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Abstract

A recent set of case studies on resilience of ecocultures forms the basis for our review of and comment on the resilience literature. We note the diversity of definitions of resilience and the confusion this creates in implementing resilience studies. We develop a synthesis view that establishes a framework for defining resilience in an implementable way. This framework emphasises the importance of defining the source of and magnitude of shocks. Next, we outline measurement issues, including a variety of performance measures that can be used to gauge resilience. We argue that self-determination and local ownership of resources is supported in the cases, and review the effectiveness of the informal insurance arrangements observed in the cases. We close with the variables suggested by the case studies to include in a resilience index and lessons for regional governments developing resilience policy.

I. Introduction

The purpose of this paper is to present a basis for policy discussions of resilience at the local level. We draw on data from a recent and new set of case studies of resilience of "ecocultures", broadly defined as the system by which a culture is linked with its environment (Pretty, 2011) to study the effects of a wide variety of shocks ranging from petrol price shocks to environmental change due to global warming to population depletion due to emigration. We unite our findings into a framework for study that should be sufficiently broad to apply to resilience discussion beyond ecocultures.

The paper starts with a definition of what is meant by "resilience" and how it relates to the concept of" sustainability", which also is discussed in the case studies and is linked to resilience in many ways. We find a lack of clarity on the concept in the case studies that reflects an enormous spread of definitions used in the literature. This lack of a common vocabulary not only leads to a lack of comparability across the case studies, but also to difficulties implementing resilience policy locally: if actors cannot be sure of what they are discussing, communication becomes difficult and local policy poorly directed. We note that the core difference between resilience and sustainability is that resilience refers to the recovery of a system from shocks, whereas sustainability refers to maintaining current opportunities into the long run future. Although a sustainable system must be resilient to some degree the analysis of resilience is not completely subsumed in the analysis of sustainability, as it investigates a number of different dimensions, such as the speed of recovery of the system or the depth of the dip in performance of the system after a shock. These aspects are not essential to the broader study of sustainability. As a first element in our framework, we propose a definition of resilience that unifies a variety of approaches whilst providing some clarity on the concept.

Our definition of resilience must be linked to a measure, as resilience by one measure need not imply resilience by another. This raises two fundamental issues. Firstly, measuring resilience requires setting some levels of performance to which we will require our system to return after experiencing a shock. Unfortunately, there is no single measure of societal performance that has universal support in the economics

literature. A selection of measures will be discussed including purely "economic" measures, such as gross national product, broader measures of well being such as the human development index, and more recent and subjective measures such as happiness. In the face of this lack of agreement in the literature, local agreement on the measure of resilience needs to be a cornerstone of any resilience policy before it is implemented locally: if actors are not implicitly using the same measure of performance in their definitions, policy support may not be well coordinated. The choice of measure, in turn, needs to be rooted in the determinants of local welfare. The measure is, then, the second element of the framework.

A further issue when measuring resilience is that we must state the type of shock – mild or severe, specific or broad-based -- to which we want our system to be resilient. A social system may be resilient to one type of shock but not to another, similar to the way a society may perform well on some measures and not others. Indeed, a feature of the case studies is that one observes that the policies followed by the ecocultures often are well designed to create resilience to certain threats, but actually make the culture less resilient to other threats: a "perverse resilience", as it is termed in one of the case studies (Clifton, 2011). Hence, societies may face trade-offs in resilience policies where policy choice must be weighed by an evaluation of the likelihood and severity of certain types of threat. While this suggests that we need some method of aggregating threats to yield an idea of what we wish our region to be resilient to, this does not imply that we must use a method that simply takes the most likely threat. Indeed, precautionary methods such as real options analysis may be more desirable. Indeed, all aggregation methods that we review are imperfect, but some method must be chosen before undertaking any public consultation so that appropriate information is gathered to feed into the analytical method. The choice and measurement of shock is, then, our third element.

The second part of the paper considers the factors that come out most clearly in the case studies as impacting on local resilience. We do not limit ourselves to purely economic factors. Instead, while we search for factors based on economic analysis, we focus on broad institutions that tend to promote resilience. While we identify a large number of factors that can affect the resilience of a system, we focus on governance and insurance systems, both emphasised in the case studies. We close

with our conclusions on a framework for analysis and pressure points where local governments can play a key role in promoting resilience.

I. Definition of Resilience

The definition of resilience has received considerable attention in the economics literature. We will start here with a rough definition that we can translate into measures. We will then contrast the definition to that of sustainability and move on to discuss some of the subtleties of the definition. These subtleties are important, as they can determine whether we consider any particular system resilient or not. We close with a framework that can be used as a basis for discussion in defining resilience as a prelude to policy consultation.

a. Resilience, and Sustainability: The Role of Shocks

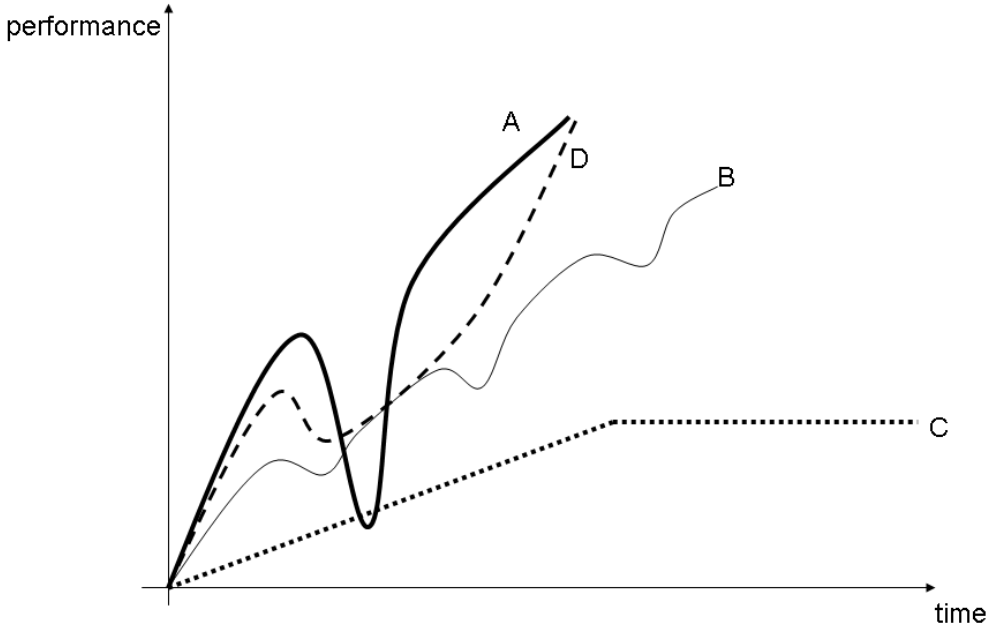
As a first cut, resilience can be defined as the ability of an economy, society, organisation or individual to *recover* effectively from an unexpected shock. This rough definition of resilience raises two related questions: what it means to "recover" and what we mean by an *effective* recovery. An example might help illustrate how the two issues are linked as well as how they can be put into practice. Suppose that we only care about economic performance and that we take GDP per capita as our sole measure of this performance. The term "recovery" can then be made more precise. It might mean to go back to the same level of GDP per capita as before the adverse shock, or to reach the same growth rate in GDP per capita as before, or to reach the level of GDP per capita that would have prevailed at the same time had the shock not occurred. Any one of these, or other GDP levels, including even those lower than before the shock might be deemed a "recovery". Once we know how to measure "recovery", measuring its effectiveness is relatively straightforward: it would be the shortfall in discounted GDP per capita between the time where the shock occurs and the time where recovery is achieved. In other words, once we are willing to establish some measure of performance or "health" of a society and a standard of performance for "recovery" to be said to have occurred, we can readily translate the definition into measures of effectiveness.

This example raises a series of issues. First, resilience is quite distinct from sustainability, which has its own extensive literature. While resilience relates to recovery of a system from a shock, sustainability relates to the long term trajectory -- or opportunity set -- of a social system. Resilience requires definition of a shock to be applied, whereas sustainability does not. The cases that motivate this study include examples that illustrate the distinction between "locally sustainable" but "globally non-resilient" systems. The Puruvesi seine fishing community investigated by Mustonen, 2011, describes a system that is sustainable in the sense that it does not deplete its resources beyond the level at which they renew (so that its capital stocks, including natural capital, are not depleted). Further, the society is able to maintain consumption based on these resources potentially indefinitely when taken on its own terms. In this sense, it illustrates a locally sustainable system. On the other hand the case also shows that the same system is not resilient to the shock of changing outside opportunities, especially for youth. Indeed, emigration appears to be a major threat endangering the culture, as the study reports that there are no young seine fishermen at all in the community. Extinction is, then, a real threat when the shock of exposure occurs despite the sustainability of the system when not subjected to this shock.

b. Discounting: Resilience and Weight on the Short Term

Our evaluation of resilience depends on the term of our analysis. Referring to our GDP example and postulating a set of growth trajectories illustrated in the figure, below, we have systems A and D which are differently resilient, but neither is necessarily more resilient than the other: our answer depends on whether resilience is defined as the depth of the dip in performance or the total discounted cost incurred during the dip. Further, A and D have the same long run performance so that in the long term there is little difference between the two. B is subject to more frequent dips (perhaps because it is susceptible to a greater variety of shocks but is more resilient to each one) so that it is, again, "differently" resilient. B also has lower long run performance. C suffers from no short term shocks at all but has the lowest long run performance. Hence, it is the most resilient of the systems in the short term, but has the worst long run performance characteristics. Indeed, if a minimum level of performance is necessary for sustainability, this system may not be sustainable at all.

For policy purposes, we need some basis for discussion to decide whether A, B, C or D would be the optimal policy or design for our system.



A and D achieve the same final performance level, but their paths of adjustment to shock differ (short and sharp with A, much more sustained depression in D). B is quite resilient to shocks, but is susceptible to shocks more frequently so that it is probably susceptible to shocks that A and D do not feel but when it does feel a shock it recovers quickly. C is not affected by shocks at all, but has a low long run performance potential. Its sustainability is questionable if this performance is low enough.

Figure 1

We need to have a guide on how much weight to allocate to the shorter or longer term in order to make such a policy choice. When we review the variety of definitions of resilience in the literature, however, we note that some focus purely on the long term viability of a system while others include some weight on shorter term viability. For example, extinction as opposed to short term fluctuations is the focus of the definition of Holling, 1973. Indeed, in this sense, the definition is more in line with what appears as sustainability in the economics literature and would single out trajectory C as perhaps the least "resilient" despite its short term stability. On the other hand, Perrings', 2006, definition of resilience as "the ability of the system to withstand either market or environmental shocks without losing the capacity to allocate resources efficiently or to deliver essential services" leaves the term of analysis indeterminant. Clearly, however, we need a more precise sense of the weight that the shorter term will play in our decision process if we are to choose among policies leading to paths A, B, C, or D.

To resolve this, we note that under *any* positive weight given to current generations, we are potentially concerned with both long and short term performance. Indeed, if the time to recovery is infinite, then the system is neither sustainable nor resilient from the point of view of the actors taking the decision today. This just states the implicit current state of play in policy: for example, all current policy suggestions on human population control as a means towards sustainable or resilient ecological systems takes current human well-being and human rights into account as a matter of law. This does not filter through into all the literature on the definition of resilience, however, nor does it filter through to a precise weight to apply in economic analysis to shorter versus longer term policy. Indeed, economic analysis does not provide the tools to specify a single "right" discount rate. Instead, the precise weight must be the subject of discussions that establish a framework for resilience policy and can only be the fruit of open consultation. We are left, then, with little direction from the literature but with *implicit* weight given to current generations' well being in practice. What is needed is an *explicit* time frame given to policy so that all participants are on the same page in developing policy responses.

Holling and others draw a distinction between stability and resilience, where stability refers to (short term) fluctuations of a system such as the system's population, whereas resilience refers to the (long term) persistence of the ecosystem itself to retain its functional characteristics. Hence, a resilient system can still fluctuate greatly in the short term where we have low stability in the face of long term resilience. Common and Perrings, 1992, translate this distinction into economic modelling, suggesting that stability refers to fluctuations in *variables* and resilience refers to constant *parameters* of a system. Our view is that this distinction is not crucial to economic modelling. If we accept the Common and Perrings interpretation then this distinction is actually just a modelling choice: it is up to the modeller to determine what will be parameterised and what will be left as variable in *any* economic study. The choice is determined by the focus of the study: what is left variable usually is the focus of the model and the behaviour of that variable is the reason for conducting the modelling exercise. If we are interested in the characteristics or function of a system, as we might be in a resilience study à la Holling, then the stability of variables relating to the system's integrity and

functioning would be the focus of our modelling (and would appropriately be left as variable rather than parameterised). Hence, stability and resilience are not distinct *concepts* in Hollings' sense in economic modelling and need not be made. What is distinct is whether one focuses on the short or the long term or on both, as we discussed above. Economics itself is agnostic about the focus, potentially allowing for a weight to be placed on either term and potentially allowing any aspect of a system to be a variable of interest. The role of government is clear, however, in that it is the facilitator of the process that determines the time frame to be used in resilience policy based on local preferences and social welfare.

c. Performance versus Structural Evaluation

Our example, above, of GDP measurement is an interpretation of resilience based on an output or performance measure rather than on the structural features of the system underlying that measure. We defined "recovery" in a way that leaves our measure of systemic "health" (GDP per capita in the example) at its original level but allows the underlying system to look rather different after the shock: while the performance measure may have recovered to earlier levels, that performance may be derived from an evolved social system. This performance view is consistent with the idea of introducing important changes to societies to improve the stability of their livelihoods via projects to diversify food sourcing methods or energy production.

On the other hand, Walker *et al*, 2004, have defined resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change, so as to retain essentially the same function, structure, identity and feedbacks." Hence, this definition encompasses the stability of a structure, rather than focus purely on the performance outcomes of that structure.

Indeed, looking across the case studies, one sees that "ecoculture resilience" has been understood in a variety of ways. Sedlmayer and Boehm, 2011, Accorigi, 2011, and Bunting *et al*, 2011, consider environmental management projects that build maintenance of consumption and income in the face of threats such as oil price shocks. These implicitly consider resilience as a measure of human performance (consumption, in particular). Vihar and Doon, 2011, Cullen-Unsworth, 2011, and

Hayashi, 2011, view (ecoculture) resilience as persistence of cultural properties that represent the combined works of man and nature. These three studies view resilience as the maintenance of a co-evolving system of humans and their environment, although both take a performance measure, the well-being of the humans, as *one* outcome of interest. Qingwen and Li, 2011, and aspects of Clifton, 2011, examine more narrowly ecological resilience, and focus on the importance of knowledge as a means of adaptation to shock rather than on resilience *per se*. Finally, Mustonen, 2011, focuses on a particular technology (seine fishing), a structural characteristic. A common thread is that resilience refers to maintenance of some variable, but this may be a performance measure or the structure of a system or sub-system or even a mix of both. Hence, we need to decide for policy discussion whether resilience will refer to a performance or a structural outcome or whether positive weight will be placed on both.

The case study of Uttarakhand (Vihar and Doon, 2011) points to an interesting subtlety of this choice. Two valleys faced with climate change are contrasted, one of which has moved away from agriculture into other income sources, modified agricultural practices significantly, and exploited transport routes to integrate into the rest of Indian society to effect a large scale transformation in the livelihood of the valley. The other valley has kept its traditional crops and agrarian focus but draws on government support to maintain this structure with acceptable levels of consumption. Which of these valleys has been more resilient? In this case, the authors point out that one would not want to identify societies that adapt significantly to change as non-resilient. In other words, we should not interpret the definition of resilience as implying that the system itself should remain unchanged. Surely the ability of a system to *change itself* without unnecessary upheavals in the face of external shock must be part of any sensible notion of resilience. One would like a definition of resilience to include those societies that are plastic, as long as the change occurs in an orderly and incremental fashion[1]. On the other hand, if we define the function of the society as being anything other than simply maintaining the well-being of the

[1] Notice that this is related to the discussion of separate concepts of adaptability and transferability in Walker *et al* (2004). Adaptability as a separate concept is particularly well illustrated in the study by Mustonen *et al* (2011). Notice that the knowledge base – its extent and the technology by which it is accumulated and maintained -- is illustrated in a number of the case studies, including Mustonen *et al*, Mustonen, and Clifton, all 2011. Knowledge is viewed as the wellspring of adaptability in this optic.

populous, then one of these two valleys may have lost its "function" by essentially extinguishing its previous ecoculture. *Any* weight placed on structure, often introduced via an attempt to capture the "function" of a society, may tend to make a rigid response look more resilient than a large adaptation.

The authors of this case study discuss well-being measures of the populations of the two valleys, pointing out that the valley with the rigid response also is the valley with the lower levels of well-being (measured by a variety of performance outcomes including satisfaction levels as well as development measures). Indeed, economic modelling, based as it is on a utilitarian philosophy, usually takes performance measures as the outcome of interest. In this sense, economics takes performance as "trumping" any functional or structural characteristic. Taking a performance measure as the basis for evaluation automatically incorporates adaptability into an economic study of resilience although some outcomes of interest, such as distributional issues, could be incorporated into performance but generally are not. The argument to place full weight on performance measures, whatever those are, is, then, that any weight given to structural measures rules out large adaptations that may be desirable responses to certain types of shock.

An alternative method of incorporating adaptability into the analysis is presented by Perrings, 1998, who suggests that a system is resilient if it maintains its basic organisation in the face of exogenous shocks without undergoing "catastrophic, discontinuous change". While this definition places more emphasis on structure than might be consistent with an implementation of adaptability, it does add to the definition that the *nature* of the change may be the determinant of resilience, rather than the *presence* of change. Note that the nature of change can be accommodated with an output measure, as measuring whether change is catastrophic or not would necessarily be related to the cost of change, both psychological and physical. Hence, the cost of change can be viewed as an alternative formulation of performance. In terms of measuring the cost of change, in the simple GDP example presented above, the discounted value of GDP per capita lost during the period of recovery was a natural measure incorporating both the speed of recovery and the consequences of failure of a system.

The study of Greenland by Hayashi, 2011, and the study of Bangladesh by Bunting *et al*, 2011, identify a role for governmental bodies in the introduction of new features that allow the society to adapt in the face of environmental change. In other words, one primary role for government is to identify changes and ensure that they do not occur in a catastrophic manner. The interventions in the cases take the form of introducing new techniques of earning livelihood (techniques of hunting new species in the case of Greenland and techniques in agriculture and aquaculture in the case of Bangladesh). Clifton, 2011, identifies the government's role in sedentarisation of the Bajau, intended as a way of integrating these basically nomadic people into the mainstream of Indonesian society, but instead resulting in significant social exclusion.

Which performance measure is more appropriate depends in part on the question policy wishes to answer with the resilience study. We answer the question of "If we wish to maintain performance under stress, in what way and by how much will society need to change?" or "If we subject the society to stress, what will the cumulative cost be before the society reaches a new state of stability in both performance and structure?" then a cost of adjustment outcome would be appropriate. If we wish to answer "If we subject a given societal structure to stress, by how much will performance suffer?" then we would take the performance of our measure of well-being as our focus.

d. A Synthesis

In sum, we are faced with a variety of points that need to be specified in order to develop resilience policy: we need to define a term of analysis, outcome measures that we target, and a measure of the nature of change. One way to achieve this could be to require that any definition of resilience comprise three elements: what one cares about (i.e. what is worth preserving or returning to), the type of shock with respect to which resilience is assessed, and a metric telling us how effectively the system maintains or returns to what one cares about after a shock is experienced. For example, one might care about infant mortality, study resilience with respect to tsunamis, and measure the performance of the system in terms of the loss of well-being (e.g. extra infant mortality) over the period required to return to what has been defined as a "recovery level". The measure could include an element of the cost of abrupt change in order to

incorporate the idea that the nature of change – catastrophic or gradual – affects whether we consider a system resilient or not.

A distinction of this approach is that we place considerable emphasis on identifying the source(s) of the shock(s). Identifying the source of the shock is surprisingly rare in applied work on resilience. It is our focus because we wish to take a management perspective on the ecoculture, rather than an *ex post* perspective: if we wish to be able to manage the system so as to generate resilience, we need to know which measures to undertake. Since the appropriate measures tend to be specific to the type of shock, we need to be able to prioritise. We return to methods of prioritising later in the paper. For the moment, we merely signal the importance of the source of the shock as part of the definitional framework.

Further, notice that the integrity of the system itself will play no role in our assessment of resilience, although the cost of change does. Indeed, this approach implies that we should only care about retaining the "function, structure, identity and feedbacks" of the system *if* these have (performance) value in themselves. In other words, the list of what one cares about as outcome measures defines the list of elements we must return to: the precise elements are not integral to the definition itself and will change depending on the priorities and preferences of the region itself. The definition is *a priori* agnostic about how flexible or rigid we are in defining what we are to return to compared to the original "base" structure we evaluate. As such, it hopefully captures a broad spectrum of interpretations of what "resilience" can mean.

Applying this approach to a particular definition of resilience, consider the intriguing economic study of regional resilience conducted by Musson, 2011. She defines regional resilience for her study to mean "maintaining or enhancing the attractiveness of [a] territory [to private firms]" as a means of generating sustainable development. This definition has the advantage that it is implementable and clear for policy makers what method is to be used to achieve resilience. On the other hand, it does not specify the term of analysis, the (outcome) measure of sustainability for policy evaluation, the cost of change to be considered, or the type of shock that could affect attractiveness or sustainability. In the interviews conducted of business leaders later in the study, the paper points out that uncertainty about the sense in which sustainability is meant, the

cost of alternative policies, and the type of shock to be faced colour the responses. Indeed, the responses are difficult to compare and analyse partly due to this. A similar lack of clarity dogs the case studies that are the data for this paper. What we attempt is a template to ensure clarity of implementation so that more can be gleaned from these resilience analyses.

II. Multiple Equilibria, Threshold Effects and Path Dependence

If we push our definition further to consider how to implement mathematically a definition of "resilience", we find two additional concerns: those of threshold effects and path dependence. Even if we do not wish to construct a mathematical model, policy discussion surrounding resilience will need to address these concerns in order to obtain desirable consequences from policy interventions.

Most economic modelling is equilibrium modelling. Equilibrium is, roughly speaking, the behaviour that a system "tends towards" if there are no shocks. If a system has a stable equilibrium, then it will tend to move back towards the same behaviour even after a shock. Hence, stability could be interpreted as a general mathematical implementation of the concept of "resilience", which can be translated directly into formal economic modelling.

This interpretation would be too hasty, however. Another important aspect of economic equilibrium is that of uniqueness. An economic or social system may not have a single equilibrium. For example, economists have studied so called "poverty traps" where a country may get caught in a "bad equilibrium" even though the underlying fundamentals are also compatible with a "good equilibrium" where the economy escapes poverty into development. Hence, a single social structure can be compatible with several different behavioural and performance outcomes. The social system can be at equilibrium in several states, but one of the states is more desirable from a performance standpoint. As each of these equilibria is stable, the system would always return to its initial equilibrium following small external shocks. On the other

hand, a sufficiently large shock can push a system from one equilibrium to the other, making the system return not to the original equilibrium but to a new state[2].

If we stick to a narrow interpretation of "resilience as stability of the original equilibrium", we have several problems. First, a move in response to stress from the less desirable to the more desirable equilibrium could be seen as a lack of resilience. Such an approach would not make much sense if we wish to allow for improved performance as an outcome for a resilient society. This suggests that resilience should not be defined in terms of a specific equilibrium but in terms of some measure of performance that can be compared across equilibria, where behaviour can differ considerably between the equilibria. This allows upwards movements in performance to be distinguished from downward movements, with resilience policy aiming at more restriction of downward movement. This is consistent with the general approach implicitly taken by the case studies in this project: the authors and the members of the societies studied do not seem to be concerned that their lives are improving too much. Rather, they are concerned solely with reductions in well-being.

Multiple equilibria can also mean that a system might be highly resilient to small shocks but very non-resilient to large shocks. This could be the case if a system exhibited threshold effects (so that small shocks had little effect on the equilibrium but large shocks caused the equilibrium to change). Both of these features are common in economic models of the effects of environmental change[3] as well as policy discussions of climate change. For example, the effects for Europe of a cessation of the Gulf Stream accompanying a global temperature increase could be dramatically different from the effects of a change in global temperature without a Gulf Stream effect. As part of the specification of the *source* of the shock on a system that we discussed above, we should then add that any specification of resilience must include the *magnitude* of the shock since policies may be specific to magnitudes as

[2] This is similar to the Walker *et al*, 2004, concept of the "latitude" of a system: the degree to which it can be perturbed and still return to the original state. The difference between latitude and our point about stability is our emphasis that the original state is not necessarily the desirable one: our view is that the concern about "latitude" is not symmetric: policy wishes to restrict downward and not upward movements.

[3] See for example, Wu *et al*, 2000, where sufficient cumulative conservation is necessary to overcome threshold effects to obtain desirable environmental enhancement. See Perrings, 2006, for discussion of the dimensions of resilience and the role of threshold effects.

well. We will return specifically to the distinction between resilience to large versus small shocks when we discuss insurance, below.

As Bruneau *et al*, 2003, point out, a further important issue with multiple equilibria is the speed and path of adjustment of a system from one equilibrium to another, not just the change in equilibrium itself. In other words, the adjustment process itself may have desirable or undesirable features, regardless of the final performance level at the equilibria. The first concern echoes Perrings', 1998, concerns outlined above, that the features of this adjustment path can affect the type of policy change we recommend, as the transition period from one equilibrium to another might need to be supported with policies to ease the adverse performance consequences of change. A second and more novel concern about adjustment is that the equilibrium of a system may be path-dependent, where decisions from the past may limit the features of the equilibrium one can have in the future. In other words, the transition process itself can affect the nature of the equilibrium that is finally attained, making the final state sensitive to inter-rim decisions[4]. Hence, any policy decision on how to intervene needs to evaluate the short term conditions that can shape long term outcomes: even if one takes a very long term perspective on resilience, then, one cannot ignore short term behaviour in any sense.

Summarising, then, a resilience study needs to be sensitive to the presence of multiple equilibria. While focussing on performance measures can overcome certain problems with multiple equilibria, threshold effects may imply that distinct analyses for large and small shocks must be conducted. Finally, path dependence can imply that short term analysis must form part of the study, as the short term behaviour and policies can limit long term attainable states.

III. Measuring Resilience: Defining Goals and Sources of Shocks

If we take the performance perspective discussed above in order to measure resilience we need some standard of performance (or "health") to which we wish our system to

[4] See, for example, Havrylyshyn, 2001, and citations within.

return after a shock. The case studies in this project illustrate the possibility of using single-dimensional economic measures (such as income or consumption, as in Sedlmayer and Boehm, 2011, or Accorigi, 2011) or environmental measures (as in Qingwen and Li, 2011). Such an approach could be misleading, however, as societal performance may be highly multidimensional.

Many multi-dimensional indices have been proposed. For example, the Human Development Index, used by the United Nations Development Programme as a measure of well-being, includes measurements of real income, lifespan and education[5]. The HDI index is relatively well correlated with subjective well-being for a broad variety of countries[6], where subjective well-being has been measured in a variety of ways. Reviewing a large number of papers, Blanchflower and Oswald, 2011, broadly suggest that subjective well-being defined as "happiness" can be measured as a function of age, gender, income, education, marital status, diet, other personal characteristics, regional characteristics, and country characteristics. Hence, happiness is a composite measure reflecting a large number of societal features. High levels of measured happiness also correlate relatively well with low societal inequality, high social capital and strong friendship networks, low unemployment and inflation, high levels of democracy and democratic participation, high levels of trust, strong welfare states and public spending and low pollution[7].

Blanchflower and Oswald point out, however, that no clear *causal* link has been established between societal correlates and happiness. In other words, while happiness seems to be related to whether one eats a diet rich in fruit and vegetables, it is not clear that forcing us all to become vegetarians would actually cause our measured happiness to rise. Hence, the point here is two fold. First, the performance measure we choose will determine how systems appear to fare in terms of resilience. Second, since societal characteristics relate to well-being as correlations and not causations, it is not clear how we should "engineer society" in order to obtain higher resilience

[5] (See http://hdr.undp.org/en/statistics/hdi/ for more detail).
[6] There is rough positive correlation between the human development index and some measures of subjective well-being. See Johnson, 2010 (figure 2). Some discussion complementary to Blanchflower and Oswald, 2011, on the measurement of subjective well-being also is available in this paper.
[7] Blanchflower and Oswald (2008) have used blood pressure measurements to attempt to find a good and easily measurable proxy for levels of happiness.

based on such a measure. Indeed, for policy purposes the choice of an index such as happiness may not be very useful: if we cannot control it by clear policy levers, then its use in a study will not yield any useful policy recommendations.

Bruneau *et al*, 2003, comment that the measure of resilience can potentially be multi-dimensional, where they consider reduced probability of failure of a system, reduced consequences of failures -- should they occur -- and reduced time to recover from failure as three dimensions. In practice, then, we might measure "resilience" by an index that weighs each aspect of resilience and combines them into an overall aggregate. We might, for example, measure performance and structural change and the degree of both as well as some concept of the dislocation that has occurred along the adjustment path. Each receives a weight, determined by preferences of the region, and as diagnosed by the policy-maker. Alternatively, we might care about only a single aspect, such as social wellbeing, but that aspect might not be the same in all societies or in all time periods. For example, while health concerns were the sole motivating force behind the Clean Air Act in the United States in the early 1970s, current debate on this legislation takes into account other considerations. In other words, some dimensions might receive a weight of zero, but this weight may change over time as policy revisions occur and societal preferences change. Clearly, the choice of weights can also affect whether a society appears resilient or not.

Note that local resilience policy may have substantial externalities to other regions. This means that the choice of preference of one region may constrain the choices available to another. Where such externalities exist, coordinated choice across regions is appropriate in both the choice of goals and weights. To return to the case of clean air, externalities can be far more significant than in the case of land contamination. Hence, the degree of externalities determines the degree of regional control over resilience policy, and will tend to vary with the type of variable resilience policy is addressing. There is no "one size fits all" recommendation on where resilience policy should be seated.

The other crucial input we need for our measurement of resilience is some measure of the type of threat faced by a community so that we know the nature of the shocks to which the community needs to be resilient. Let us take the example of organic food.

There may be a presumption that, because it reduces a community's ecological footprint, moving from "modern" to more traditional or organic methods also increases "resilience". This might or might not be true depending on the *mechanism* through which organic food promotes resilience. For example, one could argue that, by reducing dependence on chemical products that are imported, organic farming makes the community more resilient to unexpected shocks in international transport prices, changes in exchange rates, or even politically motivated embargoes. On the other hand it might be that organic farming is actually more vulnerable to sudden infestations of pests that are, for example, new to a region. Hence while organic farming could perform well in the face of oil price shocks, it could perform poorly in the face of the appearance of a new species due to climate change. The point is that to the extent that a policy is specific to certain types of threat, any given policy has the potential drawback of creating "perverse resilience" in the sense of creating a society that is very stable in one sense, which could be an advantage in response to certain threats but a disadvantage when faced with other circumstances. Clifton's 2011 study of the Bajau proposes the term "perverse resilience", in fact, when referring to the society's focus on subsistence in the face of a need to undertake marine management for the longer term in order to sustain the sea's ability to support their way of life.

In order to perform social engineering for -- or to simply evaluate -- resilience, we need some way of combining these mechanisms into a global evaluation of a policy that may affect resilience with respect to different types of shocks and through several mechanisms at once. This is necessary because policy-makers face the daunting task of deciding on which way we need to organise our society before knowing exactly which threats we will face in the future. An index of the threats likely to face a community, weighted by their probabilities would be one approach to this.

Of course the probabilities would need to be assessed. Accorigi *et al*, 2009, aptly summarises a wide variety of techniques to put rough numbers on these probabilities, incorporating a variety of stakeholders. A key point in Accorigi et al's discussion is how complex, fragile, time consuming and costly these techniques are to implement. If one is serious about evaluating resilience of a society, this is a venture that takes time and resources. Indeed, one of the points one could draw from their paper is that the time and resource constraints accompanying real policy debate often do not allow

for these techniques to be implemented in a full or desirable way. Given how broad the concept of resilience is, how complex it is to evaluate, and the likely lack of agreement on measures and goals of resilience analyses one could be sceptical about whether any quantitative evaluation of resilience relying on these techniques would be conducted in general in any more than a cynical way[8]. Recalling the Musson, 2011, study cited above, qualitative techniques may be more enlightening but only if the framing of the resilience issue is sufficiently well-defined.

On a more positive and perhaps constructive note, a point that is not emphasised in Accorigi's review is the role of real options analysis in such quantitative evaluations as a way of incorporating policy responses to small probability but catastrophic events[9]. As small probability catastrophic events may be of particular concern in resilience work, any quantitative analysis would be well-advised to exploit such techniques. As has been pointed out in the literature, real options analysis has the qualitative effect of introducing precautionary concerns into policy evaluation.

IV. Governance

Suppose that, using Accorigi's techniques for organising public debate and defining preferences, we have decided on the question we wish to ask of our resilience study, the resultant definition of resilience and the consequent performance standards we wish to use to judge the system, and we have identified the likely sources of shocks and the term of analysis. What sort of policy levers will we likely need to use to manage resilience of a society? Can economic theory combined with the case studies give us a hint of the aspects of society that might generate resilience or reduce resilience? These aspects would form input to the construction of a model and a policy response for resilience. To use the terminology of the literature, while Walker *et* al, 2004, specify adaptability and transferability as "precursors" of resilience, can economic analysis help us to be more specific about the sources of these precursors? How would the contribution of economics compare to and add to the discussion from other social sciences?

[8] Accorigi et al (2009) chapters 2-4 particularly go through stakeholder analysis, methods of achieving participation at the local level, and methods of building scenarios. Chapter 5 goes through evaluation techniques, including computable general equilibrium and cost benefit analysis.
[9] See Perman, 2003, for discussion.

The economic approach to resilience would share many common themes with the analysis of specialists from other fields. In particular, any microeconomic analysis of resilience would put significant emphasis on the issue of *governance*. Hence the economic and social institutions of the affected communities – whether formal or informal – are of the utmost importance in assessing their resilience.

Within the broad area of governance, there are several dimensions that affect resilience particularly and have been themes in the economics literature. First, as a general principle, there will be a trade-off between centralisation and decentralisation: centralisation allows for better coordination of the community's reaction but, especially under some types of shocks like natural disasters, it suffers when communication networks break down so that assimilating locally relevant information becomes time consuming. This trade off already suggests that different types of governance confer greater resilience to different types of shocks. For example, one might believe that decentralised systems would perform better (initially at least) in case of localised natural disasters, while a more centralised system might be better equipped to deal with a widescale crisis. The reason for this is several-fold. One, already mentioned, is that decision makers need the complete information to tailor their decisions to the actual circumstances they face. Another is that the two types of crises have different contagion properties, which also must be managed: a local natural disaster might be contained quite readily if each region was self-sufficient. Where contagion occurs rapidly due to connectedness of regions, a centralised response system can control the broader effects quickly as different regions can be coordinated. Clifton's 2011 Bajau study points to the advantages and disadvantages of the insular nature of the Bajau community in the face of various threats. Specifically, in the face of the generalised threat of environmental (marine) degradation, there is an inability to mobilise generally to incorporate external ideas that would allow the community to create a quick and effective response. Finally, when responding to a widespread threat, a hierarchical system can be quicker than a decentralised or otherwise egalitarian system. Again, the Bajau study cites egalitarianism as creating a barrier to both a quick and effective response to an external and widespread threat to the marine environment. Supporting a point we

made earlier, these suggest that connections between regions in resilience decision-making and policy need to be shock-specific and multi-level.

Second, there would be a similar trade-off between rigid social/economic institutions, which are good in ensuring commitment to certain fixed goals or values, and more flexible ones that might be better at adaptation to unusual or unanticipated circumstances. Indeed, one of the issues mentioned in the three northern case studies that underlie this paper (Hayashi, Mustonen et al, and Mustonen, all 2011) as well as the Bhaghirathi valley case study (Vihar and Doon, 2011) is that the threat facing each of these communities is the unpredictability and novelty of weather patterns created by climate change. The system in place to respond to threats in each case is an oral tradition rooted in experience-based knowledge, which equips these communities well to uphold their values in the face of threats that have been encountered before, but does less well in equipping the group to face novel challenges. The method of incorporating a wider set of tools into the knowledge base is weak, creating lack of flexibility of response, even though the existing system is both well-tailored and sufficiently flexible to create resilience to historical threats. Again, no "one size fits all" recommendation emerges: depending on the type of threat a relatively rigid and "closed" system or a rather flexible and "open" one is appropriate. A multi-level response is then indicated.

a. Local Ownership and Property Rights

Interestingly, the case studies underlying this paper emphasise a *particular* governance structure fairly consistently: that of self-determination and local ownership and control of resources. The primacy of ownership and control and its ability to generate efficient outcomes in a decentralised way without government intervention receives support from the economic literature based on two theoretical concepts: the Coase Theorem suggests that decisions on how resources should be managed can be decentralised to individual private parties and will lead to efficient use of the resource (i.e. use that maximizes the resources net benefits, taken to be defined broadly to include monetary and non-monetary benefits); Principal-Agent theory suggests that maximizing benefits can require delegating power as well as ownership to a party that internalizes the full set of benefits and information about a

resource. Both the Coase Theorem and Principal-Agent theory do recommend government intervention in some circumstances, so that we can use both theories to diagnose why and when government intervention could be needed.

First, consider local ownership – in other words decentralisation of the decisions on how to manage local resources -- as a mechanism to achieve resilience, or more generally to achieve some target in desired resource management. In a case where use of a resource by one party can degrade or deplete the resource available to other parties, or where the resource is a public good, the resource tends to be subject to over-use when it is not wholly owned by a private party. For example, if a fishery can be exploited by multiple parties, each of whom extracts from the fishery so as to only take into account its own private benefits, then that fishery is likely to be depleted: each party will not tend to take into account the damage its own fishing does to the stocks of fish available to others, including the future beneficiaries of the fishery. Returning to the cases, the lack of a sense of ownership by the Bajau led them to share their marine environment fully with commercial fishing boats. Over-fishing has resulted, as the commercial boats do not take fully into account the costs their harvest imposes on the Bajau's ability to harvest using their traditional techniques and the Bajau do not take fully into account their own harvest's effects on the commercial take. Indeed, without clear allocation of ownership or even a clear concept of ownership among the Bajau, it is not obvious how such externalities could be taken into account by the parties: no basis for discussion exists between the parties at present.

On the other hand, suppose that one party were given full control of fishing rights in the fishery. If one party wholly own the resource – potentially in perpetuity-- then that party has full incentive to extract the maximum value, whether this is value in terms of current earnings, future earnings, enjoyment, extraction of a livelihood, or any other monetary or non-monetary benefit from the resource. As the private party stands to benefit fully from the resource, now and in the future, it also has full incentive to manage that resource for the current and future periods. Full ownership has greater benefits than this, however. When the private party has whole ownership, it also has full control of the resource and access to it. Hence, whole ownership aligns the incentive of the owning party with maximizing the value of the resource; it

also creates the ability to manage both resource use and access so as to attain that maximum value. In this sense, decentralising management and ownership to the local group can work well to ensure that the resource is not exhausted and is also managed to maximise its livelihood benefits.

How this ownership right is used is, however, crucial to whether or not full value is extracted. Suppose that we gave full ownership to the Bajau who, as was stated in the case in this project, have little sense of what property rights mean. It is not at all clear that they would enforce any exclusion of others with or without compensation, nor is it clear that they have sufficient knowledge of the usual institutions for enforcing property rights to be able to enforce them in any realistic manner. In other words, ownership rights would only be useful to the Bajau if they enforced those rights in the presence of continued threats from commercial fleets. If the Bajau are unlikely to enforce their rights, then giving them ownership as a way of ensuring wise management of the resource might not be very useful.

A further issue is that the case states that the interests of the Bajau are oriented towards current extraction of fish for subsistence, in the face of a rising population. In other words, while the Bajau live in family groups that would normally allow current generations to understand and take into account fully the needs of future generations, it appears that population pressures are resulting in a poor representation of future generations' interests in the preferences of today's Bajau. Hence, a relevant constituency in the decision process of how to manage the resources appears poorly represented under the current organisation. Further, scientific marine management techniques that could help to ensure similar opportunities as today's population enjoy in marine exploitation appear not to be accessible for the Bajau. In this sense, even if they did put primacy on future generations' needs, it is not clear that they have the skills necessary to do this. Under these conditions – lack of skills and lack of weight placed on future generations' needs, it is not clear that the fishery will be maintained productive in perpetuity. Hence, it is not clear that ownership rights allocated to the Bajau resolves the resource management problem viewed as a bargaining problem where the interests of future Bajau should be taken into account.

The Bajau face a further problem in potential negotiations over the use of marine resources, even assuming that there were no problem with the concept of ownership: they organise in insular groups that do not coordinate well across groups. To the extent that commercial fishing is concentrated in a relatively small set of hands – or at least is able to organise its interests -- while the Bajau are a dispersed and uncoordinated set of independent family groups, the bargaining that the Bajau conduct would likely be ineffective. This is because each individual family group would have an incentive to "let others do the negotiating" so as to reap the benefits of negotiations without necessarily being the party to exert the effort to learn enough to conduct the negotiations. Further, each individual group would be unlikely to represent the interests of the entire Bajau community. Both of these problems with a dispersed set of interests could cause bargaining inefficiencies that would reduce the value that the Bajau could extract from local ownership.

Moving on to other cases, the Mustonen et al's 2011 study of the Puruvesi fishermen states that this group has very clear ideas of ownership, so at least this concern would not be the same as in the case of the Bajau. The case suggests, however, that this group also does not seem to have been very effective at negotiating their way to resource use that preserves their cultural and livelihood value. A problem here could be that the fishermen in question may not be very skilled or informed negotiators compared to other groups that wish to have access to the same resources for their own purposes. In order for ownership to work to create efficiency, bargaining and negotiations have to be efficient as well. If information about the use to which the resource will be put by all parties is not available or understood by the different parties, for example if information on pollution consequences of certain activities is not available to local groups, then bargaining may not occur efficiently. Again, ownership does not work on its own to ensure that local groups extract full value from the resource in such a case, as the bargaining that should lead to extracting full value happens subject to incomplete or asymmetric information that can allow parties to misrepresent their own interests so as to skew the bargaining results in their favour.

Hence, the Bajau and Puruvesi studies suggest that decentralisation of the resource management to local groups is unlikely on its own to solve the resource management problem: the local groups may not be able to enforce their ownership rights due to

lack of information or lack of understanding, the local group may be unable to organise so as to bargain effectively, and in any case the interests of future generations may not be guaranteed under decentralisation. Finally, even if the society in question has a clear sense of ownership and institutions to enforce ownership rights, the Coase Theorem only holds when negotiations can be conducted with low transactions costs. If property rights are too dispersed, large negotiation costs can result whenever resource use issues arise since many parties need to be assembled to access resource rights. Hence, how much decentralisation occurs depends in part on how much can be achieved whilst still allowing low enough negotiation costs that efficient resource exploitation is possible in a Coasian manner[10].

Addressing these problems, Cullen-Unsworth and Wallace's 2011 study of the Australian aborigines in Queensland suggests a role for government in creating a structure for ensuring that ownership is exploited so as to generate value efficiently. In the Queensland case, informed representatives work with the local group to ensure that the group speaks with a single voice in negotiations, and has the information and skills necessary to be effective negotiators. Resources are provided so that ownership rights can be enforced via the court system, with the advisors to the tribe as guides through this process. Negotiations occur at the tribal level so that few points of contact exist for outsiders, minimising transaction costs. In this sense, the Queensland case maps out a system that addresses the issues above of (1) understanding and enforcement of property rights, (2) informed and skilled (low cost) bargaining, (3) the need for the local group to speak with a unified voice, and (4) the scientific support needed to manage the resource for current and future generations. Hence, if one wants ownership rights to transfer value to local groups, a comprehensive support system as in this case may be necessary for such a system to work. It is clear from the case that such a complete system requires time and significant resources to establish, and also requires the trust of local groups. These are demanding conditions to transfer to the other cases in this study: even if the system functions very efficiently once implemented, the cost, time, and skill

[10] Indeed, much recent literature has developed on the "anticommons" – cases where overlapping property rights are decentralised to the point that markets become inefficient at generating value. Pooling of rights is one solution to this problem, consistent with the Queensland case discussed in the text. For a seminal exposition of "anticommons", see Heller and Eisenberg (1998).

necessary to establish it creates a significant *ex ante* opportunity cost to this type of endeavor.

The Coase theorem suggests that when a system is created, perhaps on the model of the Queensland case, to ensure efficient bargaining it does not matter whether the local groups hold full ownership of the resource or whether some external private body does. In other words, once all parties have a fully informed and effective "seat" at the bargaining table, while who owns the resource matters to how the value is split it does not matter to how much value is created in total. Hence, ownership of the waters on which the Puruvesi or the Bajau do their fishing could be held by a commercial interest, and the land on which the aborigines live could be held by a private entity -- full value should still result, but the proportion of this value going to the local group could change. Unfortunately, economic analysis does not give a definitive answer on the optimality of the various possible distributions. Indeed, one could argue that an alternative solution to generating value from resources is to have some support for local groups in bargaining, but otherwise not to transfer ownership to the local groups.

If the value of the resource were purely monetary, then this argument could perhaps hold true. However, maintenance of the cultural heritage of the local group is one of the sources of value in all the cases that form the data for this paper. If this value were purely a benefit to the local group, then the Coase theorem suggests that as long as bargaining is efficient, this value would still be maximised regardless of who owns the resource. On the other hand, these cultural values are, in themselves, a resource is available to many people beyond the local group that creates them. This "public good" aspect of cultural rights suggests that ownership by a private entity other than the local group would likely not result in maximising the cultural value of the resource since the cultural heritage value would remain a public good whoever owns the resources that generate them. Hence, cultural heritage as a public good is an argument that suggests local ownership with support is a better solution to maximising the value "broadly understood" from the resources than ownership by some other outside party. Indeed, the Puruvesi and Bajau cases emphasise the problems of non-ownership by the local group in an environment with relatively little government support and cultural heritage issues.

b. Agency Issues

It should be emphasised that the solution proposed in the Queensland case is emphatically not a fully centralised solution. A common objection to full centralisation is that decentralised decisions tend be able to incorporate special circumstances that are known only at the local level. In other words, knowledge tends to be dispersed and difficult to pull together in complete form for any central authority. A benefit of decentralisation is precisely that local information can be taken into account more efficiently than it might be under fully centralised (for example, government) management.

This support for decision-making by agents that tend to possess better information than a central directing body is supported by a second strand of theory in the economic literature: Principal-Agent theory. In the case where a local group does not have full ownership and control of the resources it uses for its livelihood and to support its culture, such as the North Greenland case (Hayashi, 2011), or if it has ownership (or land rights) but does not have the resources to manage the resources itself, such as in the Queensland case (Cullen-Unsworth and Wallace, 2011), or if it simply wishes to delegate to another negotiator to minimise transactions costs or place management in the hands of the most capable party, it must rely -- to some degree -- on others to manage its resources for it. For example, imagine that the local group does own its resources (for example, its land) but does not have the expertise or resources to manage that land fully and so delegates this task to a government bureau or a private party. If the local group is poorly informed about the plans (or implications of the plans) for resource management by the body actually doing the management then the local group is likely to be poorly served by this arrangement. The reason is that the manager of the resources may not have exactly the same goals as the local group. For example, even if the manager is a government bureaucrat, if that bureaucrat is subject to influence by parties that would deplete the resource excessively then the manager can undertake such depletion for its own gain without full knowledge by the local group. Hence, the problem here is that, even with ownership by the local group, if management of the resource is conducted by a separate and independent body the local group's benefits may not be fully realized if

the local group does not have full information on the policies or implications of the policies undertaken by the manager. In such a "principal-agent" relationship there is a trade-off between control, which would ensure exploitation aimed at the local group's preferences albeit perhaps inefficiently exercised due to lack of expertise, and delegation, which ensures that those exploiting the resource have the required technical and commercial expertise to optimise exploitation but may do so to other purposes.

The usual solution to the principal-agent problem lies in either transfer of responsibility for management to the owner, or in aligning the incentives of the manager and the owner by means of a contract or judicious choice of manager. The contracts that aim to align incentives can get quite sophisticated, which creates another hurdle for local groups, as designing complex contracts can be an expensive proposition. Moreover, contracts only help alleviate the principal agent problem if they can be enforced. This presumes that some measure of the agent's performance can be adequately monitored and that conflicts would be resolved quickly and fairly by the local judiciary. As effective monitoring might require a formal training not available within the local ranks and the "governance structure" of the local judiciary might itself be inadequate to enforcement, delegation is likely to be less attractive. Perhaps this is why the case studies generally support both local ownership and local management of resources rather than management by any remote body. Rather, taking the Queensland case (Cullen-Unsworth and Wallace, 2011) as an example, the participation of remote bodies is primarily in terms of legal and informational support and advice rather than active decision making on how the resource is managed. Indeed, in his treatment of the trade-offs between centralised and decentralised management of resources using a combination of economic approaches, Farrell, 1987, recommends that centralised economic institutions such as government control and intervention, and decentralised institutions such as bargaining and ownership rights, be viewed both as complementary and as "checks and balances" on each other.

Of course, local ownership and management of a resource also implies that the local group's fortunes will be tied to some degree to that resource's value. In other words, with direct control and ownership may come an increased risk borne by the owner. Unless a stable stream of support is available from the resource, simple ownership

may not preserve the local group as a viable entity. Some form of diversification of livelihood, as emphasised by the North Greenland case (Hayashi, 2011) or the Bangladeshi case (Bunting et al, 2011), may be necessary to insure against such fluctuations in livelihood. Without some form of insurance against lean years or diversification of livelihood to provide a smooth consumption stream – plus some form of support in terms of how to manage the local resource so as to generate a livelihood that is likely to be resilient -- local ownership may not go far enough to ensure viable local cultures. We treat insurance issues specifically in the next section.

These are significant caveats, and often mean that self-determination is not enough on its own. In particular, if the local group lacks the tools, including the information, to manage their own resources fully, then other groups need to be brought in for assistance to the extent that decision making is delegated. This risks degradation of the resource unless the local group can monitor the actions of the manager and impose penalties if the resources are not managed properly. Independent monitoring is a possible solution for this problem, coupled with a system of awarding damages to the local group if their resources are not managed properly. Either those damages can be revealed via the courts or they can be taken into account by a bond, payable by the manager to the owners upon detection of mis-management.

None of the case studies used as data here appear to have a fully developed system of self-determination in the sense of both ownership and control or a system of agency with the sorts of supporting institutions and monitoring suggested here, although the Queensland case probably gets as close as any to a complete system in this sense. That case outlines an exceptionally complex and well-funded "partnership" system between the indigenous group and the Australian government. In the case, the indigenous group has obtained government funding for a set of "rangers" who perform as stewards -- informed and empowered spokespeople -- for the indigenous group, a system of involving indigenous people in the management structure alongside government representatives, and funding grants to support conservation activities. Even this system, however, does not extend to independent monitoring and damages in the case of mismanagement, at low resource cost. The system in that case appears to rely on the existing legal system for dispute resolution, which would be quite costly to use to this purpose. The system does not address as extensive a set of

conflicting interests as we find in some of the other cases (such as the Bajau case), where a stronger centralised intervention might be necessary. Finally, the resource demands to create and maintain such a system are substantial and may be beyond what other governments are willing to commit.

V. Risk and Insurance

To fully understand a community's response to a specific unexpected shock, economists would look at a number of dimensions that are commonly studied in other social sciences. For example, levels of trust and concepts of fairness are likely to be important determinant of the community's response, especially when more formal lines of authority and command are adversely affected by the shock. Similarly, social networks and other mechanisms through which the community deals with issues of risk and insurance would be examined. Finally, the ability of savings to absorb shocks would normally also is an area of interest. These threads have recently been combined into studies of risk sharing that bear upon resilience, as resilience could be conceived as the degree of "insurance" of a community against threats.

a. Savings and Insurance

A standard way of "insuring" against fluctuations in income is saving. Precautionary savings as a method of cushioning shocks is a standard strategy of individuals and households[11]. Insurance extends beyond savings, however, to a large number of methods of pooling risks via formal and informal insurance, including government-provided insurance as well as family or other social network support[12]. The effectiveness and design of these as means to assist regions to recover from disasters has been investigated extensively[13]. Insurance mechanisms deal with shocks by providing for savings and resources that can be transferred to areas or individuals that

[11] For example, see Kimball and Weil, 2009, and references therein.
[12] For example, see the discussion of the effectiveness of foreign aid in mitigating disasters in Bourgignon and Sundberg (2007).
[13] There is a huge literature in this area, including papers involving crop insurance design and effectiveness (for example Sherrick et al, 2004) earthquake insurance (for example Palm, 2004), insurance from family structure, (for example, Portner, 2001), health insurance (for example Asgary et al, 2004) and financial insurance (for example, Cull et al, 2005). See references contained in these articles for other, including seminal, articles in these and other areas of insurance.

need them in order to facilitate recovery, but do not necessarily prevent the effect of the shock in the first place. Of course, incentives that are priced can be added to those insurance arrangements in order to induce local agents to take steps to reduce the effects of shocks or their likelihood.

It is interesting to note that certain local insurance (or, more generally "smoothing") mechanisms are present in in our data at the expense of savings as another mechanism. For example, several of the case studies such as the agri-food case study by Sedlmayer and Boehm, 2011, and the energy provision study by Accorigi, 2011 emphasise systems that are currently quite costly and so may reduce the savings that would normally be expected to serve as a means of absorbing shocks. For example, an (implicit) alternative solution to the peak oil problems, which is emphasised in some of the case studies such as Accorigi, 2011, is to continue to use oil as the cheapest current alternative, but to build up a fund to use in the future to cushion the effect of peak oil prices. Hence, "insurance" of one type is bought by sacrificing "insurance" of another type.

Indeed, one could think of both of these studies as emphasising the importance of diversification of sourcing (of food in the case of Sedlmayer and Boehm and of energy in the case of Accorigi). There is considerable emphasis on diversification of the sources of livelihoods as a means of coping with new and unpredictable challenges in the case studies. This is found in the Bunting et al (2011) case study of Bangladesh, the Greenland study of Hayashi (2011) and in the contrast between the two valleys studied in Vihar and Doon (2011). In all these cases, the basic nature of the culture was rooted in a broad method of obtaining food ("hunting", generally defined in the Greenland study, "coastal aquaculture" in the Bangladesh study, and "highland farming" in the two valley Uttarakhand study), but not a particular technology, species, or crop. This allowed diversification strategies in food production so that, across time or even within a particular season, a variety of food sources could be accessed to provide a livelihood even if a particular food source became scarce or a technology became ineffective. Diversification is a general strategy that, while it often has the downside of not allowing full exploitation of any single resource -- which may result in higher costs and so reduced savings -- allows for smoothing of the flow of consumption or income. In this sense, diversification is

like self-insurance for a community albeit at the cost of fewer specialisation economies.

The issue of the cost of achieving resilience runs through this project. As a result, while we have discussed some of the governance, social networks, and insurance mechanisms that underlie resilience to a variety of shocks, we cannot assume that greater resilience is always desirable. Consider the example of unexpectedly heavy snowfall in England. The authors' own experience in recent years is that the UK and its economy are not very resilient to this type of shock….but what should be done about it? Is it worth investing more in snow removal equipment to deal with what remains a rare occurrence? One reason why snow is very disruptive is that many workers travel significant distances to work. So, in the name of increased resilience, should we move to a society based on small self-sufficient communities? Clearly, such a drastic change involves significant costs even in the longer term and would not be feasible in the short or medium run. Because of this "cost side" of resilience, one should be quite careful in drawing lessons for desirable policy, transferring lessons from one country to the other, or over time. While the case studies often mention the investment needed to achieve resilience for an ecoculture, the magnitude of this expense would need to be balanced against any benefits derived from resilience in order to judge accurately whether such a resilience policy would be socially desirable to pursue when weighed against other potential investments.

Stabilizing mechanisms or "insurance mechanisms" have been the subject of a great deal of economic research on both developed and developing economies. The mechanisms that have been catalogued in the literature are large, involving intertemporal mechanisms that even a single individual or family can practice (such as pecuniary or non-pecuniary savings, including storing food across seasons), diversifying crops held within a single family or across a community[14], purchases or sale of assets (like livestock or land)[15], borrowing/lending[16], gifts/transfers from networks[17], pulling children out of school or increasing family size, diversifying earning stream to both agricultural and non-agricultural sources (including migrant

[14] For example, see Walker, Singh and Jodha (1983).
[15] For example, see Rosenzweig and Wolpin (1993)
[16] For example, see Jodha (1978) , Bell, Srinivasan and Udry (1997), and Kochar (1997)
[17] For example, see Rosenzweig and Stark (1989) and Rosenzweig (1988)

income, for example)[18]. Many of these mechanisms are difficult to separate out into distinct groups. For example, Banerjee and DuFlo, 2007, note that since savings cannot be held in bank accounts or other secure facilities for many of the world's population, lending is the natural way to "save". In addition, such lending serves to smooth consumption of others and so helps to provide some kind of insurance to them. Second, while some of these institutions, such as diversifying income streams outside of agriculture, have insurance implications, they also serve to use the individual's time efficiently and fully throughout the year. Finally, intermediaries sometimes play a role in these arrangements, such as lending and borrowing arrangements, but the nature of the intermediation and at what scale the intermediation begins and bilateral or small multilateral arrangements end is somewhat fuzzy.

We see a wide variety of insurance institutions represented in the case studies in this project. For example, we see food source diversification strategies in Sedlmayer and Boehm, 2011; energy source diversification strategies in Accorigi, 2011; changes in cropping pattern or crop mix as well as shifts among pastoral, agricultural activities, and other sources of livelihood such as remittances or participation in the tourism industry in Vihar and Doon, 2011; adopting flexible and diversified methods and aims of hunting activities in Hayashi, 2011; credit and catch networks, sharing of boats and other tools, as well as reciprocal gift exchange within clusters and trading alliances with other land-based communities in Clifton, 2011.

Whatever the mechanism, insurance against income fluctuations appears to be provided to a surprising level in many communities, including our data. Indeed, it has been observed that, despite wide fluctuations in income, consumption in developing countries remains comparatively stable. While Banerjee and Duflo (2007) comment, based on empirical and observational studies using a wide variety of countries, that insurance arrangements appear to be neither complete nor efficient, despite the welfare benefits that this could generate, Townsend's (1994) work suggests that almost full global insurance against certain types of shock may be obtained at the village level. Hence, we may not be "far away" from the optimum even if we are not

[18] For example, see Banerjee and DuFlo (2007) and references therein.

fully there. We investigate to what extent recent work indicates that this is the case, below.

Much of the earlier formal insurance literature focused on a model of interactions among potentially insured individuals that was more appropriate for developed economies. In such a model, (generally homogeneous) individuals can fully insure against a wide variety of risks by writing complete contingent contracts[19]. This type of model implicitly assumes a degree of development in institutions such as markets and their legal framework as well as the presence of intermediaries to facilitate contracting among all parties to the insurance "pool" that may not be directly applicable to any of the cases underlying this study. Another stream in this literature has focused on imperfect information flows, such as less information about relevant risks held by the insurer than by the insured, and heterogeneous individuals. This stream has examined characteristics of insurance contracts that would allow insurers to reduce risk exposure[20].

While these models provide insights into actual insurance arrangements in both developed and developing countries, they do not fully capture the structure of many informal insurance markets which dominate the case studies in this project. In particular, the assumption underlying these models that all agents in a community potentially participate on an even footing in insurance arrangements does not square with observation. Indeed, we have three insurance questions that we can pose for the case studies: one is the descriptive question of how the informal insurance arrangements actually work, second is the question of why and how such arrangements might arise as equilibrium phenomena, and third is how good these arrangements are: whether they can be improved for their participants by (imposing) some other type of design.

In a homogeneous population model of the type described above, Genicot and Ray, 2003, note that the larger the group the higher the per capita utility from risk sharing so that one would expect that efficient insurance arrangements should be observed at the level of the community as a whole. However, they comment that this is at direct odds with the observation that most insurance arrangements in communities (of the

[19] See Arrow (1971).
[20] See Rothschild and Stiglitz (1970).

type in our case studies) are not at a community level. Indeed, the small or even bilateral nature of many informal insurance arrangements has been noted by a wide variety of authors[21] with specific arrangements covering the gamut we have outlined above.

Murgai *et al*, 2002, propose that such balkanisation may be due to the transaction costs incurred when setting up an insurance network. These include "assignment costs", which are the time or other costs of establishing a link between individuals for the purposes of insurance and "enforcement costs", which are the time or other costs of making the insurance contract "pay" in the case of a negative shock. Indeed, the fact that many studies find that informal insurance networks generally contain individuals who could be linked for other natural reasons (for example, family members, village members, members of the same caste or occupational group, members of the same gender, or other subgroups) suggests that these costs are indeed important to determining who jointly insures, especially among populations with few resources. One could imagine that, to the extent that these costs are barriers to the formation of larger networks, management of these costs could lead to the formation of larger groups that could then rely on larger resource pools and survive larger or more wide-spread shocks. The standard way of managing this sort of cost is the establishment of intermediaries.

Several recent papers using the techniques of social network theory have investigated the theoretical characteristics of insurance networks that are composed of subgroups rather than a single, perhaps undifferentiated, group. These papers address the question of whether we can expect "chunky" insurance arrangements to arise in an organic sense and remain stable. Genicot and Ray, 2003, note that there can be theoretical – strategic -- reasons for mutual insurance groups to remain small quite apart from Murgai *et al*'s 2002 transaction cost reasons. Genicot and Ray investigate insurance arrangements that are required to be stable to "defections" by groups of insured individuals who may depart to form their own mutual insurance arrangements. Their standards generate the sort of chunky market we observe. More interestingly,

[21] See, in addition to Udry (1994), Genicot and Ray (2003), Murgai et al (2002), Park (2006), Fafchamps and Lund (2003), and references within these works. The papers in this area cover many different types of community, from Pakistani (Murgai) to Bangladesh (Park) to the Philippines (Fafchamps and Lund) and many others, reviewed in Banerjee and DuFlo's discussion.

however, Genicot and Ray, 2003, note that in their model and many other models of insurance (even those focusing on insurance that is stable in the face of individual defections), the configuration of these insurance arrangements is very sensitive to the precise parameters of the model. Investigating this within their framework, they find the surprising result that an increase in the need for insurance (such as an increase in the natural disasters suffered by the community) can have the perverse effect of reducing the insurance provision since the stable group size can easily change. This change in size requires existing arrangements to break down and new arrangements to form, which clearly would generally imply poor insurance coverage for a transition period and – perhaps – no improvement in coverage afterwards if stable group size falls. This cautionary note does not, it should be emphasized, require a change in the nature of the insurance risk that the group faces. The implied fragility of the arrangements suggests a heightened need to intervene in the face of changing external threats, since indigenous arrangements may not carry over well to the new circumstances.

Bloch *et al*, 2008, also attempt a more institution-based approach by specifying exogenously to their model that only bilateral insurance links can form. Further, and probably realistically, individuals are not even aware of the entire network of links that cover their community: they only are concerned with their own "local" insurance arrangement. The authors search for insurance institutions that satisfy criteria set out in the model of stability (longevity), and a consumption norm for the insured pairs. The arrangements must be self-enforcing so that no external authority is present to impose arrangements; rather, the insurance institutions that arise must do so "organically". They find that either very thickly or very thinly connected networks satisfy their requirements, suggesting that networks of the type that is observed (small networks that are not well integrated into the whole) satisfy their criteria in a theoretically consistent sense. The intuition for their result is that the network's longevity relies upon ostracism as a sanction – in other words, the threat for not fulfilling insurance commitments is exclusion from the group. Thinly connected groups can ostracise easily, as the person who is excluded is poorly connected in the first place so that relatively few complaints will serve to exclude the individual completely from their network. Thickly connected groups also ostracise easily, as word travels very fast and very far. Hence, the enforcement power is high in either of

these networks and this lends each of these designs staying power. Note that this enforcement regime, if it ever came into use (which it will not as long as the network remains in its stable state), would result in individuals who are excluded from any insurance arrangement. Banerjee and Duflo, 2007, note the existence of such excluded individuals in their comprehensive survey. Indeed, even in the recent discussions in the UK of changes in the NHS, the argument for centralised insurance provision has traditionally been to ensure that excluded individuals receive cover. Local insurance arrangements, while they do not generate exclusion in equilibrium in such models, can generate exclusion off the equilibrium path[22].

These theoretical papers add to the list of "why" local insurance arrangements might arise by showing that stability concerns generate "chunky" insurance networks that arise organically. These can be added to the transaction cost reasons, proposed above. The papers cited so far do not argue, however, that this sort of arrangement is optimal in a wider sense. For example, the earlier models that assume more connectedness among individuals implicitly assume some form of (trusted) intermediary that achieves this connectedness at low cost. We could very well be better off with intermediaries that can reach a large number of individuals rather than bilateral agreements among neighbours, particularly if the threats to the community are broad-based rather than local.

The difficulty is that the intermediaries that we observe often are extortionate (as in the case of local money lenders, discussed in Banerjee and DuFlo, 2007) or otherwise are not trusted. Karlan *et al*, 2009, suggest that family ties form a natural "collateral" that facilitates transactions in networks and, further, the level of connectedness among individuals, which generates this trust, will determine the value of transactions that the network supports where family ties generate especially valuable links for insurance purposes. Indeed, we see this reflected in the Clifton, 2011, case study in this project, where family groups based on "trust and obligation" form the basis of the insurance provided to the society's members, although this study also indicates that the local gift exchange system has existed side-by-side with wider trading

[22] Related to this, Bramoullie and Kranton (2007) find that cross-community risk sharing can increase welfare for those connected across villages (and in the aggregate), but tends to reduce the connectedness within villages. This can reduce the welfare of peripheral individuals, so that the welfare gains are by no means evenly spread.

relationships at some points in history. Ambrus *et al*, 2010, propose village elders as natural intermediaries for their own analysis and could perhaps be thought of as a good place to start in developing more complete insurance systems.

It is not clear how much intermediation is necessary, however, to achieve something very close to full insurance for certain types of threats. Ambrus *et al*, 2010, pose the question of whether local arrangements can, in aggregate, supply good global risk-sharing where threats are in the form of idiosyncratic income shocks. Note that this implies that resource constraints are not an issue in their paper so that the advantage of large insurance networks of pooling large amounts of resources is not present.

While Ambrus *et al*, 2010, find that full insurance requires that all agents be connected in a particular and extensive way which is not observed in many settings, a relatively loosely connected network can generate "almost" full insurance[23], although the effectiveness of insurance provision improves dramatically as connectedness increases even modestly from very low levels. This implies that for the type of threat considered, a local system can perform as well as the sort of global system that we could achieve with, for example, effective and trusted intermediaries who serve to connect all agents in a very tight way. Further, they find that insurance organizes endogenously in a chunky way, with little risk sharing across chunks, but full risk sharing within chunks[24]. In such a chunky set-up, shocks propagate much more locally than at a distance in the network. Further, the local nature of risk sharing can lead to poor insurance for larger or more global shocks. Hence, the real problem comes when shocks are broadly-based or extremely large (so that an entire group's consumption could be inadequate). In such cases, we find the informal arrangements lacking.

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[23] Their results differ starkly depending on whether the risk sharing occurs in a network that is "planar" or "linear". The linear network has poor risk sharing properties, while the plane does rather well assuming equally strong connections. (In other words, if my husband and I are connected to our parents on both sides we do much worse in terms of insurance than if we are also connected to two other independent households and are connected with equally strong bonds as to our parents.) Ambrus et al note that the plane can be thought of as corresponding to communities where households have social connections locally and in multiple directions. In a line, individuals would have contact with immediate neighbours but no one else. The plane, they argue, fits their data and may be closer to reality for many "village type" situations.

[24] Essentially, each chunk has members who share the same consumption, but increasing chunk size trades off this sharing against placing the new member at the same consumption level as the rest. It may be better to place this new member in a different group which shares the same level of consumption, but not the same level as the first chunk. Chunk size grows with the capacity of the links.

Wrapping up this section, insurance is important to a "resilience toolbox" because resilience could be conceptualised as the degree of insurance provided for a community. The literature combined with evidence from the cases suggests several areas where insurance may be lacking. First, some insurance arrangements may be quite sensitive to changes in the risk environment, perhaps failing to perform precisely when the nature or size of shocks changes. This could indicate a fragility that would require specific intervention to address. Second, the types of informal arrangement that we observe perform surprisingly well to insure residents against shocks that are relatively small, idiosyncratic, and local but do not fare well against larger or more widespread shocks or those shocks requiring a large infusion of resources. Again, some form of intervention may be indicated in this case. Third, exclusion may result from informal local mechanisms to the extent that they rely on exclusion as an enforcement mechanism. To the extent that intermediaries can result in wider or better functioning of insurance, either by connecting local residents better into a larger network or facilitating transfers at low cost, trusted intermediaries are at a premium. Village elders or other individuals who command a high level of trust or have some form of social collateral that could be at stake could serve well to organise insurance provision. Finally, small increases in connectedness in relatively unconnected societies can have disproportionate gains in terms of insurance. Further increases after moderate connectedness is achieved have much more modest effects.

VI. Creating an Index of Resilience

Any empirical analysis of resilience using the statistical techniques commonly accessed by economists requires a sufficient number of observations. These observations can come from available data sets or can be constructed from a large enough number of case studies. The preferred method is then to statistically correlate (and, if possible, identify a causal link) factors that favour or hamper resilience (right hand side variables) and measures of resilience (left hand side variables). This is why there are a number of studies of economic resilience to earthquakes (see Bruneau *et al*, 2003): such events are quite frequent and their effects are fairly well reported. For example, Bruneau et al propose a comprehensive framework that specifies four dimensions of community resilience: technical, organisational, social, and economic, which all find potential data sources for each of these in the earthquake example. The

measure of resilience constructed in such a study can potentially be multi-dimensional, including reduced probability of failure of a system, reduced consequences of failures (should they occur) and reduced time to recover from failure. Which of these aspects of resilience receives most weight will partly depend on the objectives of the researcher or policymakers.

The case studies underlying this project suggest that a similar methodology could be used to build a composite index of "resilience capacity" adapted to eco-cultures, where the coefficients obtained in the statistical regression discussed above could be used to determine the relative weights of various factors included in the index. Based on the sort of information that is present in the case studies that could be formalised into input data, we could propose an index of resilience as a function (for simplicity, a linear function) of a set of variables that would include qualitative and quantitative measures. Based on the case studies, this could include a measure of the susceptibility of a region to threats, including contagion from other regions, a measure of resource stocks that are available for short term mitigation of the shock such as liquid savings and physical resources that can be mobilised quickly, a measure of resource stocks available in the longer term such as non-liquid saving and physical resources that are available only with delay such as alternative crops or prey, the nature of social cohesiveness or social adaptability that captures the ability of human resources to be directed towards the threat, a measure of external support available to the region, and a measure of integration of the region including in or out-migration, transport links, and linguistic integration. A measure of governance that reflects the ability to control and manage resources and human response would need to be included in the index.

As a note on this sort of equation and its relation to the four areas that Bruneau *et al*, 2003, suggest for inclusion while it is clear that organisational, social and economic issues have been incorporated into the index of the previous paragraph certain proxies, it is less clear what the role of technology is. Indeed, the underlying technology of the community enters into this equation in a number of ways. For example, the Bajau case study (Clifton, 2011) emphasises the importance of the fishing technology of the community in creating susceptibility to environmental degradation and competition: in the face of mechanised fishing by outsiders and

pollution, with its consequent depletion of marine stocks, the Bajau's traditional hook and line technology is performing less and less well at providing subsistence yields. On the other hand, technology can be a resource to allow recovery, and enters into the Bajau case study as a solution, not just as a cause of environmental problems. Modern marine management techniques to counteract loss of mangrove stands, water pollution, and respond to threats commercial fishing could all have a technological as well as a regulatory dimension. One finds an echo of this sort of two-edged nature of technology in the Bunting et al (2011) Bangladesh study as well.

Armed with such a specification, data on each of the variables (which are largely qualitative) would need to be constructed for a relatively large number of cases in order to use regression techniques to estimate the weights to be given to each factor with enough reliability. Combining the case studies accessed here with other studies of resilience, then, could result in a meta-analysis that could generate a useful, well-grounded resilience index. Clearly, the current study provides a start but not an end to this process. Clearly, too, the conclusions of such a piece of work are specific to the definitions, measures, and concerns used as was indicated earlier in our discussion of quantitative implementation of the resilience concept.

VII. Conclusion

Recent work on resilience has drawn attention to the lack of clarity in the literature on the concept. This lack of clarity can be an impediment to developing policy in this area. More precisely recent work, such as Musson (2011), has underlined the importance that actors place on the opportunity cost of resilience policy when deciding whether to support it. Without a clear definition of what resilience means, this opportunity cost is extremely hard to define.

This paper has attempted a synthesis framework for analysing resilience from an economics viewpoint. Much of the literature on resilience has come from other fields, and so the frameworks developed in those areas need to be adapted somewhat to incorporate economics concerns. Specifically, we have argued that short term considerations should receive weight in resilience analysis. Structural considerations have received weight in some definitions, whereas we argue that performance

considerations should trump these in economic analysis of resilience. Finally, we have argued that, in addition to specifying what performance level we must return to, an implementable definition of resilience must specify relatively precisely the source of shocks to which the society needs to be resilient and the measure of both the shock and the performance. This specification must be rather precise: observation suggests that many resilience policies are quite specific to the shock and measure used. Hence, roughly stating "we want resilience to climate change" is not generally enough to give a guide to policy or to the evaluation of opportunity cost: we would need to know which precise effects of climate change we wish to consider, including whether the change is large (a reversal of the Gulf Stream) or small (a modest increase in frequency of high winds).

Governance and insurance issues figured prominently in the case studies we reviewed. In particular, they have generally supported delegation of control and ownership of property rights to local authorities in many cases. On the other hand, they have underlined the crucial role central authorities can play in disseminating information, smoothing bargaining and negotiations processes in deciding on how resources are managed, and setting up dispute and enforcement institutions. A wide variety of insurance mechanisms seem available and accessed by local communities to generate resilience. These mechanisms can be very efficient at dealing with idiosyncratic shocks, but require additional support to deal with larger and more widespread disturbances. Further, informal methods of insurance can rely on exclusion for their effectiveness, so that the distributional characteristics of these types of insurance may not be desirable even if their efficiency characteristics are good.

Clearly, this paper only makes a start at mapping out resilience analysis. One of the challenges to actual policy makers, for example, is that the source of the shock is important to generating specific policy recommendations but is often unknown. While our general recommendations apply regardless of the source of shock, clearly in such a case specific techniques would need to be used to allow for policy to be generated despite this lack of information. Clearly, quantitative techniques apply most directly to those shocks that can be identified with more precision; however, real options analysis can be used to incorporate concerns over small probability but catastrophic events. While such quantitative and qualitative techniques exist to deal

with a lot of the more difficult aspects of resilience analysis, Accorigi, 2009, exhaustively points out that all these techniques have significant drawbacks. Resilience policy is, in large part, a matter of "doing the best we can with the tools at hand" whilst waiting for better tools to emerge.

As a final note, the economic approach mapped out here certainly does not provide a policy recommendation that resilience is something we should be favouring above other social goals. Standard economic tools are available to evaluate policies that lead to resilience within a larger policy debate. Indeed, a menu of decision rules on which policy among many to accept is relatively well established, with cost-benefit analysis being a standard technique[25]. The issue to be considered outside of the realm of economics is whether resilience should be given added weight beyond what it usually would receive in a cost-benefit analysis in order to give it more prominence in policy decisions. In other words, as an example, speedy recovery of a system will normally give rise to a larger stream of discounted benefits than a system without speedy recovery. Whether we should give this an even larger role by means of weighting the speed of recovery itself is an issue to be discussed in how to incorporate resilience as a concern into policy analysis. Economics itself cannot provide guidance on this matter, even though it can help to implement policy preferences once they have been defined.

[25] See Accorigi, 2009, for a summary of a variety of approaches, including but not limited to cost-benefit analysis.

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