.' Investment in diversion infrastructure was a non-deployable asset so the mobility constraint was binding. Specifically, the mobility constraint was close or equal to one. As a result, we would expect that private rights would be used to allocate to water on the goldfields – and this did occur. In this context, private rights had two advantages over common rights: 1) because diversion capacity was constructed based on the amount of water claimed seniority guaranteed a return on sunk investment costs. Several commentators identify the importance of this aspect of prior appropriation (Blackstone in Getzler, 2004; Trelease, 1965; Tarlock, 2000). Blackstone claimed that physical competition for appropriated goods or capital such as water was not valuable competition. His argument centred on prescriptive ferries, but can also be applied to other fixed capital, such as roads or water channels (Getzler, 2004). Further, secure water rights aid the attainment of maximum benefits for the community by encouraging investment (Trelease, 1965). Investment will ordinarily be made only if the investor can evaluate the risk of losing capital. Complete uncertainty with regard to entitlement brought about by a flexible use rule, like reasonable use, therefore, may lower investment in fixed assets. Loss of capital in the form of sunk costs that is, permanent investment in facilities that cannot be transferred to other uses, can be avoided by giving water rights for a sufficient length of time to permit the investor to recapture the value of the investment through amortization. Trelease (1965) goes on to state that in addition to the fear of loss of sunk costs investment, time and money are invested and the expectation of the realisation of opportunities is the entrepreneur's most valuable asset. Further, Tarlock (2000) argues the core idea of prior appropriation is protection of investment-backed expectations from the risks of variable water supply years.

One limitation of private rights established under prior appropriation was that seniority would create efficiency losses if junior appropriators, forced to reduce or cease water use during a shortage, were more productive at the margin. However, junior appropriators, by definition, claim water at a later date so, assuming they can acquire information as to how much water at a particular source is unclaimed at the time of entrance, they would construct diversion capacity

based on this information. Specifically, the carrying capacity, and therefore, the size of their diversions would be equal to the amount of water available given other appropriators claims. The effects would be to mitigate the risk faced during shortage because of incentives for later entrants to limit diversion size, and therefore, capital investment. This would reduce losses brought about by idle capacity in times of shortage. Moreover, the ability to trade rights under prior appropriation would further act to reduce losses borne by junior appropriators due to insufficient supply. Theoretically, in the presence of a market, we would expect junior appropriators who value water more highly than senior appropriators to bargain around the priority allocation system. Junior appropriators would value water more highly if they had information that their mines had higher marginal productivity, in terms of payable gold, than senior appropriators. Compare this outcome to the use of riparian rights in the presence of deployable asset investment where trading is prohibited. Recall, slaughtering is a compliment to the non-binding mobility constraint when deployable assets dominate. Therefore, where input supplies are limited by drought, livestock numbers can be adjusted downward to combat this shortage. Further, slaughtering provides an alternative source of income for graziers, particularly sheep graziers, because meat, tallow, and hides provide them with a revenue stream in addition to wool.²⁶ In this way, productive capacity is adjusted in line with resource availability so the extent of idle capacity and foregone production is decreased. In turn, this compliments the prohibition on trading that exists under the riparian doctrine and; 2) in the presence of non-deployable assets the use it or lose it rule, that is forfeiture for non-use also made prior appropriation superior to riparian rights when applied to mining.

Gold mining was subject to ex ante information asymmetries where productivity of claims was unknown prior to investment of mining effort. In this way, before any effort was expended, the marginal benefit of water was equal across claims and uniform returns from water use prevailed. It was only once effort was expended that the relative value of any one site compared with another would be known. At this point the marginal benefit of water would diverge, so that miners at sites with greater quantities of payable gold would place a higher value on water. Forfeiture ensured maximum expenditure of effort, including full utilisation of inputs to maximise returns across the sector until productivity information could be acquired. If individuals were permitted to claim but not utilise water, this would limit the quantity available for other miners thereby reducing aggregate output and wealth. Compare this to the pastoral sector where productivity information was known ex ante because output per animal was close to uniform; therefore, the marginal benefit of water remained equal across all users.²⁷ In this way, equal sharing rules adopted under riparian rights and the reasonable use test allowed individuals to maximise profits given water availability thereby, maximising returns across the

²⁶ Fluctuations in wool prices also provide an incentive for slaughtering to capture this alternative revenue stream. For example, graziers in NSW and Victoria undertook extensive slaughtering for meat and tallow when wool prices dropped dramatically during the depression of the early 1840s (see Roberts, 1935).

²⁷ Output may have been uniform but prices varied based on the quality of wool from each flock. At shearing wool classers would grade each individual sheep output as a certain level of quality and it would be sold at auction under this quality grade. The higher the grade of wool, the higher the price received.

sector. Further, because the pastoral sector was subject to seasonal location variation the loss of water rights due to non-use would have undermined expansion because of uncertainty regarding rights to this input. The very nature of grazing circumvented any need for the definition of water rights based on quantity because animal numbers could be reduced in the face of limited supplies; and substitutes existed. Specifically, animals could obtain moisture from feed so if water supply was limited but grass was not part of the moisture requirements of flocks or herds could be obtained by increasing grass consumption. Gold mining lacked substitutes for water so the absence of a forfeiture rule would reduce output across the sector as new entrants would be unable to secure supplies to work their mines. Forfeiture ensured optimal investment of effort by all miners, maximising returns across the sector. In the absence of such a rule not only would investment in effort fall thereby reducing overall productivity but inefficiencies would be created through potential monopoly pricing. A model developed by Lueke (1995) predicts that first possession will be chosen over other allocation methods when important resources are yet to be discovered.

Other than these economic incentives for a use it or lose it rule social norms, particularly perceptions of fairness, may also have contributed to prior appropriation's adoption on the gold fields. For example, Schorr (2005) argues the primary rule of appropriation was that each party was entitled to a proportional share of water. Further, Justice Field, a pre-eminent California and US Supreme Court judge noted, "[customs] were framed to secure all comers, within practical limits, absolute equality of right and privileged in working the mines (quoted in Schorr, 2005: 17).²⁸ Forfeiture circumvented the potential for miners to claim qualities they could not utilise within a certain time period ensuring equal opportunities for all entrants to access a key input. This does not suggest that equal sharing was the rule under the US appropriation doctrine, it is simply illustrating that if an individual claimed more water than could be productively employed within a certain time frame, forfeiture would make the surplus supplies available for another claimant who could put the water to productive use. Individuals may well have claimed different volumes of water but these volumes had to be fully utilised. The beneficial use criteria that developed over time in the US created a second method by which to prevent claimants under utilising a scarce resource. In Australia, equality of opportunity in access to water was incorporated into legislation that restricted volumes claimed under appropriation. For instance, Victorian regulations limited water right claims to three box sluice-heads (1861 Gold Mining Act, section 34).²⁹ Volume restrictions were used in addition to forfeiture rules.³⁰ This supports Schorr's (2005) analysis that equality of right existed under

²⁸ This quote was from the judgment in *Jennison v Kirk* (98 US 453, 457 (1878)). Field was elected to the California Supreme Court in 1857 and was Chief Justice of that court from 1859 to 1863 (McCurdy, 1976). Field served on the US Supreme Court from 1863 to 1897.

²⁹ A sluice-head was a box fixed at the head of a water race (channel) to gauge or measure the quantity of water diverting from a river or stream. Miners were permitted to divert the number of sluice-heads provided under regulation or gold mining district by-laws (Smyth, 1869).

³⁰ Drought conditions were not the basis forfeiture. The time period after which rights would be forfeited was altered several times during the 1860s in both NSW and Victoria. In NSW, forfeiture was extended from 14 days under 1861 legislation to a month in 1869 – it remained one month for the duration of the

some forms of appropriation – particularly those adopted in Colorado and Australia. Moreover, volume restrictions and forfeiture rules reduced the racing incentive that existed under prior appropriation (Millian, 1959; Burness and Quirk, 1979; 1980). As a result, productivity was maximised across the gold mining sector.

By the end of the 1860s, the supply of alluvial gold in both NSW and Victoria fell given the technology and capital input required for smaller miners to locate sub-surface supplies. As a result, unemployment increased because of the lack of employment opportunities in the underdeveloped industrial sectors. Miners then began to demand changes to land legislation to allow them access to agricultural land monopolised by graziers.³¹ Land reform legislation was passed in both colonies in the early 1860s allowing individuals to select land up to a maximum of 320 acres anywhere in the colony. Generally, land reform was considered a failure in both NSW and Victoria because pastoralists evaded redistribution by employing several tactics: 1) ‘dummying’ which involved pastoralists contracting with agents, often employees, to select part of their property, register the claim with the Department of Lands (often under false names), and then sell it back to the pastoralist for a small fee. Legislation made this possible because, up until 1880, a farmer could transfer their claim after only one year of residence. Pastoralists’ wealth advantage over smaller farmers permitted them to undertake this practice on a large scale increasing the likelihood they retained large portions of their original holdings. Data pertaining to the number of selections transferred in NSW from 1862 to 1882, shows close to 60% of original claimants sold their land (Morris and Ranken, 1883).³² In itself, this does not suggest that all these transfers were from dummies to pastoralists, some transfers could have been the result of arid conditions that caused agriculture to fail. Moreover, the blocks of land allocated under reform legislation were far too small for these settlers to graze sheep suggesting the arid climate may have led to farmlands being transferred; 2) ‘peacocking’ was another method by which pastoralists avoided redistribution of their estates. Peacocking was a practice used primarily by dummy farmers who would pick the vantage points out of a pastoralist’s property so as to render the intervening land useless (Roberts, 1924). The information

mining boom. In Victoria, local Mining Courts constituted under 1855 legislation (Gold Fields Act) determined the period of non-use required for forfeiture. Further, several districts’ regulations did not require immediate forfeiture for non-use but instead instituted monetary penalties for miners not using their water rights. In these districts the uniform claim requirements may have reduced the necessity for absolute forfeiture. This would be more likely in districts with smaller mining populations where competition for water was not as great as at larger fields.

³¹ The extension of franchise in the mid-1850s meant that miners demands for land policy reform led to a more rapid political response than would otherwise have been the case. For details refer to Alston et al (2009).

³² For anecdotal evidence on the extent of dummying refer to: NSW, *Select Committee on the Administration of Land Laws*, Minutes of Evidence, 2nd Progress Report, Legislative Assembly, Votes and Proceedings, 1872/3; NSW, *Select Committee on the Administration of Land Laws*, Minutes of Evidence, 3rd Progress Report, Legislative Assembly, Votes and Proceedings, 1873/4; Victoria, *Board of Inquiry into proceedings in relation to certain land selection in the Wimmera District*, Legislative Assembly, Votes and Proceedings, 1873; Victoria, *Crown Land Department Board of Inquiry*, Legislative Assembly, Votes and Proceedings, 1874.

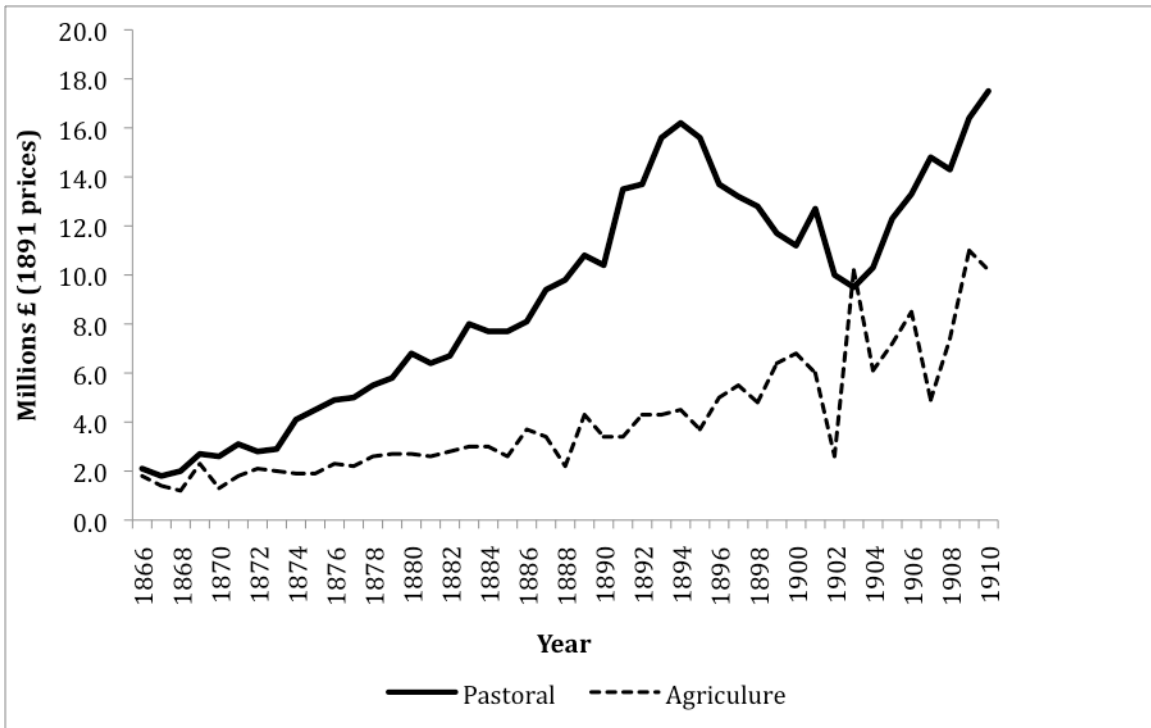
advantage held by pastoralists and their employees as to land quality assisted them in this practice and; 3) forcing an auction by either selecting the same area as a *bona fide* farmer, or by employing agents to select multiple parcels and then forfeiting these claims. Evidence suggests that between 1862 and 1882 in NSW, on average, 12% of land selected by farmers was forfeited (Morris and Ranken, 1883). However, this may have included farmers who forfeited their holdings because climatic and economic conditions were not suited to permanent agriculture. These statistics also indicate forfeiture was less prominent than dummyming. Nevertheless, forfeiture allowed pastoralists to evade redistribution to some extent because at auction capital constrained farmers were unable to outbid pastoralists.³³ All three evasion methods resulted in limited reallocation of land under the 1860s reform legislation. Roberts (1924) states that in NSW from the introduction of reform legislation until the 1880s eight claims out of every nine passed to original occupants and, by 1883, over eight million acres of colonial land was owned by 96 individuals. Further, Morris and Ranken (1883: 15) note that by the middle of the 1880s on average, only 27% of farmers remained on the land arguing land reform had resulted in: “Unintelligible chaos, in which the rights and interest of all mainly concerned have been the sport of accident, political interest, and departmental disorder.”

In NSW land reform failure was far more pronounced than in Victoria, in part because the former had a relatively smaller mining population than the latter. In turn, the continued dominance of the pastoral industry with its non-binding mobility constraint led to a persistence of common water rights in that sector. Figure one (below) illustrates the importance of pastoral sector contribution to NSW GDP from the mid-1860s to 1910. The figure shows that even after land reform, the pastoral sector continued to outstrip agriculture in terms of GDP contribution and during this period common property water rights remained dominant. As the agricultural sectors contribution to GDP began to increase post-1902 irrigation became more a more prominent farming method.³⁴ In turn, there was a growth in non-deployable asset investment. The framework developed in section three predicts that once irrigation expands water rights will evolve toward private rights. Outcomes in NSW conform to this predication with the Irrigation Act abolishing riparian rights in 1912. This legislation replaced common water rights with state ownership. In turn, state agencies allocated water use rights to individuals with a guarantee these rights would be available in most ‘ordinary’ rainfall years. As a result, in line with the predictive framework once non-deployable asset investment increased water rights evolved toward private rights.

Figure 1: Value of agriculture and the pastoral industry to GDP 1866 -1910 (NSW)

³³ Refer to Alston et al (2009) for a more detailed discussion on evasion methods used by pastoralists to avoid redistribution.

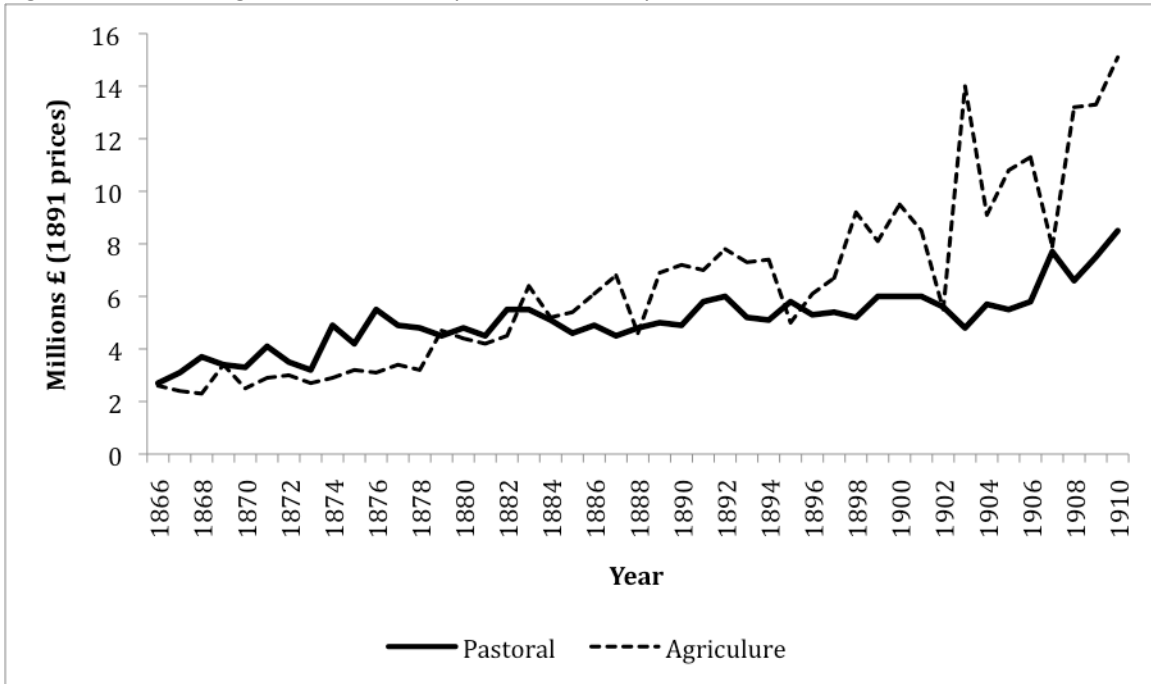
³⁴ In part, this was the result of the 1902 drought that caused widespread crop losses across the state.



Source: Adapted from figures in Haig (2001), Table A3.

Due to the relative increase in farming population under 1860s land reform, Victoria experienced a growth in irrigation earlier than NSW. This predicated a move from common to private rights three decades before NSW. Private investment and experimentation in irrigation expanded from the late 1870s onward. Figure two (below) shows the increasing value of the agricultural sector compared with pastoral sector from the late 1870s onward when growth in the former was underpinned by an expansion in irrigation. As has been established, irrigation requires investment in non-deployable assets so that the development of this farming method creates a binding mobility constraint. Paralleling this, our framework in section three predicts that we should see a move toward private water rights and this occurred in Victoria. Common water rights in that colony were abolished in 1882 under the Water Conservation Act. Further, like NSW, albeit at an earlier juncture, government ministries became responsible for allocating water between individual users. In other words, as predicted, water rights evolved toward private rights once investment in non-deployable assets created a binding mobility constraint.

Figure 2: Value of agriculture and the pastoral industry to GDP 1866 -1910 (Victoria)



Source: Adapted from figures in Haig (2001), Table A4.

Let us now consider if the predictive framework developed in section three can be used to explain the evolution of water rights in the US.

4.2 California and Colorado

As noted, there are two distinct regimes applied across the arid western states of that country: the hybrid system known as the California doctrine; and ‘pure’ prior appropriation, known as the Colorado doctrine. For simplification, the analysis presented here is only going to focus on the two states where these doctrines originated: California and Colorado. However, where appropriate, examples from other states that adopted these doctrines will be used to highlight the durability of the framework’s predictive capacity. Before applying the predictive framework, we need to establish the type of climate and asset investment undertaken.

All the states that adopted either of these approaches are arid, lying beyond the 100th parallel, receiving between eight and 12 inches of rainfall per annum. During the nineteenth century several sectors utilised water: gold mining, irrigation, and cattle grazing. As noted, water use on the gold fields was subject to prior appropriation in all states, regardless of whether the California or Colorado doctrine had been adopted.

4.2 States adopting the California Doctrine

In states that used the California doctrine, irrigators and cattle graziers could assert water rights based on either appropriation or riparian rights. Pisani (1987) and Kanazawa (1998) argue increasing appropriator-riparian conflicts, particularly in California during the 1880s occurred

because mining on public land was governed by appropriative law and irrigation on private land by riparian law. Evidence from that state's Supreme Court does not support this argument. For example, the court explicitly stated the position of appropriators in *Duckworth et al. v Watsonville Water and Light Co. et al.* (89 Pac. 338, 343 1907: 343):

The right to appropriate water, under the provisions of the Civil Code, is not confined to streams running over public lands of the United States. It exists wherever the appropriator can find water of a stream which has not been appropriated, and in which no other person has or claims superior rights and interests...An appropriation does not, of itself, deprive any private person of his rights. It merely vests in the appropriator such rights as have not previously become vested in private ownership either by virtue of some riparian right or because of prior statutory or common law appropriation and use.

Does the framework developed in section three predict the evolution of the California doctrine? Quite clearly it does not, rather it predicts that, particularly with the growth of irrigation from the 1880s California should have evolved toward appropriative rights. Specifically, because that state is arid and irrigation, like mining, requires investment in diversions to maximise productivity we would expect appropriation to evolve. In order to facilitate this expected progression one of two things needed to occur: 1) legislation, via the Civil Code or an independent act of parliament needed to abolish riparian rights – this did not occur or; 2) judges needed to apply appropriation in the majority of water conflicts. Application of appropriation by judges could be achieved either by finding in favour of the individual claiming rights under prior appropriation in all cases or; by determining conflicts based on the appropriation test. Evidence shows the former did not occur, but the latter was a way in which courts overcame potential rigidities imposed by riparian rights. As discussed, the appropriation test developed in England during the 1700s. In this case, it was used to determine conflicts between riparian users. Specifically, it allocated rights to the flow of services from the asset (water) to a defined group of users – those that owned or occupied riparian lands. In turn, the appropriation test created individual rights to the amount initially utilised. Subsequent uses were conditional on these volumes being available without interference. As a result, individual group members that had access to the resource stock did not have equal right to the flow of services from the assets. Compare this with a test like reasonable use that made individual use conditional on the equal rights held by other users. Each right holder had an obligation not to interfere with other group members' rights to utilise water. In turn, a later arrival could prevent extant users from continuing certain activities if they negatively affected his ability to make use of the water, either by reducing quality or quantity.³⁵ The result was that individuals had equal right to the flow of services from the asset. Reasonable use therefore, created a greater degree of commonality between users than did the appropriative test. The important issue here is that the tests courts applied to determine water conflicts defined the degree to which individual

³⁵ At common law this was subject to previous users not having redress to establish prescriptive rights. Prescription allowed individuals to claim uninterrupted occupation and use of a resource for 20 years implied a title had been granted, but had subsequently been lost. For example, if A had continuously diverted 50 per cent of a stream flow for 20 years and B took no action against this use, under common law A would have prescriptive rights to continue her use even if at some later date B objected.

rights to the resource were private compared with correlative (held in common). Specifically, at the aggregate level property rights may reflect common property characteristics however, at the individual level rights may resemble private rights. If the appropriation test is applied to all users, not just a small group, for example, those with riparian rights, then this will create rights that are akin to private rights rather than correlative. Evidence from the California Supreme Court shows it consistently applied the appropriation test in water disputes.

Prior to the late 1870s few water disputes came before the court, but in those that did, the courts generally supported the first comer, regardless of whether they asserted claims based on riparian or appropriative rights (Freyfogal, 1985).³⁶ However, it is generally argued that by 1886, in the famous *Lux v Haggin* (69 Cal. 255, (1886)) because the court upheld riparian rights this signalled it's intention to uphold the doctrine in spite of California's arid climate (Wiel, 1913; Schieber and McCurdy, 1975; Freyfogal, 1985; Miller, 1985; Pisani, 1987; Kanazawa, 1998).³⁷ But previous studies have ignored one important aspect of this case – Lux's water use pre-dated Haggin's. The outcome, therefore, is more consistent with the courts previous approach. Further, at no point did the court rule Haggin was not to use the water source in question, it simply found that if he did so thereby interfering with the extant users prior rights this was an infringement of their legal rights to a defined volume. This was the very basis of the appropriation test.

Subsequent California Supreme Court rulings from 1890 to 1910 continued to apply the appropriation test regardless of whether a plaintiff asserted rights under the riparian doctrine or prior appropriation. During this period 24 water disputes came before the court; of these, the court adhered to the appropriation test in 20 (refer to Appendix 1 for a list of cases). In all 20 while either the plaintiffs or defendants may have owned or occupied land by which they acquired riparian rights, the court found for the prior user. For example, in *Wutchum Water Co. v Pogue* (90 Pac. 362, 364 (1907)) the court stated: "as to the plaintiff's title to the water, it is indisputable that [his diversion ditch] was constructed...prior to the time that Pogue acquired any of his rights either as an owner of riparian lands or an appropriator." Again in *Huffner v Sawday* (94 Pac. 424, 427 (1908)) the court found: "the plaintiff, whether as a riparian owner or as a prior appropriator of all water ordinarily flowing in the stream, had a right superior to that of the defendant." Further, the court adopted another aspect of the appropriation test: limiting a riparians rights to the volume that could beneficially be utilised (*Senior v Anderson*, 62 Pac. 562 (1900)). The court also acted to limit application of the riparian doctrine via two methods: 1) it permitted diversions of water not being utilised by riparians (*Modoc v Booth*, 36 Pac. 430

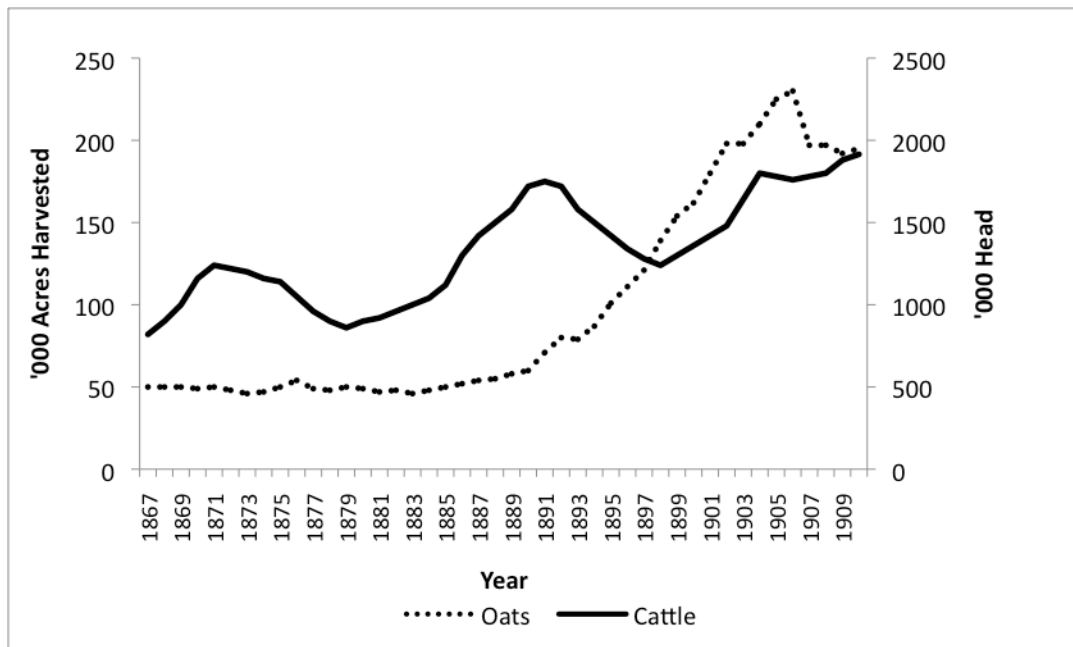
³⁶ For a detailed discussion of the courts treatment of relevant cases, refer to Freyfogal (1985: 501-504).

³⁷ In this case, Lux was attempting to secure an injunction by asserting riparian rights to prevent Haggin from diverting water for irrigation that had significant impacts on flow, particularly during drought years. Lux was a grazing company known as Miller and Lux. Miller (1985) notes the Miller-Lux Company formed a riparian rights association with a group of cattlemen in order to prevent 'threatened interference' from upstream canal companies. The association's immediate goal was to stop Haggin from diverting water that the cattlemen felt had exacerbated the effects of the severe 1877 drought on their lands.

(1894); *Fifield v Spring Valley*, 62 Pac. 1054 (1900)). In *San Joaquin v Fresno Flume* (112 Pac. 182, 183 (1910)) the court reaffirmed its opinion that: “It seems clear that in no case should a riparian owner be permitted to demand as of right, the intervention of a court of equity to restrain all persons who are not riparian owners from diverting any water from the stream at points above him” and; 2) it narrowed the circumstances by which individuals could obtain riparian rights. For example, by preventing acquisition of rights on once contiguous blocks for which the government had issued separate titles (*Boehmer v Big Rock Creek Irrigation District*, 48 Pac. 908, (1897)). Combined, these circumstances show the Californian common law tended to evolve toward private water rights, conforming to the expected evolutionary pattern outlined in section two.

This shift occurred as irrigation and corollary investment in non-deployable assets expanded while deployable asset investment fell. Using oat production as a proxy for irrigation expansion, figure 3 shows growth in acres harvested of oats from the 1890s while the number of cattle in the state was falling. Although oats are not a perfect proxy given many early irrigators produced alfalfa, statistics for which are not available, it does serve to illustrate the main point. Combined with the evidence from the state Supreme Court, the progression of water rights conforms to the predictions outlined in section three: that in the presence of aridity and non-deployable asset investment, private rights will evolve.

Figure 3: California oat production and cattle numbers, 1867 to 1910.



Source: US Department of Agriculture, National Agriculture Statistics Service, www.nass.usda.gov [accessed January 8, 2010].

4.3 States adopted the Colorado Doctrine

Now, let us consider the evolution of water rights in Colorado and determine if the framework employed here can explain exclusive reliance on prior appropriation in that state. Like California water used in Colorado from the mid to late-1800s was for mining, irrigation, and livestock. Mining codes from the late 1850s supported prior appropriation.³⁸ Early irrigators also applied this doctrine and consequently, in 1860, the first legislature enshrined appropriation rules in irrigation laws (Dunbar, 1960). In 1876 the Colorado constitution exclusively incorporated appropriation as the rule for water allocation in the state with no mention of riparian rights. Subsequently, the Colorado Supreme Court applied this rule in the key case of Coffin v Left Hand Ditch Company (6 Colorado, 444-447, (1882) cited in Freyfogal, 1983). The case involved conflict between two groups of irrigators. Justice Helm rejected out of hand the plaintiff's assertion that their riparian rights had been infringed upon by upstream irrigators declaring the riparian doctrine had never existed in Colorado (Dunbar, 1960). Our framework predicts this outcome: in arid states where water use requires investment in non-deployable assets, as do mining and irrigation, private rights will evolve. However, prior appropriation was also applied to the cattle industry in Colorado that gained prominence from the late 1870s. Once this industry is incorporated into our analysis the framework appears to lose its predictive power. Specifically, because cattle are deployable and Colorado is arid, we would expect common rights to be utilised in this sector; but this did not occur. This apparent deviation from the expected outcome can be explained by taking into account one important characteristic of the Colorado cattle industry during the 1870s and 1880s: the industry faced a binding mobility constraint.

During the nineteenth century most land in Colorado remained in the hands of the Federal government and was therefore, public land.³⁹ Cattle graziers occupied vast tracts of this land underpinned by first possession principles. In the early years of this occupation limited competition meant graziers had to invest little in definition and enforcement of their land and water rights. However, over time as cattle prices increased and railroad infrastructure was extended bringing frontier land closer to markets, competition rose. As scarcity increased so too did the returns from investment in property rights definition and enforcement. In turn, because of the absence of low cost fencing technology such as barbed wire graziers established commons arrangements via cattlemen associations. Associations protected members' rights to use land and water available on the common range, preventing encroachment and therefore over grazing that would have resulted if open access conditions had been retained.⁴⁰ Once a

³⁸ Gold was discovered in Colorado in May 1859. By June of that year there were 5,000 people at the Gregory diggings (named after the first discoverer), northwest of Denver (Schoor, 2005). Given the migration of many "forty-niners" from California to Colorado application of prior appropriation in the latter states mining districts is not surprising (Dunbar, 1960).

³⁹ A proportion of land had been transferred to private ownership under the Homestead Act (1862), The Timber Culture Acts (1873 and 1878), and The Desert Land Act (1877).

⁴⁰ Aside from the economic incentive for cattlemen to avoid overuse of the commons, two other factors encouraged cooperation by associations: 1) the need to enforce individual ownership of cattle. This was achieved via the use of brands registered with associations, and later under state law; and 2) the need for a roundup. Roundup activities faced economies of scale problems, increasing incentives for collective action to establish rules and administration of the bi-annual activity. Only members of each cattlemen's

range was considered fully stocked the association would advertise it was closed usually via local newspapers. After closure was advertised, it was impossible for new entrants to use the range or participate in the bi-annual roundup unless they bought range rights from an existing association member. Range rights were acquired by buying cattle on their usual range and with cattle came good will and the privilege of using the range for grazing (Scott, 1967).

Range closure imposed both land and water constraints on association members. The constraints on water inputs transformed cattle into non-deployable assets creating a binding mobility constraint on members. Specifically, because a majority of ranges were subject to claims by different associations, cattle owners were unable to move their livestock to water located outside the boundaries of their associations' range. On each range, water sources were limited to the rivers or streams that flowed through the common pasture. Moreover, even if individual graziers could move their herds, each association had the same incentive to prevent new comers by advertising range closure. Consequently, there would have been very few, if any opportunities to make use of cattle mobility to access water supplies outside a given range. One way cattlemen may have overcome this constraint was to hold rights on several ranges simultaneously. Evidence of branding registration suggests this may have been done (Osgood, 1929). Nevertheless, it may not have been frequent practice given the cost of acquiring range rights. Dennen (1976) estimated, based on two transactions of range rights, exclusive of cattle and land, a value of approximately \$200,000 (USD). Further, in order move cattle and utilise multiple range rights to counter water shortages an owner would have to roundup their cattle that were intermingled with others on one range in order to move them to another location.

There were two main drawbacks for an individual roundup: 1) the activity was labour intensive making it high cost for an individual compared with a group so that there was economies of scale in having one roundup rather than several; and 2) a roundup was stressful on cattle (Alston, et. al 2009). Individual roundups also had costs for the collective because they created the potential for stealing thereby increasing monitoring costs. As a result, the incentives facing individuals and associations would have discouraged movement from range to range even in the face of water shortages. In turn, cattle were transformed from deployable to non-deployable assets. Compare this to the Australian economy where sheep grazing was the primary activity outside gold mining areas.⁴¹ Two factors reduced the need for associations of the type used in

association could participate in the roundup on a given range. This created another method by which exclusion from the range could be accomplished. These economic incentives for cooperation and creation of informal rules of use in the absence of formal law led to cattlemen's associations being the main form of organisation for graziers in many Western states during the nineteenth century. For more details on the organisation and operation of cattlemen associations refer to Osgood (1929), Dennen (1976), and Anderson and Hill (2002; 2004).

⁴¹ On and around gold fields certain locations were designated for local residents to graze sheep, horses, and cattle. These pastures were subject to commons rules devised by local committees and approved by the Governor in Council. The rules established had all the features of common property including: limits on who could utilise the commons; restrictions on the number of animals an individual was permitted to graze; charges for using the commons; the use of registered brands to identify animals permitted to graze

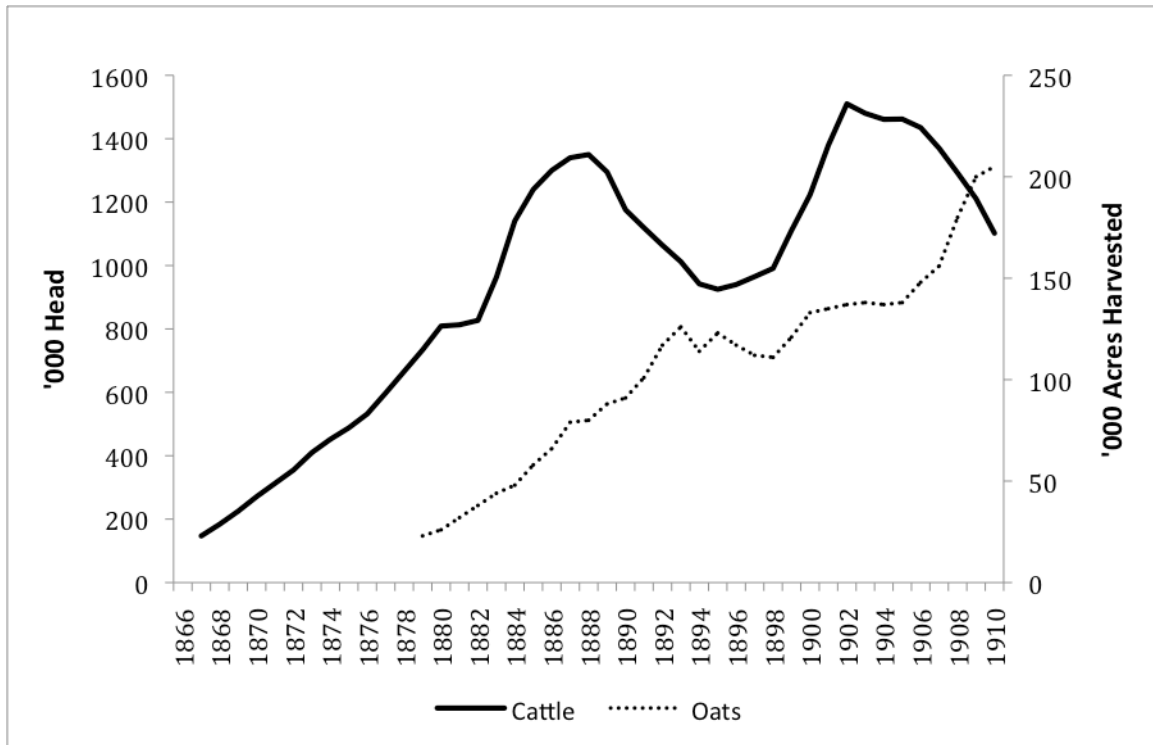
Colorado's cattle grazing sector so that sheep retained full mobility: 1) private occupancy rights to land occupied by pastoralists were granted via a licence system established in the 1830s. Under the licence system graziers could occupy as much land as they wanted for £10 per annum. In response to this they scattered land claims over a wide geographical area to combat water supply extremes and seasonal patterns of feed availability. Private land rights reduced the likelihood that flocks would intermingle and thereby the costs of enforcing ownership; legislation also required registration of sheep brands. Land occupation licences were enforced by a government officer (Commissioner of Crown Lands) and employees placed on all parcels claimed under the license system. Consequently, licenses were effective defence of individual rights against all parties but the Crown and; 2) sheep did not have to be cooperatively rounded up because on the open range, they were controlled by shepherds (Anderson and Hill, 2002). Shepherds prevented encroachment by other individuals or natural predators (for instance, native dogs) reducing costs of enforcing ownership. Further, norms had evolved to restrict the number of sheep each shepherd was responsible for to 520 so as to maximise returns from their efforts.⁴² Combined, the nature of the sheep grazing and land settlement policies acted to maximise the inherent benefits brought about by livestock mobility. As a result, in Australia, sheep producers faced a non-binding mobility constraint while in Colorado the need for cattlemen to cooperate created a binding constraint. In turn, given climate in both regions is arid, our framework predicts common water rights will evolve in the former context and private rights in the latter. Empirical evidence from both cases supports these predicted outcomes.

Figure 4 (below) illustrates the importance of the cattle grazing industry in Colorado from the mid-nineteenth century until about 1908/09. In order to make the figure comparable to figure 3 (above) we have included oat production as a proxy for irrigation expansion. The dominance of the cattle industry serves to indicate why Colorado legislators adopted the 'pure' appropriation doctrine early in the states history. Moreover, with the growth of irrigation output after the first decade of the twentieth century the continued application of prior appropriation conforms to the predicted outcomes in section three.

(and therefore, any trespassing animals); and appointment of herders to protect stock. Typical examples of these regulations can be found in the Victorian Government Gazette, August 24, 1874, p. 1592 and August 28, 1885, p. 2484. Outside these areas occupational licenses conferred private rights to land.

⁴² This norm was the result of three factors: 1) areas in which sheep first grazed in NSW were scrubby, creating the potential for large losses due to the inability for one shepherd to manage a flock larger than 520 (Curr, 2001). This norm was adopted in Victoria even though sheep grazed on flat pastures; 2) if flocks numbered over 520 it was believed that pastures over which flock travelled would be wasted and stronger sheep would consume the bulk of the grass and; 3) early shepherds were convicts and they had little incentives to prevent sheep losses. All three points taken from Alston, et al., 2009).

Figure 4: Colorado oat production and cattle numbers, 1866 to 1910



Source: US Department of Agriculture, National Agriculture Statistics Service, www.nass.usda.gov [accessed January 8, 2010].

Application of the Colorado doctrine in states where water was utilised in the cattle industry, for instance, Wyoming and Montana verify these findings, strengthening the frameworks durability. In the absence of cattle grazing, adoption of the Colorado doctrine in states such as Arizona, New Mexico, and Utah was the result of non-deployable assets investments in irrigation and/or gold mining. For example, in Arizona and New Mexico appropriation has its origin in Mexican irrigation custom (and Spanish law). In Utah, early Mormon settlers diverted water for irrigation that recognised prior use as the basis for allocations. The framework developed here predicts this outcome in the states that bypassed common rights entirely, given irrigation was dominated by non-deployable asset investment.

4.3 Eastern US and England

Paralleling development of the California and Colorado doctrines in Australia and the western states of the US during the nineteenth century, US eastern states and England were refining the riparian doctrine. Can the predictive framework explain this evolution? These locations are not arid and therefore, typically, water was not used for extensive irrigation. Water use was dominated by the textiles industry that relied on hydropower to drive cotton spindles. Like

irrigation and mining, cotton or woollen mills, and associated waterwheels, were non-deployable assets, as were investments in altering river flows to maximise mill productivity. These investments included the construction of weirs, dams, river widening, sluices, bridges, and mill channels (Getzler, 2004). Further, in both the US east and England as mills developed, water conflicts were intra-group, specifically between mill owners. As a result, our framework would predict that because these areas were not arid with investment in non-deployable assets, common rights to water would evolve – and this did occur.

As explained water rights in England could only be acquired by individuals occupying land that came in contact with the watercourse, the same rule applied in the eastern US. Water rights therefore retained common property characteristics by excluding individuals that did not occupy land coming in contact with the watercourse. As discussed, it was the tests courts applied to determine intra-group riparian conflicts that established the degree to which individual rights to the resource were common compared with private. Reasonable use established equal sharing rules between riparian owners thereby creating a greater degree of commonality between riparians than alternative tests, such as the appropriation test. Once courts in England and US eastern jurisdictions adopted reasonable use, they effectively created a more precise set of common property rights to water dictating that each member of the group was equal in both right and obligation. However, the degree to which interference would be tolerated differed in each setting so that English courts appear to have adopted a more narrow interpretation of what would be considered reasonable compared with eastern US jurisdictions.

The basis for the reasonable use test was founded in the US Federal Court case *Tyler v Wilkinson* (4 Mason's U.S. Rep. 400, 1827)). In this case Justice Story clearly laid out the test as it would be applied in the US stating:

When I speak of this common right, I do not mean to be understood, as holding the doctrine, that there can be no diminution whatsoever, and no obstruction whatsoever, by a riparian proprietor, in the use of the water as it flows; for that would be to deny any valuable use of it. There...must be allowed of that, which is common to all, a reasonable use. The true test of the principle and extent of the use is, whether it is to the injury of other proprietors or not. There may be a diminution in quantity, or a retardation or acceleration of the natural current indispensable for the general and valuable use of the water, perfectly consistent with the existence of the common right. The diminution, retardation, or acceleration, not positively and sensibly injurious by diminishing the value of the common, is an implied element in the right of using the stream at all. The law here...acts with a reasonable reference to public convenience and general good, and it is not betrayed into a narrow strictness, subversive of common sense, not into an extravagant looseness, which would destroy private rights (4 Mason's U.S. Rep. 400, 474-5 (1827)).

This was a far more liberal version of what would be considered reasonable than was adopted in England in *Embrey v Owen* (6 Exch. 353, (1851)). In this case, Parke B, citing US precedent noted:

In America...a very liberal use of the stream for the purposes of irrigation is permitted...in England it is not clear that a user to that extent would be in every case deemed a lawful enjoyment of the water, if it was again returned to the river with no other diminution than that

which was caused by absorption and evaporation attendant on the irrigation of land of the adjoining proprietor. This must depend upon the circumstances of each case. On the one hand, it could not be permitted that the owner of a tract of many thousands of acres of porous soil, abutting on part of the stream, could be permitted to irrigate them continually by canals and drains, so as to cause a serious diminution of the quantity of water, though there were no other loss to the natural stream than that arising from the necessary absorption and evaporation of the water employed for that purpose; on the other hand, one's common sense would be shocked by supposing that a riparian owner could not dip a watering-pot into the stream, in order to water his garden, or allow his family, or his cattle to drink it. It is entirely a question of degree...(6 Exch. 353, 371-2 (1851)).

In both cases, while the exact application of what was reasonable varied at the margins it is clear the framework developed in section three retains its predictive power: in locations that are not arid where investment is primarily in non-deployable assets, common rights will evolve. One of the most important aspects of reasonable use was its flexible approach to resolving water disputes that could be adapted given the specific context of conflicts. Getzler (2004) argues, at least in the case of England, two main reasons for a movement toward this test: 1) during nineteenth century industrialisation, the costs of administering justice based on reliance on detailed factual pleadings became prohibitively high. The use of appropriative tests to determine riparian disputes was extremely fact sensitive, increasing the costs to judges because of parallel efforts to reduce the discretion of juries. In consequence, there was a greater drain on judges' time by relying on factual pleadings at a time when the judicial system faced increasing conflicts. This prompted a simplification of common law intention-based concepts that emphasised the objectivity of user rights exemplified by tests such as 'reasonableness' of uses and; 2) the common law, as a third party norm enforcer, used the reasonable test founded on parties own conduct to restrain destructive competition of the common pool resource. In turn, the common law paid careful attention to agreements, understandings, and the practices of parties using the water resource – something that would vary over time and space. Reasonable use allowed courts to adjust their findings given the circumstances of a dispute. Circumstances influenced by norms and repeat transactions that established a pattern of expected behaviour from users of the common pool.

So far, the empirical examples presented here conform to our expected outcomes given the alternative combinations of climate and asset type as outlined in table 1 (above). Specifically, we have identified five cases in which three of the cells have been explained: 1) in California, Colorado gold mining and irrigation, and in the Australian gold mining sector private rights evolved in an arid climate with non-deployable asset investment; 2) in the eastern US and England common rights evolved in a climate that was not arid with non-deployable asset investment; and 3) in the Australian pastoral industry common rights evolved in an arid climate with deployable asset investment. These findings indicate that by adding investment type to climate and determining the net effects on scarcity we can provide a more complete story of water rights evolutions in different historical contexts. Further, the framework predicts that when a location is not arid with deployable investments, common rights will evolve. But, there is no empirical evidence of this outcome. Theoretically, in the face of competition, the

combination of relatively abundant rainfall and deployable investment would combine to create very low levels of scarcity thereby making common rights a logical end point. The creation of common property rights in a setting such as this depends on the coordination and internal governance costs faced by users as outlined in section two. If these costs were prohibitively high then we could reasonably expect open access may prevail. However, because we assume competition would be increasing over time theory suggests the return from common rights would also increase leading their creation. An empirical example verifying this expected outcome would add much value to the findings presented here.

5. Additional considerations

The preceding empirical analysis provides sound evidence to justify incorporation of investment type into studies of water rights evolution. Nevertheless, there may be constraints on the durability of the framework in alternative settings with the introduction of additional variables that influence water scarcity in an appreciable way. One such factor was identified by Rose (1990) namely, water use type. Water use falls into two categories: consumptive and non-consumptive. Consumptive uses reduce the flow of water at the source via extraction, for example, irrigation or gold mining. Non-consumptive uses do not reduce water flow at the source for example, waterwheels for power. Assuming competition exists but remains constant in the short-run then use type affects scarcity in the following ways: where consumptive uses prevail, scarcity is high; where non-consumptive uses prevail, scarcity is low. In turn, the argument would follow that the use type that dominates alters scarcity; thereby affecting property rights evolution. Specifically, in Rose's (1990) analysis, the use of common rights to allocate water in the eastern US and England compared with the western US was the result of different water uses at each location. In the US east and England, water use was primarily non-consumptive because it was utilised for powering waterwheels. Like navigation, to operate effectively waterwheels required a sufficient depth and speed of flow. If all users along a stream required a uniform depth and flow speed then water takes on public good characteristics becoming non-rival and non-excludable. Theory predicts that when a good exhibits non-rival and/or non-excludable characteristics the ideal property right allocation will be common property. As a result, the value of water is higher when used in unity so water rights regimes that ensure the corpus of the stream remain in tact are preferred. Moreover, because water remains in-stream it becomes available for other non-consumptive uses thereby limiting scarcity even in the face of intense competition. In the US west water use was predominately consumptive for use at gold mining sites. Once water was removed from the source, it exhibited private good characteristics of rivalry and excludability at the point of diversion (capture). Theory predicts that were a good is rival and excludable the ideal property rights allocation will be private rights. Further, because water is taken away from the source and very little is returned, in the presence of competition, scarcity increases.

Nevertheless, there are two reasons why use type cannot adequately explain water rights evolution in these locations: 1) cattle and sheep water use is consumptive but prior appropriation was not adopted among Australian graziers. As noted, by the mid-1860s total

sheep numbers in NSW and Victoria totalled 16.5 million head (Davidson in Vamplew, ed., 1987). Water consumption by one sheep would reduce the amount left for others to consume so sheep grazing was a consumptive use of water. Average quantities of water required per sheep vary based on age, pregnancy status, and feed type. In addition, consumption is affected by climatic conditions and is 40 per cent more in summer than in winter due to changes in feed type available.⁴³ Under extreme conditions water consumption can increase up to 78 per cent of normal requirements. Therefore, in the absence of drought or extreme temperatures, an adult sheep that is not pregnant or has lambs and is fed on grassland will drink an average of two to six litre of water per day (Department of Primary Industries, 2007). If Rose's (1990) reasoning regarding use type holds then it is clear water rights in the Australian grazing sector should have applied prior appropriation. This evidence implies that while use type may impact scarcity, these effects are not sufficient to explain water rights evolution. Asset type provides a much better explanation regarding the persistence of common rights in Australia by emphasising the role mobility plays in reducing water scarcity. This lowers the gains that would otherwise accrue under a private property regime; making returns to individuals from such a shift lower than when non-deployable assets dominate. Compare this with adoption of 'pure' prior appropriation in Colorado where restrictions on water access by cattlemen's associations created a binding mobility constraint, thereby increasing the gains from private rights and; 2) intensive mill use in England did not date from the rise of the reasonable use doctrine as argued by Rose (1990). In fact, by 1700, before the industrial 'take-off' there were 10,000 to 20,000 water mills in that country; these numbers increased rapidly during the eighteenth century as waterpower became the basis for industrial expansion (Getzler, 2004). As a result, the evidence cannot support the claim reasonable use was a response to increasing non-consumptive uses. Moreover, Getzler (2004) argues that most modern English cases were often concerned with consumptive uses like mining, irrigation, and municipal and domestic water supply. The framework presented here predicts the use of common rights in locations that are not arid and non-deployable asset investments dominate. Mining, irrigation, and municipal water supply all require non-deployable asset investment and therefore, the framework presented here provides a better explanation of the rise of the reasonable use test in England. It also predicts the use of the reasonable use test in the eastern US with the rise of waterpower for textiles during the early 1800s. In addition, like England, the eastern US required water for municipal water supplies at the same time demand for waterpower was increasing so that water use was both for non-consumptive and consumptive uses; Rose (1990) presents no evidence to suggest the former dominated the latter. As a result, the exact effect of use type on scarcity and water rights evolution remains subject to some doubt.

⁴³ During drought stock require more water, in part due to changes in the availability of easily digestible and moisture rich feed (for example, grassland).

6. Conclusion

Property rights will evolve from open access to private rights as scarcity increases. Water scarcity is affected by two main factors, climate and investment type. In turn, these two variables will determine where and when we can expect common or private rights to evolve. By combining these two variables the framework developed here leads to four expected outcomes: 1) in arid climates where non-deployable assets dominate, scarcity is high and private rights will be adopted. Outcomes in nineteenth century California gold mining and irrigation, Colorado gold mining and cattle grazing, and Australian gold mining support this expected outcome; 2) in arid climates where deployable investments dominate scarcity brought about by lack of rainfall will be counteracted by a non-binding mobility constraint. As a result, common rights will evolve. Empirical evidence from the nineteenth century Australian pastoral industry supports this expected outcome; 3) in climates that are not arid where investment in non-deployable assets dominates scarcity will be low and common rights will evolve. Evidence from the US east and England support this expectation and; 4) in climates that are not arid where investment in deployable assets dominates scarcity will be very low and theoretically we would expect common rights to evolve. As noted, there is a lack of empirical evidence to support this predicted outcome however; the durability of the framework has been sufficiently demonstrated so as to support these theoretical expectations.

Including water use type in the analysis potentially served to undermine the predictive framework's durability via its impacts on scarcity. Specifically, where consumptive uses dominate, scarcity is high and where non-consumptive uses prevail, scarcity is low. Nevertheless, empirical evidence shows that use type cannot adequately explain water rights evolution in the locations considered here because common right persisted in Australian grazing areas while consumptive uses dominated. Further, the timing of changes to riparian rights in England, particularly the shift to the reasonable use test that increased the commonality of water use rights did not occur at a time when non-consumptive uses were increasing. In fact, as industrialisation accelerated both non-consumptive and consumptive uses co-existed. The findings here suggest that asset investment may be better able to explain how and why water rights evolve toward common or private rights at certain times and in particular locations. Application of the framework to a greater number of empirical examples is necessary to strengthen the findings presented here.

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Appendix 1

Water Cases heard by the California Supreme Court 1890 – 1910

Case Name	Citation information
Last Chance v Heilbron	25 Pac. 415 (1890)
Conkling v Pacific Improvement Co.	25 Pac. 899 (1890)
Riverside Water Co. v Gage	26 Pac. 889 (1891)
Mott v Ewing <i>et al</i>	27 Pac. 194 (1891)
Spargur <i>et ux</i> v Heard <i>et al</i>	27 Pac. 198 (1891)
Modoc Land and Live-Stock Co <i>et al</i> v Booth <i>et al</i>	36 Pac. 431 (1894)
Vernon Irrigation Co. v City of Los Angeles <i>et al</i>	39 Pac. 762 (1895)
Hargrave <i>et al</i> v Cook <i>et al</i>	41 Pac. 18 (1895)
Boehmer v Big Rock Creek Irrigation District <i>et al</i>	48 Pac. 908 (1897)
San Luis Water Co. v Estrada <i>et al</i>	48 Pac. 1075 (1897)
Gould v Eaton <i>et al</i>	49 Pac. 577 (1897)
Bathgate <i>et al</i> v Irvine <i>et al</i>	58 Pac. 442 (1899)
Senior <i>et al</i> v Anderson <i>et al</i>	62 Pac. 563 (1900)
Fifield v Spring Valley Waterworks	62 Pac. 1054 (1900)
Newport <i>et al</i> v Temescal Water Co.	87 Pac. 373 (1906)
Anaheim Union Water Co. <i>et al</i> v Fuller <i>et al</i>	88 Pac. 978 (1907)
Duckworth <i>et al</i> v Watsonville Water and Light Co. <i>et al</i>	89 Pac. 338 (1907)
Wutchumna Water Co. v Pogue	90 Pac. 362 (1907)
Montecito Valley Water Co. v City of Santa Barbara <i>et al</i>	90 Pac. 935 (1907)
Cohen v LA Canada Land and Water Co. <i>et al</i>	91 Pac. 584 (1907)
Huffner <i>et al</i> v Sawday <i>et al</i>	94 Pac. 424 (1908)
Miller and Lux v Madera Canal and Irrigation Co.	99 Pac. 502 (1909)
Miller v Bay Cities Water Co. <i>et al</i>	107 Pac. 115 (1910)
San Joaquin and Kings River Canal and Irrigation Co v Fresno Flume and Irrigation Co.	112 Pac. 182 (1910)
Miller and Lux v Fresno Flume and Irrigation Co.	112 Pac. 182 (1910)