FROM DROUGHT TO FLOOD: ENVIRONMENTAL CONSTRAINTS AND THE POLITICAL ECONOMY OF CIVIC VIRTUE

Francesco L. Galassi

No 643

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF WARWICK

From Drought to Flood:
Environmental Constraints and the Political Economy of Civic Virtue.

Francesco L. Galassi
Department of Economics, University of Warwick
f.galassi@warwick.ac.uk
Dipartimento di Economia, Università di Ferrara
galassi@economia.unife.it

Abstract

The paper models co-operative engagement under varying environmental constraints giving rise to different forms of collective action problems, specifically focussing on water management in pre-industrial societies. I show that societies where water availability is strongly seasonal develop no mechanism to encourage society-wide co-operative behaviour because the benefits of water storage are fully excludable. With pre-industrial technology water storage is a pure club good, and optimal club size can be shown to be very small under credible parameter values, converging to 1 in some cases (private good). The social consequences of the environmental constraint include strongly circumscribed co-operation and rent seeking. In contrast, areas where water management involved flood control and irrigation develop society-wide institutions based on self-sustaining co-operative engagement assisted by external policing. The model thus offers an explanation of varying levels of "civic virtue" in different areas..

I would like to thank Jon S. Cohen for the initial idea and helping me develop the conceptual framework. This paper represents the first step in our joint research into the material basis of social behaviour. Comments from the participants in the Seminar at the *Ente Einaudi* in Rome on 12 November 2001 are gratefully acknowledged. The usual disclaimers apply.

Introduction

The last few years have seen a flurry of interest among economists for a concept originally "imported" from other social sciences, most notably sociology (Portes 1998), and usually referred to as "social capital", defined in a number of different ways but usually referring to the accumulation of norms and beliefs that sustain in-group co-operative engagement. This concept has been proposed as an explanatory variable for economic and social development in different parts of the world, most famously by Putnam for Italy and the US (1993, 1995). The effort to understand persistent Third World poverty (Collier 1998) has also invoked the same idea. The approach is appealing: if by social capital we mean the propensity of members of a particular group to engage in co-operative activities, then it makes sense that societies where individuals find it difficult to trust others will have to devote a higher proportions of their resources to monitoring, policing and punishing defectors, than societies where the prevailing ethos is one of civic "virtue". This should, *ceteris paribus*, reduce the ability of low-social capital groups to accumulate and grow.

Promising though this idea may be, it has to be handled with a great deal of care. In the first place, as Durlauf (1999) has argued, social cohesion leading to high levels of civic engagement has a darker side, one that comes prominently to the fore in totalitarian societies. High social capital can be a social "bad". Furthermore, behaviour that has been blithely explained as resulting from different levels of social capital has been shown to have rather different causation. I have argued elsewhere (Galassi 2001) that differences in co-operative behaviour between Southern and Northern Italy reflected objective constraints rather than "cultural" proclivities.

This hits at the core of the social capital argument, which is fundamentally based on the idea that some cultural traditions are better at teaching people to behave "civically". Questioning this view does not mean questioning the idea that culture has an impact on economic choices, quite on the contrary. The problem with the social capital argument, rather, is that it is fundamentally circular. To put it differently, the argument may aim to explain more successful societies as having been born out of stronger traditions of social engagement, but can neither test this causation nor can it really offer a cogent explanation of different levels of development. Unless the social capital argument can explain why different societies have developed different rules of social interaction its explanatory insight is, in the end, negligible.

Appealing to historical experiences and thereby explaining social capital as essentially a path dependent phenomenon is not a convincing way out of this problem. First, this implies an infinite regression at the end of which one is still left with the original question. Secondly, identifying which historical events build up or tear down social capital is extremely dubious precisely because it is always possible to counter that a preceding event had set up conditions that in some way predetermined, or at least made it extremely likely, that the subsequent event would turn out in a particular way (Gambetta 1988). Either way we are right back with the problem of an infinite regression.

An interesting example of this is a forthcoming paper by François and Zabojnik (2002). They assume that observationally equivalent individuals are either co-operators or defectors depending on the education they have received. If parents decide on what values to impress upon their children on the basis of the net rewards they observe accruing to co-operators or defectors, there will be a minimum probability of interacting with a co-operator below which social co-operation will collapse to a Cournot equilibrium. Above this threshold, the rewards of co-operative engagement are sufficiently high that each generation of parents will produce a rising proportion of co-operatively-inclined offspring (for a similar approach see Guttman 2001). Insightful though the dynamics of the model are, it does not explain how a society comes to be above or below the threshold in the first place.

There appears to be only one way to resolve this problem, that is, only one way to turn the idea of social capital into an analytically incisive tool. This is to model the decision to engage in co-operative behaviour prior to the existence of a co-operative culture. This means identifying conditions under which co-operative outcomes are more or less likely not based upon pre-existing habits, social relations or institutional arrangements. Indeed, these relations and arrangements must be the *result* of individual optimisation in different circumstances. One way to proceed is to study the choice between co-operating and defecting with respect to the provision of different public goods and to reconstruct which public goods induce the highest probability of co-operation. We would then have a testable hypothesis as to where to find institutions that over the centuries have produced social capital.

Before proceeding it is important to be clear on what is being compared and explained. The modelling proposed thus far appears to take as the alternative to co-operative engagement a pure Nash-Cournot: co-operation vanishes and society becomes a Hobbesian war. However that is a difficult result to conceptualise because minimal levels of co-operation are observed in every society (Henrich *et al.* 2001). It may be more realistic to approach the choice as generalised co-operation versus strictly contained co-operation. In one setting, that is, individuals co-operate only within a well-specified group (*e.g.*, the family), while in the other co-operation is extended to all members of society.

The argument of this paper that the public good features of water management projects created an early incentive to engage in generalised co-operative games where water was abundant, while where water was scarce the benefit of generalised co-operation were much weaker. Repeated generalised engagement with tangible benefits was self-reinforcing and gave rise to a whole host of other institutions based on widespread trust. Where the benefits were negligible, on the other hand, actors concentrated on harnessing their own resources or those of small groups, and social capital remained low (co-operation was contained). The model focuses only on the benefits of the original decision to engage or not in co-operative behaviour, leaving the dynamics of repeated games for successive work. Bevilacqua and Rossi Doria (1984) discuss a historical setting for these decisions, though without formalisation. The model is simple but its result very suggestive. The context is a pre-industrial society and its management of water resources, but the analysis might apply to other collective action problems.

Section 2.1: Water regimes and co-operation.

This section outlines the basic features of the model's production and monitoring functions. Assume that there are two farming areas, for simplicity called Dryland and Wetland. In Dryland water delivery is strongly seasonal, with a drought in the summer months followed by high water availability in winter. In Wetland, by contrast, water is continuously available, though its distribution across space is not optimal from the point of view of farmers. The functional forms of both production and monitoring are identical in Wetland and Dryland, and the two areas differ only with respect to the costs incurred in building water management systems. First, consider the production function.

Assume there are two inputs, labour (*L*) and water (*W*). Actors control *L*, while *W* is a normally distributed random event with mean m_w and standard deviation s_w. Actors must commit *L* before they know what *W* will be. I assume that $Q(L,W)$ with $Q'>0$, $Q''<0$ in both arguments. It is convenient to model *Q* explicitly, so I will use a constant returns Cobb Douglas, $Q=XW^xL^{(1-x)}$, where labour inputs are normalised. Since there is no reason to expect that the absolute values of Q' and Q'' will be the same in Wetland and Dryland, distinguishing between them involves setting $X=A$ and $x=a$ for Dryland and $X=B$ and $x=b$ for Wetland. It may be that empirically $A=B$ and/or $a=b$, but results derived from the model in no way depend upon particular values of *X* or *x*.

Monitoring costs may be of two types. In principle, farmers have to monitor first the building of the water works (input monitoring) and second the use of water (output monitoring). Input monitoring costs are negligible in this case: if farmers themselves physically build the water works, everybody can see whether the i^{th} farmer is there and helping., while if they contribute a payment, input monitoring consists drawing up a list of who has paid. Matters stand differently for output monitoring. Here, farmers have to monitor, first, that those who have *not* contributed to the building of water works are not stealing water and, second, that those who *have* contributed are receiving only their allotted share. This suggests that monitoring has a fixed cost that will be incurred regardless of how many farmers co-operate in building water works, and a variable cost that will rise with the number of farmers involved (rather than with the amount of water delivered). If it is reasonable to think that monitoring water usage by 10 farmers is more than 10 times more expensive than monitoring water usage by one farmer, then monitoring costs, *M*, increase more than proportionally to the number of farmers, *n* , so the following functional form can be used: $M \circ gn^m$, $m>1$. Each farmer's share of *M* will be $m=M/n$.

In short, production in both Wetland and Dryland is characterised by constant returns to scale while monitoring incurs rising costs as the number of people being monitored increases. The differences between the two areas are in their cost functions.

Section 2.2: Water regimes and co-operation. Dryland.

This section focuses on the decision to engage in co-operative activity in Dryland. In this area, production occurs over two seasons, where inputs have to be committed in $s=\{1, 2\}$ even though output Q only becomes known at the end of $s=2$. I use l_s and w_s to indicate the amount supplied in season s. What matters in modelling water delivery is that this is a strictly sequential process: if $w_s=0$, output will be 0 no matter how much water is delivered in the other season. One way of modelling this involves setting $W=w_1w_2$, so that the marginal product of water in one season depends upon water in the other: if water is abundant in $s=1$ and scarce in $s=2$, the marginal product of w_1 will be lower than if water was abundant in both seasons. Further, the marginal product of water in either season is positive but decreasing for any given amount of water in the other season.

Dryland farmers can make themselves better off by reallocating water from the wet to the dry season. This involves n *(=1)* farmers co-operating to build a reservoir of capacity R *(*if $n=1$, the reservoir will be a private good). Only farmers who helped build the reservoir receive stored water in the dry season, a share r *(=R/n).* The reservoir is begun during the wet season of year 1, completed during the dry season of year 1, fills during the wet season of year 2 and is used to water crops during the dry season of year 2. For the moment the analysis is limited to these two years, although it can easily be extended. Specifically, we can think of this interaction as a repeated game in which each year farmers who have taken part in building the reservoir have to decide anew whether to remain in the club and co-operate further or leave the club. Remaining involves benefiting from the stored water but also involves paying an ongoing cost in repairing and maintaining the reservoir. The conditions for exit can be specified but lie outside my current concern, which is to focus exclusively on the original co-operative decision.

The two-year periodisation allows me to frame the question of the reservoir in a convenient way, in that farmers have to balance the cost borne in year 1 with the PDV of the additional income made possible by the reservoir in year 2.. This means modelling the reservoir construction costs. The total cost of building the reservoir is of a conventional quadratic form, $K°k_0+k_1R+k_2R^2$, where the ks are technical coefficients. Cost per farmer participating in the reservoir is $k°K/n$. If the reservoir is purely private, $n=I$, $M=m=g$,, $K=k$, and the conditions for which that is an optimal value are defined below.

There are two decision nodes faced by the farmers of Dryland, the first being the choice between building and not building a reservoir and the second between building a private or a club reservoir. The first one is in a sense trivial: the reservoir (private or club) will be built if the PDV of the increase in output in year 2 net of monitoring cost M is at least equal the costs incurred in year 1. I refer to this as the "minimum condition." What is more important to my purposes is the choice between a private and a club reservoir.

For the individual farmer, the expected benefits from building the reservoir in Dryland are E:

$$E = \frac{dARW^{a} - M - K}{n} \qquad [1]$$

where d is the appropriate discount factor. Farmers will join the club as long as $E>0$. The first order conditions to maximise [1] are

$$\frac{k_0 + \left(k_1 - dAW^{a}\right)R + k_2 R^2 + (m-1)gn^m}{n^2} = 0$$

$$\text{and} \qquad [2\text{ a - b}]$$

$$\frac{qAW^{a} - k_1 - 2k_2 R}{n} = 0$$

and the equilibrium value for n, $n*$, is

$$n* = \left(\frac{k_0 - k_2 R^2}{(m-1)g}\right)^{\frac{1}{m}} \quad for \quad k_o \geq k_2 R^2 . \qquad [3]$$

Note that if $k_0=k_2R^2$, $n*=0$, which simply says that no reservoir will be built. However, the interesting solutions are those for which $n=1$, so in developing these relations the latter condition will be applied unless otherwise indicated.

Result [3] is intuitively compelling: optimal club size increases with k_0, the fixed cost of building the reservoir ($\P n*/\P k_0=(k_0-k_2R^2)^{(1-m)/m} / m[(m-1)g]^{1/m} > 0$) and decreases as scale *dis*economies increase ($\P n*/\P k_2= - R^2(k_0-k_2R^2)^{(1-m)/m} / m[(m-1)g]^{1/m} <0$). Another way of thinking about this is that club size is technologically determined: if construction costs rise rapidly with reservoir size, there will be little incentive to gather together in large clubs. In fact, as club size rises, not only will the minimum condition require a larger reservoir, which will increases construction costs more than proportionately, but a larger club will also increase monitoring costs more than proportionately. Optimal club size is therefore determined, for a given reservoir size, by the relative values of k_0 and k_2. The larger are the fixed costs of construction, k_0, the more significant are scale economies and the larger is the optimal club size. Conversely, if scale *dis*economies predominate (k_2 is large relative to k_0), club size will be small, *ceteris paribus.*

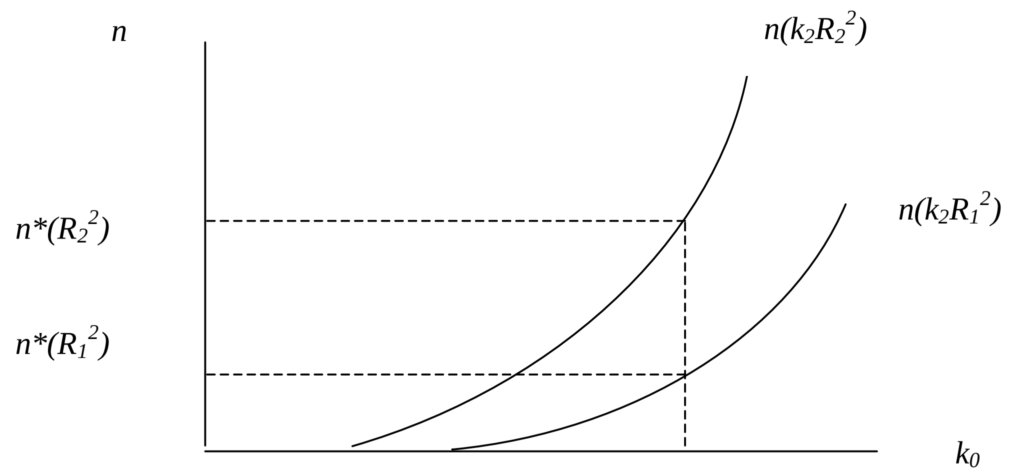
A less intuitive, but extremely interesting, result can be obtained by deriving [3] with respect to R:

$$\frac{\partial n^*}{\partial R} = \frac{-2k_2 R\left(k_0 - k_2 R^2\right)^{\frac{1-m}{m}}}{\left[(m-1)g\right]^{\frac{1-2m}{m}}} < 0 \qquad [4]$$

This says in effect that increasing reservoir size is only desirable if club size becomes smaller. The intuition behind this is that if construction costs rise rapidly in R, and monitoring costs rise rapidly in n, a larger reservoir including more members will be more expensive both to build and to run. Thus a large reservoir will not be an attractive way of using resources unless one is running it with few members, and possibly with only one (private reservoir). This result is striking: in Dryland, the optimal unit of co-operative organisation appears to be a small group. I will return to this aspect below, after defining the switching function between private and club reservoirs.

Graph 1 illustrates possible equilibria, plotting club size on the vertical axis and k_0 (fixed construction costs, and thus scale economies) on the horizontal one. Assume $R_1>R_2$. For a given k_2, the value of k_0 at which $k_0-k_2R^2=0$, that is, the value of k_0 at which no club will be formed (not even one where $n=1$), will be greater for the larger reservoir R_1 than for R_2. The equilibrium club size will therefore be smaller for the larger reservoir, as demonstrated. The slope of the function will become steeper as k_0 rises (that is, as scale economies become more important, optimal club size will increase more than proportionately), and flatter as k_2 and/or R increase. So, a larger reservoir is not *in itself* an attractive option because as R increases the range of values of k_0 over which nobody will be willing to begin construction increases. In other words, increasing reservoir size will be beneficial only if there are strong positive scale effects in construction to offset rising monitoring costs. Putting this yet another way, we can imagine situations where R would need to be so high to meet the minimum condition that no reservoir is ever built and no co-operation ensues. That is indeed the likely outcome if scale economies are weak. This is not an unlikely characterisation of reservoir-building technology in the years preceding reinforced concrete.

Graph 1



I focus now on the range of parameter values over which the reservoir will be a private good. From [3],

$$n^* \begin{Bmatrix} > \\ = \end{Bmatrix} 1 \quad iff \quad R \begin{Bmatrix} < \\ = \end{Bmatrix} \left(\frac{k_0 - (m-1)g}{k_2} \right)^{\frac{1}{2}} \quad for \quad k_0 > (m-1)g$$

In effect this expression defines the critical path between deciding to build a club reservoir and building one's private reservoir. For given parameter values, an increase in the expression under the square root will reduce the value of *R* where the construction of a club reservoir is preferred to a private one. Taking the limiting case *n=1*, in fact,

$$R(n^* = 1) = \left(\frac{k_0 - (m-1)g}{k_2} \right)^{\frac{1}{2}} \qquad [5]$$

and differentiating with respect to k_0:

$$\frac{\partial R(n^* = 1)}{\partial k_0} = \frac{1}{2\,\sqrt{k_2\left[k_0 - (m-1)g\right]}} > 0 \qquad [6]$$

This is hardly a surprising result: if scale economies in construction costs become more important, for a given value of k_2, reservoir size where club will be preferred to private will decrease.. If construction scale diseconomies rise, on the other hand,

$$\frac{\partial R(n^* = 1)}{\partial k_2} = -\frac{1}{2}\left(\frac{k_0 - (m-1)g}{k_2^3} \right)^{\frac{1}{2}} < 0\,, \qquad [7]$$

the reservoir size where we switch from a club to a private solution will increase. Once again, if technological constraints make achieving scale economies unlikely, as was probably the case in pre-concrete days, the model suggests that small groups or private reservoirs will predominate.

To summarise so far, assuming the minimum condition is met (in effect this implies $k_0>k_2R^2$), the decision these farmers have to take is whether to build private or club reservoirs. There are two problems that need to be settled so as to reach that decision, reservoir size and club size (including *n=1*), with technical parameters (construction and monitoring costs) being the choice criteria. Counterintuitively, equilibrium club size and reservoir size are inversely related to one another: a large reservoir is costly to build, so small groups where monitoring is cheap will have an advantage running it. If construction technology is characterised by scale diseconomies, furthermore, the equilibrium club size will be very small.

The implication is that with pre-modern technology reservoirs will be built by small cohesive groups, resulting in a social organisation characterised by circumscribed co-operative engagement, and the most obvious group within which such engagement can take place is of course the family. This highlights certain characteristics of the society organised around the reservoirs of Dryland which, while not explicitly modelled, are strongly suggestive. In the first place, while the family appears a natural form of organisation under these circumstances, it is probably well to avoid thinking of Dryland as a collection of family-run reservoirs. Not all locations will be equally favourable to constructing a reservoir, and not all families will be able to finance the initial cost. I call these "exogenous asymmetries", conditions that differentially affect reservoir building costs (that is, the levels of k_0 and k_2). Examples of exogenous asymmetries are credit market imperfections, or geographic structures. Specifically, if construction is characterised by high sunk costs (high k_0) , a credit constraint may prevent most farmers from building private reservoirs. Expensive credit, that is, may make it impossible to meet the minimum condition. Individuals with substantial assets will then be in a position to finance private reservoirs. If monitoring is cheaper within the family, wealthy families will enjoy an additional advantage. If not all locations are equally suited to the construction of reservoirs (that is, k values are higher in some locations than others), even without a credit constraint geography may put some individuals in a better position to meet the minimum condition. Once one or more of these asymmetries has given rise to a particular distribution of reservoirs, those individuals/clubs who have been thereby favoured will be in an enviable position. Not only will they have a resource that will yield higher output (the effect of reallocating water between wet and dry seasons), but they will have a commodity (water) they can sell. If wealth and/or geography have permitted only a few reservoirs to be built, the sellers will act in an oligopolistic (and possibly cartelised) market, where they will be able to extract a large proportion of the surplus generated from the commodity they sell, whether in cash or in political power and influence. In turn this will reinforce a strongly asymmetric wealth distribution

The point is simply that there is no pressure towards a society-wide co-operative solution given the environmental constraints faced by Dryland. There will instead be sustained in-group co-operation for a few powerful "clubs" enforced by sanctions administered by the group itself rather than by a public authority which, unlike the case of Wetland discussed below, appears nowhere out of this simple model. The political implications of these environmental constraints are clear: a central political authority may of course arise as powerful clubs compete for supremacy (in the terms of the model, this means competing for good reservoir locations), but there is nothing to suggest that this authority will perform any type of collective action.. On the contrary, the suggestion is that power flows from the walls of the reservoir, and that therefore it will be used purely as a means to capture rents. The stationary bandits of Dryland have no responsibility to society at large and owe their position wholly to the excludability of the income stream generated by the solution to the collective action problem. In addition, the flavour of the results is that politics will remain intensely local and tribal, and the maintenance of authority will involve patron-client relationships as individuals not favoured by the exogenous asymmetries that have given rise to a skewed distribution of resources vie for favours and protection from the powerful. Rent seeking may well become more attractive in Dryland than producing for the market. The habits of behaviour that will be remunerative in this setting are those that Banfield (1958) has described as "Amoral familism."

Against this rather grim background, I now turn to the water allocation problem in Wetland.

Section 2.3: Water Regimes and Co-operation: Wetland.

The fundamental problem in Dryland was redistributing water from one season to the next. The problem for Wetland is not distribution across time but across space. Unlike Dryland, Wetland is a fundamentally water rich environment, so that its problem is to control water to ensure appropriate delivery to cultivation. Water delivery may or may not vary seasonally in Wetland, but that is in a sense inconsequential provided that Wetland is not *systematically* subject to drought, that is to conditions in which *lack* of water significantly affects crop yields.

Having plenty of water is however a mixed blessing at best, in that abundant water in the wrong place can be just as damaging as insufficient water. I use the concept of flood to describe this situation, though emphasising that "flood" is not a discrete event. This means that as water delivery increases, output will rise, given the specification of the production function, albeit at a declining rate. In reality, however, there will come a point where adding yet more water will result in water-logging the ground if drainage rates are below rates of delivery. This has a negative impact on yields, and it seems reasonable to presume that the more water is unable to drain, the greater the reduction in yields. It goes without saying that this point will be reached a different water levels for different crops (rice will have a higher threshold than olive trees) but the general principle should stand. In this perspective, a flood is simply an event in which drainage rates are dramatically below delivery rates.

If that is right, then Wetland's production function will have an inverted U shape with respect to water, *W*. This does not mean a different functional from the one used in Dryland. Rather, the specifications that model the temporal distribution of exogenous events (water) in Dryland have to be re-worked to focus on the spatial distribution of water in Wetland. "Where" the water is matters in Wetland as much as "when" it is matters in Dryland.

Two forms of water delivery exist in Wetland, rainfall (r) and groundwater (g). Groundwater is essentially rainwater that has fallen in a different area and has been conveyed to Wetland through natural drainage (rivers, streams). In the "state of nature" groundwater will simply flow to Wetland and thence more or less onward depending on the delivery/drainage differential. Human intervention can alter that by means of building embankments for rivers and drainage channels that will increase the top drainage flow or, to put it differently, increase the proportion of water that can be drained in any period. Drainage and embankments however have their own problems, because if they are effective they diminish the amount of water actually delivered to crops, which in turn means that drainage and irrigation systems have to be built together. Herein lies the rub, the crucial difference between the Dryland and the Wetland equilibria.

In Dryland farmers decide to build a private or a club good depending on certain marginal conditions. In Wetland, the drainage system is essentially a public good: it is non excludable. In Dryland free riders can be controlled by means of monitoring reservoir usage. In Wetland no sanction appears to exist against them. This may seem like an inauspicious situation on which to build an interpretation of high social capital, except for one important consideration. Excludability exists in Wetland in the form of irrigation. Those who do not contribute to building flood control systems are excluded from irrigation. This means that although they may benefit from the reduction in flooding resulting from others' efforts, they will suffer from the diversion of water which comes with it. Under certain conditions, then, co-operation can be shown to be self enforcing,. Still, the free riding problem will remain because self enforcement will not be perfect, so that sub-optimal amounts of flood control will be built. There will be therefore room for a stationary bandit to step in.

One last point before proceeding with the formal modelling. No flood control system is likely to block all groundwater entirely. Streams form at each new rainfall, and blocking one will shift some proportion of its water to another path. Therefore just as floods are not discrete events neither are the effects of embankments and drainage channels.

Let h by the proportion of ground water g that is *not* captured by drainage and irrigation systems in any given time period. In the production function, water will therefore equal $W=r+(1-h)g-hg$. Normalising as before for $L=1$, the production function discussed in 2.1 above can be written as

$$Q = B\left[r^{b_0} + (1-h)g^{b_1} - hg^{2b_1}\right] \qquad [8]$$

where B, b_0, b_1 are technical coefficients. The function captures the idea that as less groundwater is controlled through flood and irrigation systems (h rises) output will fall more than proportionally (the hg term is raised to twice the technical coefficient of production giving the inverted U shape)[1].

Intuitively, h will depend on the number of people participating in the construction of flood and irrigation works, presumably in such a way that $h'(n)<0$,

$h''(n)>0$. However, unless completely unrealistic assumptions are made about the distribution of landholding along water courses, it is reasonable to presume that the proportion of water that escapes flood works for the i^{th} farmer is also a function of the distance between that farmer's land and the relevant water course. The farther away i's land is from the water course, the lower will h_i be, becoming vanishingly small as distance (d_i) becomes very large. As a first approximation let $h_i {}^{\circ} a/nd_i$ where a is a technical coefficient measuring the ease with which water spreads.

Construction costs still have to be defined, given that as in the case of Dryland, monitoring cost are not related to the actual performance of the construction task but rather consists of enforcing property rights once the desired geographic or temporal allocation of water resources has been obtained . Monitoring costs thus have the same form as in Dryland, namely $M {}^{\circ} gn^m$, $m>1$. Construction costs are, on the other hand, significantly different in Wetland. In the case of the reservoir, the average cost curve turned up at some R depending on the value of k_2. That is not self evidently true in the case of flood and irrigation systems: it is difficult to see why extending embankments and canals should run into rising costs. If so, the following cost function can be used:

$$C = c_0 + c_1 d + c_2 n \tag{9}$$

which suggests that average costs decline continuously both as the size of flood works rises (i.e., n rises) and as the average distance to farms benefiting from irrigation rises. With this formulation the cost borne by each individual farmer is a function of the distance of his particular land from the watercourse.

The next step is to study the payoffs resulting from participating as opposed to free riding. The expected net benefits of participation, E_P, may be defined as the difference between the income of participants who receive irrigation water but have to pay construction and monitoring costs, Y_P, and the income of free riders who avoid these costs but are also excluded from irrigation, Y_F.

---

[1] Again, it may be that empirically $b_0=b_1$, but no theoretical reason exists why this should be so and the model's results do not depend on any specific value of b_0 or b_1.

$$E_P = Y_P - Y_F = B\left[r^{b_0} + (1-h)g^{b_1} - hg^{2b_1}\right] - \frac{M+C}{n} - B\left[r^{b_0} - hg^{2b_1}\right]$$
$$= B(1-h)g^{b_1} - \frac{M+C}{n}$$

[10]

In other words, a farmer who chooses not to participate in building the water works will still benefit from the non-excludability of a lower *h* obtained thanks to others' efforts, but will suffer from being excluded from the irrigation works built as part of the water control system (he will, of course, receive just as much rainwater *r* as all others). As long as $E_P>0$, it will pay the marginal farmer to participate. This is where the importance of the distance variable *d* comes into its own: if *d* is very small, E_P will be very large, or more precisely it will be positive over a greater range of *n*. In fact, finding the first order conditions for [10] yields

$$\frac{\partial E_W}{\partial n} = \frac{Bag^{b_1} + c_0}{d} - (m-1)gn^m + c_1 = 0$$

[11]

from which the equilibrium value of *n, n**, is

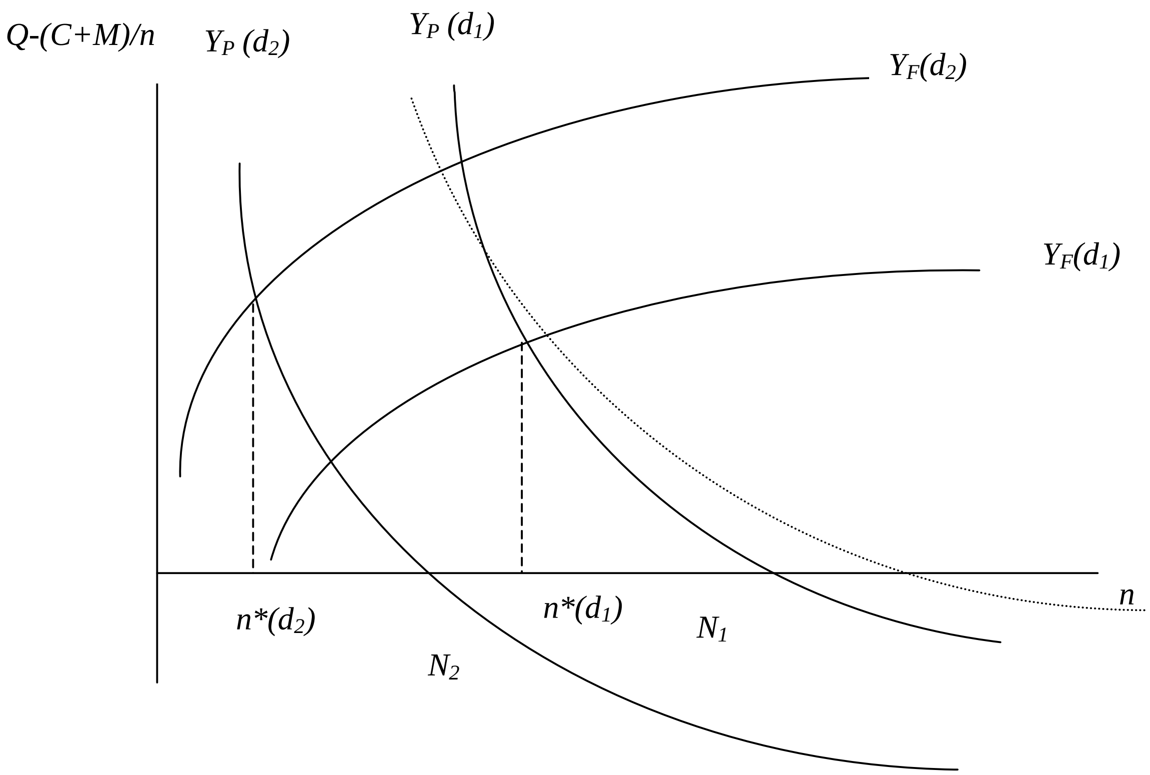
$$n^* = \left[\frac{Bag^{b_1} + c_0 + c_1 d}{(m-1)gd}\right]^{\frac{1}{m}}$$

[12]

In this case, *d* is the distance of the average or representative farmer's land from the watercourse.

It is important to distinguish clearly between the equilibrium value *n** and the optimal value of *n, N*. The equilibrium outlined in [12] defines the "self sustaining set", that is the number of farmers who will choose to participate because they are better off than by free riding. This is not the optimal number of farmers to participate in building the water works, though, that is, it is not the number of farmers where the marginal benefit from building the works falls to zero. This may be seen in Graph 2.

Graph 2



The vertical axis plots output net of monitoring and construction costs and the number of participants is on the horizontal axis. As n rises, net output for participants, Y_P, decreases because of the shape of the monitoring cost function. As long as a marginal farmer with a given d obtains a positive net output by participating, the number of participants will rise. As more farmers join, however, the non-excludable benefits increase. The socially optimal solution, given average distance d_1, is N_1. The problem is that private incentives stop well short of that point, because as more farmers join, free riders benefit indirectly from the non excludability of the flood control work. Thus the income of free riders for average distance d_1, $Y_F(d_1)$ rises continuously, albeit at a declining rate, in n. The self sustaining set is therefore *n*£$n^*(d_1)$. If d rises, that is, if farmers are on average farther away from watercourses, the self sustaining set will be smaller (*e.g.*, $n^*(d_2)$). This may be thought of on an individual level as well: for any given farmer, the incentive to participate varies inversely with his distance from the watercourse and the number of participants. So farmers who live close by ($d_i<d_2$) have an incentive to participate over a larger number of other participants than farmers who live farther away[2].

Are there parameter values for which participation will be optimal, that is, $N=n^*$? The answer is, no. The public goods aspect of the water works means that there will always be some people whose incentive is to let others do the building and the monitoring of the irrigation systems: even being excluded from irrigation will be preferable to paying their share of costs. Putting this differently, formers who live very close to watercourses have an incentive to participate because their h is very high. This in effect means that they will receive a large amount of "uncontrolled" water because of their location. Even if there are many other farmers participating, the proximity to water will give them a greater incentive to help building the control system than the threat of exclusion from irrigation. As d rises, on the other hand, h declines, and a smaller h will make free riding more attractive.

What is interesting to current purposes is that a self sustaining set exists at all. Even this has to be qualified, however, because we can imagine values of *a, d, m, g,* and c_j $j=(0,1,2)$, for which

$$B(1-h)g^{b_1} < \frac{M+C}{n} \qquad [13]$$

In this case, the self sustaining set does not exist. There will therefore be no co-operative solution to water control problems if population is on average removed from the watercourse, if monitoring and/or construction are very costly, and if flood waters

2 In this sense, we can think of farmers arranged along the n axis in ascending order of d.

do not spread easily (a is low). In sum, self sustaining co-operative water control projects will be most likely in flat areas[3] where the population is settled along rivers and communication to control the distribution of (and exclusion from) irrigation is relatively cheap. Even there, however, it will be sub-optimal.

If optimality is always outside the self sustaining set, one obvious solution is for farmers who are close to the watercourse to compensate their colleagues farther away for the cost incurred in co-operating. This involves using part of the net benefit generated by co-operation (the distance between $Y_P(d_1)$ and $Y_F(d_1)$ for $n=n^*$ in Graph 2) to compensate (N-n^*) farmers for their loss if they contribute to building flood control systems. This can only be accomplished if

$$\int_0^{n^*} Y_P(n)dn - \int_0^{n^*} Y_F(n)dn > \int_{n^*}^{N} Y_F(n)dn - \int_{n^*}^{N} Y_P(n)dn$$

implying

$$\int_0^{N} Y_P(n)dn > \int_0^{N} Y_F(n)dn \qquad [14]$$

Whether or not [14] holds is an empirical question, and it is possible to imagine values of M, C and h such that participating farmers may simply not have enough resources to induce free riders to co-operate. Even if [14] does hold, however, there are strong practical reasons to expect that actually putting in place such compensation will be cumbersome. In the first place, it may be difficult to determine exactly what compensation to offer free riders if they co-operate because it may be hard to identify *ex ante* the marginal product of ground water (that is, estimate the values of B and b_1). Compensation has to be computed *ex ante* because otherwise participating farmers will face a strong moral hazard problem since free riders can then slack off and claim higher compensation than strictly necessary to induce co-operation. Furthermore,

[3] An important qualification here is that in narrow valleys a will be high (flood waters rise quickly in constrained space) so that we can expect high co-operative engagement not only in plains but in water-rich mountain valleys as well.

marginal co-operators have an incentive to refuse participation without compensation, and it will be impossible to determine who would have participated in building the flood control system in the first place. Finally, free riders who accept to participate also face a moral hazard problem because it is just as difficult to determine what the benefits of irrigation are for participants. In short, the transaction costs of compensating free riders to induce co-operation will be so high as to make it unlikely.

Unlikely, but not impossible. If construction costs are not divided equally among all participating farmers, the self sustaining set can be enlarged by shifting onto closer farmers a higher-than-average proportion of total cost. This is in effect a form of compensation for farmers having land farther away, and while it may not push the incentives to free ride down to zero, it is certain to reduce them. A judicious choice of differential contributions to construction costs would have the effect of rotating the $Y_P(d_1)$ function in Graph 2 counterclockwise (dotted line). This expands the self sustaining set, but interestingly also increases the number of free riders. The last effect is the result of the fact that as costs are differentially attributed on the basis of distance from the watercourse, farmers who clearly did not stand to benefit from flood control systems now become potential beneficiaries, provided an appropriate *c* can be identified to bring them into the fold. At each new differentiation of costs, however, the social optimum shifts outwards again.

If the social optimum cannot be reached through spontaneous co-operation, it still is important to follow up on what the social and political implications are of attempting to extend the self sustaining set anyway. In the first place, if free riders are to be convinced to help, a record office to keep track of who can and cannot receive irrigation must be developed, and alongside the record keeping function there will have to be a policing structure developed among the users of the irrigation projects. Both of these functions have to arise in Dryland as well, but there they are carried out by a club or a private individual, that is, by those who benefit from the exogenous asymmetries that gave rise to a particular distribution of reservoirs in the first place. In Wetland, however, first of all there no hint that *n* will be a small number (on the contrary, the cost function suggests it will be high) and secondly the cost function coefficients do not vary according to location. This means that the flood control system is general, not specific to a place, which in turn means that all farmers with certain values of *d* are affected by its presence. The list of who is in or outside the club is therefore public (that is, administered by a political process in a community), rather than private(that is, applied by a small group of individuals). Likewise, since co-operative engagement exists spontaneously, that is, since there is a self-sustaining set, social sanctions on free riders must also arise, unlike Dryland, where all sanctions are privately administered. In addition, the record keeping function will have to develop a metering system that will allow the community to determine the appropriate charges to be levied on farmers living at different distances form the watercourse. A by-product of this is a political mechanism to decide what the appropriate charges are. This is unnecessary in Dryland, where the charge for access to the fully excludable good is simply the monopoly (or oligopoly) price dictated by the reservoir club/owner. Those unwilling to pay it have no bargaining power, unlike the free riders in Wetland whose co-operation in building the flood control system may be very important to the welfare of participants. Wetland will therefore develop a representative political process in which bargains may be struck between individuals having different objective functions. Participation, generalised co-operation and political involvement characterise Wetland just as concentrated power, hierarchy and clientelism characterise Dryland

There is, however, trouble in Paradise. Co-operation and participatory politics notwithstanding, Wetland farmers will have trouble reaching the social optimum, N. In part this results from the sheer difficulty of offering adequate compensation, as discussed. However, the point is that even with differential charges (or rather, exactly *because* of differential charges), free riding incentives cannot be wholly eliminated. A coercion gap, the distance between n^* and N, remains and into this gap can step a stationary bandit.

Coercion is costly, so the gap can be closed only if the agency applying coercion can tax the beneficiaries. This raises an interesting problem, because some of the beneficiaries are already co-operating. Those that are not, that is, the farmers between n^* and N, need to be forced to co-operate but the cost of coercion cannot fall on them alone because there is a clear feedback problem. If taxes to finance coercion of first round defectors (that is, farmers who would on their own *not* help build the water control system) are raised by taxing only first round defectors themselves, h will fall for first round co-operators as well. Marginal co-operators will then have an incentive to defect, and the effect of coercion will simply be to swap one set of defectors for another.

Taxation must therefore be general. In addition, it would seem reasonable that if some agency is enforcing co-operation in construction, that same agency would also take charge of all other construction costs. In other words, it is difficult to see how defectors can be coerced into helping with the building work unless the entire coordination of building is transferred from the farmers to the stationary bandit. The latter, in this case, will tax all beneficiaries of water works and organise construction, but the bandit need not have a comparative advantage in construction.. Farmers' income will then be $Y'=Y_P-(t-C)$, where t is the tax levied on each farmer by the stationary bandit. Note that I am assuming that the actual cost of monitoring water distribution, M, is still paid directly by the beneficiaries. This assumption can be relaxed without altering the qualitative results in the model.

The amount of taxes *per capita* that the first time co-operators would be willing to pay to reach the social optimum N is obviously $t=?n(?Y_p/?n)$, where $?n=N-n*$. The optimal tax will therefore be

$$t=\left[\frac{a}{d}\left(g^{b_1}+g^{2b_1}\right)+c_0+c_1d-\left(N^m-n*^m\right)\right]\left(\frac{1}{N}-\frac{1}{n*}\right) \qquad [15]$$

Ignoring for the moment the cost of collecting t, the coercion gap can only be closed if the cost of policing both first round co-operators and defectors is less than t. To be more accurate, t is the per capita tax that participating farmers would be willing to pay to reach the optimal level of co-operation N.

What is relevant to current purposes is to observe what determines *per capita* tax. From [14], it is evident that t will rise with a, g, and c_0 and decline with g. The relation between taxes and distance is, however, ambiguous. On the one hand, a farmer located farther away from the water courses will have a greater than average incentive to defect, which should imply lower taxes. On the other hand, being farther away implies higher construction costs for irrigation systems. The precise balance is given by the value of c_1 and $a(g^{b}{}_1+g^{2b}{}_1)/d^2$ If $c_1>a(g^{b}{}_1+g^{2b}{}_1)/d^2$, the cost of providing irrigation to a far away farmer will be greater than the rent that can be extracted by taxation. If the reverse is true, however, that is, if $c_1 < a(g^b{}_1 + g^{2b}{}_1)/d^2$, taxes will decline as distance from water courses rise. Again, this is an empirical issue, but it serves to highlight the limits of the power of the stationary bandit. If policing becomes more expansive the greater the incentive to defect, rising taxes to cover costs of irrigation delivery to far away farmers will prove uneconomical.

The precise behaviour of the stationary bandit can be rigorously specified, but that would add little to the results of the model. Already from what has been shown a number important social arrangements emerge, and this is the place to follow that side up. In the first place, co-operative engagement is general and not group specific. Anybody living along the water course has an incentive to participate, and while that incentive diminishes with distance there is no doubt that those who do participate have an incentive to recruit a stationary bandit to coerce free riders. Nothing of this sort emerged in Dryland. In addition, the ability of first-round co-operators to reduce defection through the use of a stationary bandit depends very closely on the taxes the bandit can raise. Taxation that is out of proportion to the benefits received from irrigation (that is, from collective action) will encourage defection. This is an astonishingly strong result for such a simple model because it suggests that taxation will only exist if at the same time some form of representation is put into place, something that confirms the finding relating to the creation a record office and of a metering system. Unlike the reservoir owner of Dryland, the stationary bandit of Wetland performs a social function.

Whatever the merits of the bandit, the model yields some intriguing insights as a consequence of different environmental constraints in the two areas. In Wetland, co-operation is generalised rather specific, politics is representative rather clientelistic, and civic institutions (records, policing) arise from the need to define and enforce property rights generated by a collective action rather than as ways of protecting a private good.. There is no sign of civic institutions arising in Dryland. Wetland still suffers a coercion gap, but its solution depends upon a bandit fulfilling a public function. The only coercion that emerges in Dryland is unrelated to public goods and wholly concerned with rent extraction by the owners of scarce resources.

3. Conclusion.

A static model cannot, of course, explain a dynamic process such as the emergence of civic norms and what has been called "social capital". The focus of the work has been simply to identify how different forms of exogenously determined constraints could affect the solution to collective action problems. The stability of co-operative solutions described here needs to be demonstrated, but the paper establishes that co-operative engagement (as an economist might prefer to think of "social capital") can be understood as a reaction to objective constraints. Cultural traditions are not arbitrary or random: they are the direct consequences of objective functions given particular levels of technology. Dryland's circumscribed co-operation disappears (n^* rises rapidly) if scale economies in construction were to predominate rising monitoring costs. If technology with strong scale effects was unavailable over long periods of historical time it is easy to imagine that the kind of institutions resulting from circumscribed co-operation described by this model would become entrenched in areas like Dryland.

The contrast between the two equilibria is most visible in the role of public authority: Wetland's coercive power, which may extract rents but also performs a social function, stands in marked opposition to Dryland's clannish authority who extracts rent but really solves no collective action problem. It is not difficult to extend the implications of the results: in Wetland, the public authority's ability to collect rents is tied to the solution of the free rider problem, and the more completely free riders are brought into the fold the greater are the rents that authority can seize. In Dryland, rents are extracted by the sale of a privately owned resource that has been captured thanks to an accident of geography or wealth inheritance. No collective problem is involved, thus the stationary bandit has no interest in the welfare of its subjects. In Wetland, the stationary bandit is a political entrepreneur contracted to perform a collective action, in Dryland he is a private entrepreneur whose command over scarce resources endows him with coercive power. The civic society of Wetland and the tribal society of Dryland were born out of their water resources.

References

Banfield, E.C., (1958): *The Moral Basis of a Backward Society*. (Glencoe, Ill.: Free Press)

Bevilacqua, P., and M. Rossi Doria (1984): *Le bonifiche italiane*. (Bari: Laterza)

Collier, P. (1998): "Social capital and poverty." Mimeo, The World Bank, Social Capital Initiative.

Durlauf, S.N. (1999): "The Case 'Against' Social Capital." Mimeo, Department of Economics, University of Wisconsin.

Henrich, J., *et al.* (2001): "In search of Homo Economicus: Behavioural Experiments in 15 Small Scale Societies." *American Economic Review*, **91**, May, 73-9.

François, P., and J. Zabojnik (2002): "Trust and Development." *Quarterly Journal of Economics* - forthcoming.

Galassi, F.L. (2001): "Measuring Social Capital: Culture as an Explanation of Italy's Economic Dualism." *European Review of Economic History*, **5**, April, 29-59.

Gambetta, D. (1988): *Trust*. (Oxford: Blackwell).

Guttman, J.M. (2001): "Self-enforcing Reciprocity Norms and Intergenerational Transfers: Theory and Evidence." *Journal of Public Economics*, **81**, July, 117-52.

Portes, A. (1998): "Social Capital: its Origins and Application in Modern Sociology." *Annual Review of Sociology*, 1-14.

Putnam, R. (1993): *Making Democracy Work, Civic Traditions in Modern Italy*.(Princeton UP).

Putnam, R. (1995): "Bowling Alone: The Strange Disappearance of Civic America" *Journal of Democracy*, **6**, 65-78.