Physical, Human, and Social Capital as Barriers to Environmental Policy Change

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Why is environmental law and policy so resistant to change? It is not just that controversial and costly proposals are vigorously opposed by regulated industries. Simple, administratively feasible, and common-sense proposals to improve environmental policy and which easily pass cost-benefit tests, seem to die unceremonious deaths in the chambers of legislatures or in the circular file of agency bureaucrats. Many, many proposed changes are much more beneficial in economic terms than they are costly. And yet they fail. Why does this happen so frequently? And even when environmental problems ultimately do find a solution, why are they left to persist for so long? Prevailing explanations would seem to fall broadly into three categories: (i) public choice explanations, (ii) framing and education problems, and (iii) doubts about the importance of the underlying environmental problem.

Within these broad categories, the specific explanations vary. For example, one common public choice explanation is be that intensely-affected regulated industries are more motivated to resist reform than lightly-affected and widely-dispersed majorities are to advance reform.[1] If that is the case, then one might expect the politics of policy change to favor policy inertia. Another public choice explanation might be that agency actors and the industries they regulate will have repeat interactions. If that is the case, then one would expect that the capacity to reward and punish would produce patterns of cooperation, which might, in the face of policy change, give rise to a systemic resistance to change, lest that upset a status quo that benefits both regulator and regulated industry.[2] Within the category of framing problems, one explanation could be that the costs of environmental policy are more easily identified and visualized than the environmental benefits, which tend to take on statistical forms.[3] Another framing problem could be that some environmental instruments could be perceived negatively for non-substantive reasons. For example, while a variety of environmental taxes are welfare-improving, it has been often pointed out that they suffer from being a "tax." Research has shown that the exact same instrument is more palatable if it is labeled a "fee" than it is if it is labeled as a "tax."[4] Finally, along similar lines, public doubts about the seriousness of some

1 JAMES M. BUCHANAN AND GORDON TULLOCK, THE CALCULUS OF CONSENT: LOGICAL FOUNDATIONS OF CONSTITUTIONAL DEMOCRACY (1962); George J. Stigler, *The Theory of Economic Regulation*, 2 J. ECON. & MGMT. SCI. 1, 3 (1971).

2 IAN AYRES & JOHN BRAITHWAITE, RESPONSIVE REGULATION: TRANSCENDING THE DEREGULATION DEBATE, ch. 3 (1992).

3 Shi-Ling Hsu, *The Identifiability Bias in Environmental Law,* 35 FLA. ST. UNIV. L. REV. 433 (2008).

4 Edward J. McCaffery and Jonathan Baron, *Thinking About Tax,* 12 PSYCHOLOGY & PUBLIC POLICY 106 (2006).

environmental problems persist well beyond the point at which the evidence is sufficient to quell such doubts.[5]

Environmental policy inertia and the puzzling persistence of some environmental problems do not appear susceptible of a single unifying explanation. However, there is one explanation that plays a role in almost every single instance of environmental policy inertia, but is missing from the literature: that certain forms of *capital* lock individuals, firms and organizations into a strong preference for the status quo. Environmentally harmful products and practices persist because firms and people have so much invested in their persistence. The form of their investment is their capital – physical, human, and social – which is costly to obtain. Often, capital is inflexible in that it cannot be salvaged or deployed for an alternative use, making its preservation even more pressing for its owner. The intense interest in continuing to exploit capital is what drives the invested firms and people to oppose so vigorously any change which would threaten the usefulness of that capital. In fact, so deep is the investment sometimes that compensation, while susceptible of valuation is, practically speaking, impossible. Even if expensive physical capital might be monetized (and potential compensation considered), human and social capital that does not get counted can play a crucial, sometimes more powerful role, in generating opposition to change. Because capital can be so costly to obtain and maintain, and because it can become specialized to a specific industry or practice, it can come to represent the very identity of a firm, person, or group. Destroying that capital can appear to be tantamount to destruction of that firm, person, or group. Discontinuation of a product or practice because of environmental side-effects can thus pose an existential threat to the owners of that capital.

What is Capital?

A precise and widely-accepted definition of capital is elusive. Adam Smith offered a working definition of capital as the "stock of assets accumulated for productive purposes."[6] In its most simplistic applications, capital has long been modeled in economic theory (with many, many variations, of course) as one of two types of inputs to production, the other input being labor. The Cobb-Douglas production function, which every economics student learns about in undergraduate economics, posits production as a function of the quantity and productivity of just two types of inputs: labor and capital.[7] Solow's fundamental neoclassical growth model posits growth as a general function of labor, capital, and technology, the latter being a multiplier that makes the other two inputs more productive.[8] In this simple heuristic sense, capital is one of two types of things that contribute to the making of things. And yet, if one digs

5 Although still controversial, it is now very widely believed that evidence of climate change is sufficiently convincing to warrant some policy response. There are obviously conflicting accounts of whether the science of climate change is sufficient or not, and conflicting accounts of whether ulterior motives are biasing research findings, but a summary of the controversy can be found in Shi-Ling Hsu, *A Prediction Market for Climate Outcomes,* 83 U. COLO. L. REV. 179, 181-89 (2011).

6 ADAM SMITH, AN INQUIRY INTO THE NATURE AND CAUSES OF THE WEALTH OF NATIONS __ (1776).

7 Charles W. Cobb, and Paul H. Douglas, *A Theory of Production,* 18 (supplement) AM. ECON. REV. 139 (1928). The now-familiar Cobb-Douglas formulation, $Y = AL^{\alpha}K^{\beta}$, with Y representing output, L representing labor, and K representing capital, has become a foundational relation in economic theory.

8 Robert M. Solow, *A Contribution to the Theory of Economic Growth,* 70 Q. J. ECON. 65 (1956).

a little deeper into the dichotomy between capital and labor, the line begins to blur, as in the initial instance, labor is required to build the capital in the first place.[9] In that sense, capital can simply be thought of as stored labor. Joan Robinson raised the question that if output is to be measured in units of the good produced, labor is to be measured in person-hours,[10] in what units should capital be measured?[11]

These and a number of other difficulties have led to some more conceptual and less rigid formulations of capital. Gary Becker has, in his seminal work, essentially married labor and capital in developing the term "human capital" to denote the amount of human training and education that is undertaken to produce other things (or services).[12] Very generally and fundamentally (perhaps too broadly), capital can be thought of as foregone current consumption foregone to produce more income tomorrow.[13] In a similar vein, Solow has defined it in passing as generically, a "stock of produced or natural factors of production that can be expected to yield productive services for some time."[14]

This article sets forth a working definition that does not seek to bridge or synthesize the differences among the economic giants that have considered this topic. For purposes of this article, I define capital as *a costly and long-lived asset that generates a stream of benefits*. Capital is costly insofar as it either requires resources or opportunity costs to obtain. Capital is long-lived in the sense that it is meant to be durable and undergo sustained use over a period of time or over a quantity of production. And capital generates a stream of benefits because that is why it is obtained in the first place. By definition, capital is something of instrumental value, contributing to something outside of its own being.

I consider three kinds of capital: physical, human, and social.[15] There are many other kinds of assets to which the label of "capital" has been attached. But these three forms of capital, as I describe them below, are the forms of capital that have played a prominent role in retarding environmental policy reform.

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9 Hernando deSoto notes that capital must be "fixed and realized in some particular subject which lasts for some time at least after that labor is past. It is, as it were, a certain quantity of labour stocked up and stored to be employed, if necessary upon some future occasion." HERNANDO DE SOTO, THE MYSTERY OF CAPITAL 42 (1999).

10 Professor Robinson's original 1953 formulation used the gender non-neutral phrase, as every work did in that time, "man-hours." Joan Robinson, *The Production Function and the Theory of Capital*, 21 REV. ECON. STUD. 81, 81 (1953).

11 *Id.*

12 GARY S. BECKER, A THEORETICAL AND EMPIRICAL ANALYSIS, WITH SPECIAL REFERENCE TO EDUCATION 17 (3d ed., 1993) ("Education and training are the most important investments in human capital.").

13 N. Gregory Mankiw, *The Growth of Nations,* 1995 BROOKINGS PAPERS ON ECONOMIC ACTIVITY 275, 293 (1995) ("More generally, however, we accumulate capital whenever we forgo consumption today in order to produce more income tomorrow.").

14 Robert M. Solow, *Notes on Social Capital and Economic Performance,* 6 (in SOCIAL CAPITAL: A MULTIFACETED PERSPECTIVE 6-9, P. Dasgupta and I. Serageldin, eds., 2000).

15 Many scholars consider social capital to be a recent addition to the three previous widely-accepted forms of capital: physical, human, and natural. *See, e.g.,* Elinor Ostrom, *Social Capital: a Fad or Fundamental Concept?* 172-214, 172-79, in Dasgupta and Serageldin, *supra,* note 14; and Norman Uphoff, *Understanding Social Capital: Learning from the Analysis and Experience of Participation,* 215-249, in Dasgupta and Serageldin, *supra,* note 14.

Physical capital is capital that takes on a tangible, physical form. For example, a coal-fired power plant, with a typical useful life of forty or fifty years[16] is an asset that generates a stable stream of revenues in the form of consumer electricity payments. Indeed, ensuring that environmental policy does not threaten the size or the continuity of that stream of benefits occupies a considerable amount of attention from the owners of that capital. A stable regulatory and price environment is the ideal environment, if not the *sine qua non* of the investment of such capital. The costliness of physical capital such as coal-fired power plants, coupled with the long time horizons involved with in paying for such capital, lends urgency to the task of monitoring and managing, to the greatest extent possible, the regulatory and price environments.

Human capital is most often thought of as education and training.[17] Generally speaking, the higher the education, the greater the value of the human capital.[18] Education can be extremely costly, either or both in terms of money or time, not only because of direct costs, but because of the opportunity costs of foregone income.[19] But indisputably, there is a gap between observed productive output and the productive output that can be explained by the traditional Cobb-Douglas inputs of labor and capital. One element of that gap has been empirically attributed to the increased productivity of education and training, or the formation of what has come to be commonly referred to as human capital.[20] Thus human capital is, by itself, something that generates a stream of benefits, in the form of earnings that would not otherwise be realized. While human capital is most easily conceived as formal schooling or on-the-job training,[21] there are clearly many other forms of human capital. For example, Microsoft founder Bill Gates, a college dropout, owes a considerable amount of his wealth to the human capital he acquired at early stages of his life that enabled him to be one of the most innovative individuals in the history of humankind.[22] But in almost all cases, human capital requires significant costs to obtain, has the potential to be long-lived, and can generate a very long-lived stream of benefits.

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16 For example, a recent regulation by Environment Canada to apply a new emissions performance standard for power plants "at the end of their useful life" assumed a useful life of a power plant to be forty-five years. Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations, *Canada Gazette* Vol. 145, No. 35, at 14 (August 27, 2011).

17 GARY S. BECKER, A THEORETICAL AND EMPIRICAL ANALYSIS, WITH SPECIAL REFERENCE TO EDUCATION (1994).

18 *Id.* at 170 (Table 4, showing income differentials for high school and college graduates), 224 (Table 17, showing higher incomes for college graduates). Although the *marginal* returns to a college education have not always been historically higher than the *marginal* returns to high school education, the marginal returns to college education have always been positive. *See also,* CLAUDIA GOLDIN AND LAURENCE KATZ, THE RACE BETWEEN EDUCATION AND TECHNOLOGY 78-79 (Table 2.5, showing positive returns to college schooling) (Harvard Univ. Press, 2008).

19 *See, e.g.,* Theodore W. Schultz, *Capital Formation by Education,* 68 J. POL. ECON. 571 (1960).

20 BECKER, *supra*, note 12, at __; Theodore W. Schultz, *Investment in Human Capital,* 51 AM. ECON. REV. 1 (1961).

21 For example, Becker's original empirical work focuses on the measurable benefits of schooling and on-the-job training. BECKER, *supra*, note 12, at 17-21.

22 MALCOLM GLADWELL, OUTLIERS: THE STORY OF SUCCESS __ (2008).

Finally, *social capital*, as it is conceived in this article, consists of the variety of interpersonal and intra-organizational bonds that are formed when one signals to another that cooperation is sought. Among economists, there is some controversy as to whether the term "capital" can be coherently applied to something like the social interactions that make up what is popularly referred to as social capital.[23] For those economists that do engage in the concept of social capital, it is always considered in terms of how it increases productivity, just other forms of capital do. After all, what good would social serve apart from the psychological benefits of social belonging?[24] If social capital is to have economic content, then it must have a role in economic performance. What is different about social capital is that the social interactions that make up social capital do not primarily have economic motivations. The concept of social capital thus draws heavily from the work of Robert Putnam's *Bowling Alone,*[25] which chronicles the decline of social institutions in the United States, the result of which is a lack of a social fabric that made many cooperative endeavors possible in the past. Putnam's argument is that social networks enhance political and civic life without consciously having these outcomes as objectives. The economic perspective is thus analogous to Putnam's argument, in that social capital is something that enhances economic productivity without consciously having as its goal economic productivity.[26]

Drawing again on the working definition of capital set forth in this article, *social capital* is just another type of asset that is costly to obtain, is potentially long-lived, and can generate a long-lived stream of benefits. Of the three forms of capital considered in this paper, it is the least time-consuming to construct, and the stream of benefits flowing from it consists of a number of intangible benefits, be it informational benefits or just the small favors and graces extended to those within that social fabric. Nevertheless, these benefits can be extremely important. James Coleman provides a compelling example of the importance of social capital in the Jewish diamond merchant community, in which merchants entrust fellow merchants with diamonds worth very large amounts of money. The reason that thievery is non-existent in this community, despite ample opportunity to engage in it, is explained by the social interconnectedness of the merchants. Stealing would result in ostracism from a community and forfeiture of social, family, and religious ties.[27] And the social capital plays a vital economic role, lubricating merchantile relations in a very lucrative business while obviating the need for expensive and perhaps ultimately futile monitoring.

Social capital is perhaps the most egalitarian form of capital, requiring little of the financial resources that are necessary and sometimes unavailable to certain disadvantaged groups.

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23 *See, e.g.,* Kenneth Arrow, *Observations on Social Capital,* 3-5 in SOCIAL CAPITAL: A MULTIFACETED PERSPECTIVE (P. Dasgupta and I. Serageldin, eds., 2000), and Robert M. Solow, *supra,* note 14.

24 Economists argue that joining social networks have non-economic benefits, and are at least in part the motivation for joining. *See, e.g.,* Arrow, *supra,* note 23, at 3 ("There is considerable consensus also that much of the reward for social interactions is intrinsic – that is, the interaction is the reward—or at least that the motives for interaction are not economic. People may get jobs through networks of friendship or acquaintance, but they do not, in many cases, join the networks for that purpose.")

25 ROBERT D. PUTNAM, BOWLING ALONE: THE COLLAPSE AND REVIVAL OF AMERICAN COMMUNITY __ (1995).

26 *See, e.g.,* Arrow, *supra,* note 23, at 4.

27 James S. Coleman, *Social Capital in the Creation of Human Capital*, 94 Am. J. of Sociology 95 (1988).

Putnam has written that "historically social capital has been the main weapon of the have-nots, who lacked for other forms of capital."[28] Social capital could play a critical role in motivating poor, resource-based communities to fight regulation. Tight and important interconnectedness, akin to that of the Jewish diamond broker industry, have been observed in a variety of fishing communities.[29] As it happens, fishers are, even among resource industries, almost legend for their resistance to regulation.[30] As in the Jewish diamond broker example, trust and reciprocity, the social capital that is formed from long-running business relationships and is formed for the purpose of maintain them – have served a vital economic purpose for low-profit industries that cannot afford expensive or time-consuming monitoring efforts. Indeed, when social capital is low – when interconnectedness is not present – fishing communities that otherwise resemble other communities with high social capital – function much less efficiently and are much less profitable.[31]

Social capital is still, in a sense, costly to obtain, as it requires effort to earn trust and to signal the intent to cooperate. But like physical and human capital, once created by sustained cooperation or assistance, social capital can yield a stream of benefits that becomes extremely valuable and in some cases, economically necessary. Even though social capital is not readily monetizable, it can be as valuable or more valuable than tangible assets like physical capital, or recognizable assets such as human capital. Perhaps more significantly, it can be the only form of capital held by some individuals and some groups. In rural single-resource towns, social interactions tend to be concentrated in a small number of interaction sites, such as church, the town hall, the mine or plant, or the local bar.[32]

To be sure, most capital contains combinations of all three kinds of capital. Physical capital such as a coal-fired power plant contains the embedded human capital that was required to design and build a highly sophisticated and expensive piece of equipment. Social capital is invariably needed as well, in the form of the informal cooperative arrangements that are needed for such a large-scale endeavor to result in fruition. Physicality is just the most obvious aspect of capital.

The problem with long-lived capital is that some environmental problems emerge during its life that render it less socially beneficial than believed when the capital was initially formed, and possibly even socially detrimental. Of course, it is also possible that the environmental externalities of some products or practices are known during a period of capital formation, but the capital formation takes place anyway. In either case, if the continued exploitation of capital

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28 PUTNAM, *supra,* note 25, at 359.

29 James A. Wilson, *Adaptation to Uncertainty and Small Numbers Exchange: The New England Fresh Fish Market,* 11 Bell J. Econ. 491 (1980); James M. Acheson, *The Maine Lobster Market: Between Market and Hierarchy Reviewed*, 1 J. L. Econ. & Org. 385 (1985); Sean Lauer, *Entrepreneurial Processes in an Emergent Resource Industry: Community Embeddedness in Maine's Sea Urchin Industry*, 70 Rural Sociology 145 (2005).

30 *See, e.g,* SUZANNE IUDICELLO ET AL., FISH, MARKETS, AND FISHERMEN: THE ECONOMICS OF OVERFISHING __ (1999); Shi-Ling Hsu, *What IS a Tragedy of the Commons? Overfishing and the Campaign Spending Problem,* 69 Albany L. Rev. 75, 130 (2006).

31 Sean Lauer*, Relationships in Inshore Fisheries*, 23 Sociological Forum 503 (2008).

32 Kevin R. Cox and Andrew Mair, *Locality and Community in the Politics of Local Economic Development*, 78 Annals of the Assoc. of Am. Geographers 307 (1988).

creates environmental externalities that were not appreciated (or consciously ignored) at its time of formation, a split in interests emerges: cessation of use of the capital may be desirable from the social point of view, but the owner of the capital will want to continue to use the capital. This simple story is, in part, the story of almost every environmental externality ever created. It is the partial story of how almost every environmental externality has been extended for longer than a rational society would have allowed it to persist. In some way, physical, human, or social capital has gotten in the way of solving almost every environmental problem in the history of humankind.

Some examples illustrate the point, even if they do not conclusively settle it. One of the most egregious examples has already suggested itself: the world's stock of coal-fired power plants, with a combined value that is likely in the trillions of dollars,[33] that emit a number of pollutants with a wide variety of detrimental effects on human and biotic health.[34] Even as researchers discover the extent of the ever-widening circle of harm imposed by coal-fired power plants, the owners of this stock of capital have rallied to keep them running, and keep their stream of benefits as intact as possible. They have vigorously resisted regulation and questioned the reliability of the mounting evidence that coal mining and burning cause harm. They have not backed down even as the most costly side-effect yet discovered takes center stage: climate change. Even the most conservative estimates of the costs of climate change, coupled with other externalities, suggest that the benefits of this anachronistic industry are far exceeded by the costs.[35]

As the world struggles with a plethora of new environmental problems, capital continues to silently but powerfully play a role in defining the policy options. Some policy options, because they threaten the viability of existing capital, receive an effective death knell when they are tagged with the appraisal that they are simply politically unviable. But without a more probing

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33 A very rough estimate of the value of the stock of the world's coal-fired power plants can be obtained by multiplying world capacity (IEA World Energy Outlook, *supra* at 543-616, 647-640) by a weighted average of overnight costs, weighted by plant location (International Energy Agency, *Projected Costs of Generating Electricity 2010* 60 (2010). This back-of-the-envelope calculation is $2.4 trillion USD in 2009.

34 A recent analysis of the varied external damages of coal-fired electricity generation is undertaken by Nicholas Z. Muller, Robert Mendelson, and William Nordhaus, in *Environmental Accounting for Pollution in the United States Economy,* 101 AM. ECON. REV. 1649 (2011). This paper only calculates monetizable harms, however, and excludes, for example, non-market harms such as harms to ecological systems. A more comprehensive, if more qualitative, accounting of the harms from coal-fired generation is undertaken by Roberta Mann in *Another Day Older and Deeper in Debt: How Tax Incentives Encourage Burning Coal and the Consequences for Global Warming,* 20 Pacific McGeorge Global Business & Development Law Journal, __, __ (2006). The vast majority of economic harm from coal-fired electricity combustion derives from the premature deaths caused by fine particulate matter emissions from coal-fired power plants. Rigorous analysis has been undertaken over decades of epidemiological work of the link between fine particulates and premature deaths. *See, e.g.,* Johanna Lepeule, Francine Laden, Douglas Dockery, and Joel Schwartz, *Chronic Exposure to Fine Particles and Mortality: an Extended Follow-up of the Harvard Six Cities Study from 1974 to 2009*, __ Envir. Health Persp. __ (2012); Francine Laden et al., *Reduction in Fine Particulate Air Pollution and Mortality: Extended Follow-up of the Harvard Six Cities Study*, 173 AM. J. RESPIRATORY AND CRITICAL CARE MED. 667 (2006); C. Arden Pope III et al., *Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution*, 287 J. AM. MED. ASS. 1132 (2002).

35 Muller, et al, *supra*, note 34, would have to be considered a conservative estimate, since it only took account of the monetizable damages from pollution.

inquiry as to exactly why these options are politically unviable, and why it can appear impossible to compensate owners for lost, or "stranded" capital, the role of capital remains a hidden one, taking certain options off the table without a satisfying explanation.

How Does Capital Impede Environmental Law Reform?

A theory of capital is not mutually exclusive of other theories about environmental policy inertia. For example, public choice theories quite commonly identify the powerful interests with expensive capital as centers of resistance of environmental reform. But it is incomplete to argue that a firm's interest in continuing their business is strong enough to justify an expensive Washington, D.C., lobbying presence. A theory of capital would be, in such a case, a more detailed examination of exactly why a firm feels that it must continue a practice that is demonstrably harmful. A theory of capital can explain why a firm could spend more money than its capital is worth to preserve its functionality; its market value may not completely capture its value as a generator of a stream of benefits, viewed in the context of the available alternatives. This theory of capital is an exposition of exactly what path-dependency means in the context of industry, firm, and individual and behavior. A theory of capital is a form of institutional analysis applied to the choice sets facing industries, firms, and individuals that engage in harmful polluting behavior.

Capital impedes legal reform because legal reform usually requires a shift in methods of production to avoid or mitigate certain environmental externalities. The problem arises when capital that is deployed for a specific production method cannot be easily re-deployed to a different, less environmentally harmful, production method. If capital is specific enough, then any shift in production methods could effectively "strand" that capital and render it worthless. For certain expensive forms of capital, this creates an enormous incentive to resist change and preserve the value of that capital. Especially for mass-produced goods, such as electricity, the cost of capital is large relative to the units in which the benefits flow back to the owner of capital. Electricity is sold in units that are cheap in comparison with the cost of capital. Payback of electricity-generating capital is accomplished over long time horizons, and over broad populations. When production is undertaken with methods that involve high capital costs and a stream of benefits that are small and widespread – and therefore involve a long payback – a stable pricing and regulatory environment becomes extremely important. A small change in the pricing environment amplified over its application to a large number of customers and transactions results in a potentially huge change. In this pricing environment, owners of capital can be forgiven for being a bit paranoid and obsessive about protecting their capital by protecting their pricing and regulatory environment.

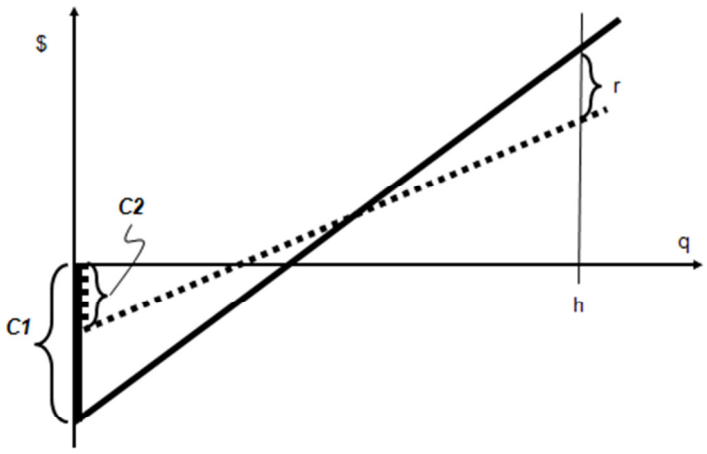
The goal of any acquisition of any capital is to enjoy a stream of future benefits, but along with a higher stream of future benefits comes the risk that the future benefits may not materialize (for example, due to an unfavorable change in the regulatory environment). To illustrate, consider a very simple example involving a firm that can choose a level of capital investment based on only two factors: the cost of capital and the stream of future benefits. There are only two types of strategies: a low-capital-cost, low-benefit-stream investment, and a high-capital-cost, high-benefit-stream investment. The expected value of the high-capital-cost, high-benefit-stream investment is greater, but there is a risk associated with this strategy. In this simple

example, the only reason to choose a low-capital, low-profit strategy over high-capital, high profit strategy is the avoidance of risk. Of course, this abstracts away from many other determinants of capital ownership, like access to capital and discounting, and abstracts away from many other attributes of capital ownership, like market power and signaling benefits or detriments (like prestige or scorn). But heuristically, it is reasonable to work from the simplifying assumptions that the only reason to take on more expensive capital and the attendant risk is to generate a larger stream of benefits.

These two strategies are depicted in Figure 1. Two different firms make a capital investment at an initial investment cost. The cost of capital instantly drives down firm profitability, but the capital generates a revenue stream that increases firm profitability as sales of the produced good generate revenues to pay back the cost of capital, and ultimately begin to generate a profit. In figure 1, the profitability of the firms, i.e., the sum total of firm revenues and expenses, is graphed as a function of *q*, the quantity of sales. Figure 1 represents the simple case in which the price and operating costs are constant for all units sold, so that profitability is linear in *q*. In an even simpler case, sales would be uniform over units and also over time, so that the horizontal axis could be time and the payback period represented by the point in time at which the profitability crosses the horizontal axis.

The profitability of the firm adopting a high-capital, high-profits strategy is shown as the solid line in Figure 1, with an initial capital cost of ***C1,*** and the low-capital, low profits strategy is shown as the dotted line, with an initial capital cost of ***C2.*** Assuming the expected life of the capital in both cases to be ***h,*** the cost of risk associated with the high-capital, high-profits strategy is ***r***. This also abstracts away from considerations having to do with discounting.

Figure 1.



Ex ante, the cost of risk is simply a premium that is assumed by the firm adopting a high-capital, high-profits strategy. After the acquisition of the capital, however, if that risk materializes, then the expected value of a loss due to regulatory change simply becomes a loss. It is this loss that a firm, having acquired capital, will struggle mightily to avoid. In figures 2a and 2b below, a regulatory change that renders the capital obsolete and valueless occurs when

the firm has sold ***x*** units. The losses for the high-capital, high-profits strategy and the low-capital, low-profits strategy are shown in figure 2a and 2b below, respectively, as ***L1*** and ***L2***.

Fig. 2a.

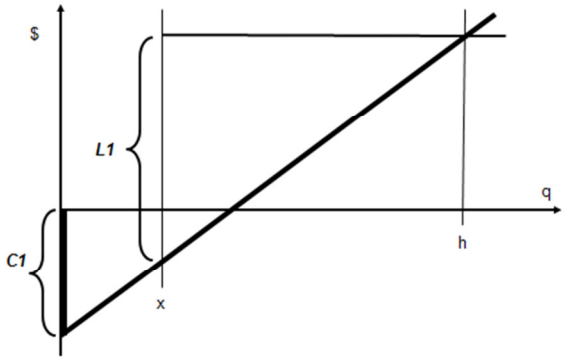
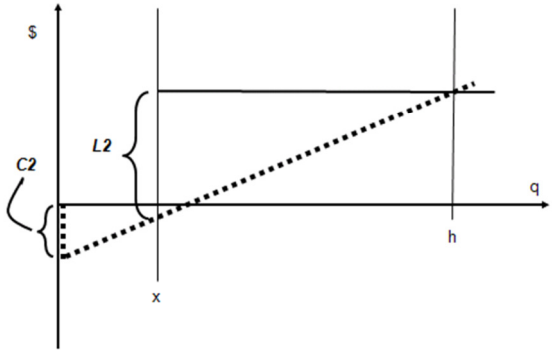


Fig. 2b.



Obviously, the loss suffered by a regulatory change is greater in the high-capital, high-profits scenario; there is a larger stream of benefits to lose. All other things being equal, as long as the high-capital, high-profits strategy yields higher marginal profits (again, this is assumed, because there would otherwise be no reason to expend higher amounts of capital), the loss ***L1*** will always be greater than the loss ***L2***. Hence, a firm faced with a regulatory change that would render its capital obsolete would spend any amount of money up to its prospective loss (***L1*** or ***L2***) to defeat the regulatory change.

What does this tell us about the role of capital in frustrating environmental policy reform? Put simply, the higher level of capital investment, the greater the stream of benefits generated; the greater the threat posed to the firm owning the capital, and the greater efforts it will undertake to defeat the regulatory change. This argument seems banal; of course we would expect that the more expensive the capital, the greater lengths that will be undertaken to defend the capital! But this conclusion is imprecise. It is not the capital itself that industries, firms, and individuals fight vigorously to protect; it is the stream of benefits that inspires such vigorous defense. It so happens that most of the time, we should expect that the more expensive the capital, the greater is the stream of benefits; expected benefits should be capitalized into a valuation of capital. But this is not always the case, and when it is not, a more precise explanation can be found in the stream of benefits flowing from the capital. Without a dynamic explanation, one might be led to imprecisely conclude that the vigor with which capital is defended is proportional to the capital costs or proportional to the risk premium. In fact, it is the foregone stream of benefits, which could be much larger than either the capital costs or the risk premium.

There is a further subtlety offered by a theory of capital. When there is human or social capital involved, the monetization of a stream of benefits could appear quite small in comparison with the value of physical capital. But when the stream of benefits generated by that human or social capital is perceived (accurately or not) to be the only possible source of income, the marginal

value of the stream of benefits generated by that human or social capital can be extremely high – possibly even infinite. Consider small, tightly-knit, and rural mining or fishing communities which enjoy only a small, sporadic source of income. Social capital plays a vital role in risk-sharing and information-sharing, and makes sustenance on small and sporadic incomes possible. But were the small and sporadic income source to dry up completely, there would be individuals in these communities whose only capital was specific to a disintegrating network of people, and for whom there are no other possible means of generating a stream of benefits. A town of miners and fishers and their families may perceive that they have no prospect of re-deploying their practices, the jobs, or their social connections. In such situations, the stream of benefits generated by their human and social capital could have infinite value, because of the absence of alternatives.

The Role of Law and Lawmaking in Promoting and Protecting Capital

The word "capital" has an almost universally favorable connotation. Economic growth models generally model growth as a positive function of capital.[36] If one asks (as numerous economists have asked) the deceptively complicated question of why some countries are so much richer and produce so much more than others, one can easily rule out the availability of labor as a limiting input, since developing countries are awash in cheap labor. What is left? Capital. Among economists, capital is universally regarded as positively related to economic growth.[37]

This worship of capital may be more pronounced in affluent Western societies, but even in developing societies there is a recognition that wealth cannot be accumulated without the acquisition of some form of capital. Hernando de Soto's *Mystery of Capital*[38] explores the reasons why people in developing countries, despite having a significant quantity of assets, do not accumulate wealth the way that people in developed countries do. His theory is that the assets of poor people in developing countries cannot be leveraged as capital the way that they are in developing countries. Poor land registries, in this story, are the problem, creating legal uncertainty that cripples the value of land as capital. Even if this theory does not explain in large part the persistence of poverty in developing countries, this piece of serious scholarship is an indication of how capital is widely viewed as being the predicate to wealth accumulation, and not a source of harm.

A variety of institutions in developing and developed countries seem to also embody an assumption that capital is an unalloyed good. A fair amount of government policy seems to be oriented towards assisting with the acquisition of capital, especially small businesses.[39] There is even a Washington-based advocacy group that extols the virtues of capital formation for its

36 *See, e.g.,* George N. Hatsopoulos, Paul R. Krugman, and Lawrence Summers, *U.S. Competitiveness: Beyond the Trade Deficit,* 241 SCIENCE 299, 301-02 (1988) (arguing for a broader definition of capital to explain relative American lagging in productivity growth); Solow, *supra,* note 8, at __; Mankiw, *supra,* note 13, at 292 ("One way to raise the capital share above one-third is to argue that there are positive externalities to capital.").

37 *Id.*

38 HERNANDO DE SOTO, THE MYSTERY OF CAPITAL (1999).

39 David M. Lynn, *Global Capital Markets & the U.S. Securities Laws 2012: Raising Capital in an Evolving Regulatory Environment,* Corporate Law and Practice Course Handbook Series (2012).

own sake, the American Council for Capital Formation.[40] Economic policy often seems to embody an assumption that if it can contribute to something with broadly-distributed benefits, like low electricity prices or low commodity prices, it should do so. It is the formation of capital, everyone seems to believe, that unleashes the industry and entrepreneurship of individuals and firms in an economic society. Whenever capital produces a broadly-distributed stream of benefits, it seems sensible to marshal the resources of government in forming capital.

Capital is even recognized as critical to the nobel goal of poverty alleviation. The 2006 Nobel Peace Prize – not the Nobel Prize in economics – was awarded to Muhammad Yunus for his pioneering work in microfinancing small projects in poor communities. Yunus started his Grameen Bank in 1976 by lending as little as $20 to Bangladeshi farmers.[41] It now operates in over 43 countries, including the United States, and has lent a cumulative total of $8.7 billion.[42] The Grameen Foundation leverages money by making small loans, often by working with local microfinance organizations. Poor people are no less credit-worthy, Yunus finds, just because they lack capital that can be offered up as collateral. Besides deSoto's prescription for better land registries and less bureaucracy,[43] Yunus's Grameen Bank is exactly what de Soto would have ordered: loans for those whose assets are not liquid enough to serve as collateral, for the acquisition of income-generating capital. Capital is good.

That is, capital is good except when it isn't. The thesis of this paper is that the stickiness and inflexibility of capital is a fundamental underlying reason that all kinds of societies, rich and poor, allow environmental problems to persist. Not only have long-lived and inflexible coal-fired power plants managed to impose a plethora of harms up and down the supply chain,[44] but also prospectively threaten to lock the future into global climate change. In 2008, coal combustion accounted for 13 billion metric tons of CO_2,[45] about 43 percent of the total emissions worldwide of CO_2.[46] It is perhaps a testament to the sluggishness of capital that most forecasts of future energy production and greenhouse gas emissions project an *increase* in coal combustion and coal combustion-related emissions.[47] It is not only the existing stock of coal-fired power plants that comprise the sluggish capital, but the human and social capital that is locked into a way of doing things, that may ultimately consign the world population to living on a climate-changed planet.

What does law do to exacerbate this problem? Like other institutions around it, law seems to incorporate an assumption that it is supposed to assist in the formation of capital, and strive to

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40 American Council for Capital Formation, url: http://www.accf.org/home.php.

41 World Resources Institute, http://www.wri.org/stories/2006/10/microfinance-entrepreneur-receives-nobel-prize

42 Grameen Bank, Historical Data Series in USD, http://www.grameen-info.org/index.php?option=com_content&task=view&id=177&Itemid=144

43 de Soto, *supra,* note 38 at

44 Robert Mendelsohn, Nicholas Muller, and William Nordhaus, *Environmental Accounting for Pollution in the United States Economy,* 101 The American Economic Review 1649, (2011)

45 U.S. Energy Information Administration, International Energy Outlook 2011, http://www.eia.gov/forecasts/ieo/pdf/0484%282011%29.pdf p. 139 .

46 *Id.*

47 U.S. ENERGY INFORMATION ADMINISTRATION, AEO2012 EARLY RELEASE OVERVIEW __ (Table 1) (2011); online: http://www.eia.gov/forecasts/aeo/er/.

avoid interfering with the operation of that capital. Most interestingly, certain aspects of the law seem to have striven to protect the value of capital.

For a time, the U.S. Supreme Court seemed extremely interested in scrutinizing land use regulations and examining whether they were so onerous as to constitute a regulatory taking of property that triggers a Fifth Amendment requirement of compensation.[48] The re-emergence of this line of jurisprudential inquiry came as something of a surprise to the legal academy, and has even gone further, extending regulatory takings into areas not involving land use at all.[49] Implicit in regulatory takings jurisprudence was a concern that land use regulations were posing a threat to capital. At bottom, regulatory takings law sought to protect *expectation interests.* A leading case in regulatory takings jurisprudence, *Penn Central Transportation Co. v. New York City,*[50] set out a three-factor analysis for whether a regulation had gone "too far"[51] so as to require compensation: the character of the government action, economic impact upon the claimant, and the "interference with investment-backed expectations."[52] Although the jurisprudence and the literature do not explicitly say so, investment-backed expectation interests are interests in a stream of benefits stemming from the exploitation of capital. The *Penn Central* Court held that "[t]he principle that underlies this doctrine is that, while most burdens consequent upon government action undertaken in the public interest must be borne by individual landowners as concomitants of 'the advantage of living and doing business in a civilized community, some are so substantial and unforeseeable, and can so easily be identified and redistributed, that justice and fairness require that they be borne by the public as a whole."[53] In the numerous regulatory takings cases that followed *Penn Central*, it is obvious the extent to which courts have paid careful attention to what owners of capital expect, and could reasonably expect from their capital, and the extent to which government and the law may interfere with those expectations. In the much-discussed case *Lucas v. South Carolina Coastal Council,*[54] the Court found that a state statute, the Beachfront Management Act,[55]

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48 5th Amendment provides that "No person shall be held to answer for a capital, or otherwise infamous crime, unless on a presentment or indictment of a Grand Jury, except in cases arising in the land or naval forces, or in the Militia, when in actual service in time of War or public danger; nor shall any person be subject for the same offense to be twice put in jeopardy of life or limb; nor shall be compelled in any criminal case to be a witness against himself, nor be deprived of life, liberty, or property, without due process of law; nor shall private property be taken for public use, without just compensation**."** See *Pennsylvania Coal Co. v. Mahon*, 260 U.S. 393 (1922) is the first case in which a regulation that had "gone too far" in affecting the use of land was treated as a taking similar to actual physical apprehension or occupation of land.

49 *Armstrong v. United States*, 364 U.S. 40 (1960) the court ruled that apprehension by the government of contractual securities (liens) owned by a private company could potentially represent a taking; *Manitoba Fisheries Ltd. v. The Queen,* 1 S.C.R. 101 (Supr. Ct. Can., 1979) in this case the loss of "goodwill" (customers and suppliers built up over years) was determined to be an asset, therefore the loss of his business was found to be a taking; *Eastern Enterprises v. Apfel*, 524 U.S. 498 (1998) the court found a retroactive economic burden, requiring that the Eastern Enterprises made contributions to pensions for workers employed in the 1950s and 1960s, interfered with the companies investment backed expectations and constituted a taking.

50 438 U.S. 104 (1978).

51 Central language adopted from a seminal regulatory takings case, *Pennsylvania Coal v. Mahon,* 260 U.S. 393, 415 (1922).

52 *Penn Central*, 438 U.S. 104 at 124.

53 *Penn Central*, 438 U.S. 104 at ___.

54 505 U.S. 1003 (1992).

55 Cite statute

effectively deprived a land developer of "all economically viable use of the land."[56] In holding the Lucas's investment-backed expectations were clearly frustrated, the Court stated that

> at the time Lucas acquired these parcels, he was not legally obliged to obtain a permit from the Council in advance of any development activity. His intention with respect to the lots was to do what the owners of the immediately adjacent parcels had already done: erect single-family residences. He commissioned architectural drawings for this purpose (emphasis added).[57]

Quite explicitly, Justice Scalia's opinion casts the regulatory takings focus on the effects of the landowner. Very little was said about the common law police power that has served as the general regulatory authority for state and local governments for decades.[58] Clearly, with the *Lucas* case, the Supreme Court had swung its attention over the landowner, and her reasonable expectations of return on property investment, as the focus of regulatory takings cases.[59]

One could argue (many have) that property law in particular has gotten carried away with thinking about rights, and neglecting correlative duties.[60] When the Court has addressed the harm-prevention goals of a land use restriction, it has scrutinized the restrictions and their effectiveness, taking a skeptical view of the assertions of the land use regulatory agencies. In *Dolan v. City of Tigard*,[61] the Court held that a set of conditions that a city attached to a land improvement permit were too speculative, and lacked an "essential nexus" to the stated environmental goals of the city.[62] In *Lucas,* Justice Scalia seemed to limit the extent of non-compensable regulation to those that were common law nuisances to begin with.[63] Critical of Justice Blackmun's reliance on the common law police power to permit harm-preventing land use restrictions, Justice Scalia writes that "[i]n Justice Blackmun's view, even with respect to regulations that deprive an owner of all developmental or economically beneficial land uses, the test for required compensation is whether the legislature has recited a harm-pre venting justification for its action….. Since such a justification can be formulated in practically every case, this amounts to a test of whether the legislature has a stupid staff."[64] This deference to landowners on the one hand, and skepticism towards the regulator on the other hand, is analogous to the one-sidedness with which we view the benefits and the costs of capital. The law, as we do, only seems to appreciate the benefits of capital formation, and not so much the costs.

The law is perhaps no more obsessed with capital than it is in the area of regulated utilities. Regulated utilities are only permitted by their regulators to charge ratepayers in accordance with the general formula

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56 505 U.S. at __.
57 505 U.S. at ___.
58 Euclid v. Ambler Realty, 272 U.S. 365 (1928).
59 Need more work on this
60 505 U.S. at __. **[more]**
61 512 U.S. 374 (1993).
62 512 U.S. at ___.
63 505 U.S. at __.
64 505 U.S. at __.

$$R = O + B \bullet r$$

where R is the total allowed revenues (to be divided up among ratepayers), O is the allowed operating expenses, B is the company's "rate base," all those capital assets from which the company is permitted to earn a return, and r is the permitted rate of return. Given this regulatory structure, it is in the company's interest to engage in "capital stuffing," expanding the rate base as much as possible in order to maximize their permitted revenues. This bias is commonly known as the "Averch-Johnson effect."[65] Although additions to the company's rate base must be "prudently incurred,"[66] the reality is that the company often has the upper hand in a ratemaking setting in which it seeks to justify its expenditures to a regulator.[67] Empirical evidence for the Averch-Johnson effect is not unambiguous, but generally supportive.[68]

The law provides other examples of biases in favor of capital formation and protection of the value of capital, to the detriment of environmental quality:

> *Grandfathering* is a common practice in lawmaking, especially in environmental lawmaking.[69] Environmental law seems particularly focused on avoiding negative impacts on capital. Because environmental regulation can severely affect the value of capital, environmental laws have often exempted existing capital from new laws or regulations. This creates a two-tiered treatment of capital, one for new capital and one for existing capital.[70] The irony is that this two-tiered treatment itself creates a valuable new asset: the grandfathered status.[71] Exemption from new, stringent environmental laws or regulations can be very valuable assets. Preserving the value of that asset also becomes an objective of owners of grandfathered capital.[72]
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> *Tax credits for capital in extractive industries*. Owners of capital in extractive industries seem to enjoy very generous tax benefits. For fossil fuel firms, a very significant tax benefit is the percentage depletion deduction, which can be used instead of a standard cost

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65 Harvey Averch & Leland L. Johnson, *Behavior of the Firm under Regulatory Constraint*, 52 AM. ECON. REV. 1053 (1962).

66 Richard A. Posner, *Natural Monopoly and Its Regulation*, 21 STAN. L. REV. 26 (1969).

67 For a discussion of the administrative law surrounding ratemaking cases, *see,* Jacqueline Lang Weaver, *Can Energy Markets be Trusted? The Effect of The Rise and Fall of Enron on Energy Markets,* 4 Houston Bus. & Tax L. J. 1 (2004); Jim Rossi, *The Political Economy of Energy and its Implications for Climate Change Legislation,* 84 Tul. L. Rev. 379 (2009).

68 *See*, e.g., Leon Courville, Regulation and Efficiency in the Electric Utility Industry, 5 BELL J. ECON. & MGMT. SCI. 53 (1974); H. Craig Peterson, An Empirical Test of Regulatory Effects, 6 BELL J. ECON. & MGMT. SCI. 111 (1975); Robert M. Spann, Rate of Return Regulation and Efficiency in Production: An Empirical Test of the Averch-Johnson Thesis, 5 BELL J. ECON. & MGMT. SCI. 38 (1974).

69 Shi-Ling Hsu, *The Real Problem With New Source Review,* 36 ENV. L. REP. 10095 (2006); Jonathan R. Nash and Richard L. Revesz. *Grandfathering and Environmental Regulation: the Law and Economics of New Source Review,* 102 NW. U. L. REV. 1677 (2007); Jonathan Masur and Jonathan R. Nash, *The Institutional Dynamics of Transition Relief,* 85 N.Y.U. L. REV. 391 (2010).

70 Robert N. Stavins, *Vintage-Differentiated Environmental Regulation,* 25 STAN. ENVTL. L:J. 29 (2006).

71 Hsu, *supra,* note 69, at __

72 Hsu, *supra,* note 69, at __

depletion deduction to expense intangible drilling expenses (such as wages and fuel) to permit a tax deduction based on the value of resources sold instead of the decrease in the value of the capital. Since the value of the resource can often be depleted more quickly than the value of capital, this tax benefit allows a front-end-loaded deduction and an effective tax deferral. Also, fossil fuel firms can use a double declining method to measure the depreciation in value of drilling equipment, again front-end-loading tax deductions providing a potentially huge tax deferral.[73] In addition to tax benefits for exploration capital, investments in clean coal and alternative coal facilities enjoy investment tax credits. Investments in clean coal facilities enjoy a 20% tax credit, and investments in "alternative coal" 15%.[74] The rationale for these preferences for capital seem to be that abundant energy creates economic growth, so the job of tax law is to assist in the formation of energy capital.[75] Again, this elides a variety of environmental externalities created by different stages of production.

Incentives for mining. Few industries create as many environmental externalities as the mining industry.[76] But apparently following in the same industrial-development rationale as that animating the energy industry, a variety of favorable tax provisions seem to facilitate the formation of mining capital. For example, Canadian federal tax law allows small mining companies to pass capital losses up to parent companies, often richly-capitalized acquiring companies.[77] The advantage of having this benefit of "flow-through" shares, which allow for small mining companies to sell, at a premium over equity, tax deduction rights along with equity in the company, is that the capital loss that cannot be exploited by a small mining company – because it has no income to offset – can be passed through to a large mining company that can. Thus, the capital loss tax benefit is formally commodified and made into a valuable asset. Empirical research suggests that this has led to overinvestment in capital in the mining industry, and below-market returns to mining capital, when compared with the petroleum industry.[78]

Capital gains tax rates. Tax codes generally tax capital gains at a rate that is lower than income (corporate or person). Gains from the sale of assets that are classified as "capital" are taxed at a lower rate than income from labor.[79] Even residences are taxed at a capital gains rate, and only after, in the U.S., a $500,000 exemption for principal residences.[80] It is tempting to conclude this is yet another legal preference for capital as opposed to other forms of expenditure. But it could also be argued that the fact that capital appreciation is

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73 Gilbert E. Metcalf, *Investment in Energy Infrastructure and the Tax Code,* 24 TAX POL'Y & ECON. 1, 6-7 (2010).

74 Gilbert E. Metcalf, *Federal Tax Policy Towards Energy,* 21 TAX POL'Y & ECON 145, 162 (2007).

75 Yoram Margolioth, *Not a Panacea for Economic Growth: the Case of Accelerated Depreciation,* 26 Va. Tax Rev. 493 (2007).

76 United Nations Environment Program, Principles for Responsible Investment, Universal Ownership: Why Environmental Externalities Matter to Institutional Investors 27 (Chart 3) (2011); online: http://www.unpri.org/files/uop_long_report.pdf.

77 Income Tax Act – R.S.C., 1985,c.1(5th Supp.) (Section 40 (2)b)

78 Gordon Lenjosek, *A Canadian Tax Incentive for Equity Investments in Mining,* 79 New Directions for Evaluation 117, __ (1998).

79 Income Tax Act – R.S.C., 1985,c.1(5th Supp.) (Section 38)

80 26 USC § 121 - Exclusion of gain from sale of principal residence

taxed *at all* biases capital decisions. It could be that capital gains taxes discourage firms and individuals from disposing of appreciated capital, in order to defer or avoid payment of capital gains taxes.[81] On the other hand, deducting capital losses from depreciated capital could be an incentive to dump capital.[82] Whether tax treatment of capital introduces a bias for or against the formation and retention of capital is a complicated topic. However, the very complicated segregation of capital as opposed to other forms of income seems to invite gaming and investment decisions that could lead to over-capitalization.

All of these laws and regulations confer some preferential, or at least special status on physical capital. But what about social and human capital? It is less obvious, but potentially more important, that law, regulations, government policy and even private firms have demonstrated tendencies to protect human and social capital. This might occur more obviously in politics, whereby rural communities are often held up as examples of parties that might be harmed by some environmental regulation. For example, one source of surprisingly virulent opposition comes from coal mining communities themselves. Voters in West Virginia, the site of many small coal-mining communities, has swung violently toward anyone but President Obama, still widely hated for his perceived hostility to coal.[83] In the state's Democrative primary, incarcerated Texas felon Keith Judd outpolled Obama in several large counties.[84] But why? Would be so difficult to buy out, for example the entire state of West Virginia? The Gross State Product of West Virginia in 2010 was about $65 billion.[85] Given the environmental externalities from coal combustion, would it be so prohibitively expensive to severely curtail coal mining and compensate displaced coal mine workers and communities?[86] And what is it about coal mine workers and their communities that make them so invested in a livelihood that is so fraught with danger and disease?[87]

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81 Janet Meade, *The Impact of Different Capital Gains Tax Regimes on the Lock-in Effect and New Risky Investment Decisions,* 65 THE ACCOUNTING REV. 406 (1990).

82 Philip R. Brown, Andrew Ferguson, and Sam Sherry, *Investor Behaviour in Response to Australia's Capital Gains Tax,* 5 ACCOUNTING & FINANCE 783 (2010).

83 Manuel Quinones, *Appalachia Fights Back Against President's Coal Policies,* ENERGY & ENVIRONMENT DAILY, May 10, 2012.

84 *Id.*

85 U.S. Bureau of Economic Analysis, Gross Domestic Product by State, http://www.bea.gov/regional/gdpmap/GDPMap.aspx (accessed May 5, 2012).

86 Muller, et al, *supra,* note 34, at 1665 (Table 2, showing Gross External Damages of $53.4 billion per year). Note Muller et al, only calculate market damages, so that actual damages can be assumed to be much higher.

87 U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, *Coal Mine Dust Exposures and Associated Health Outcomes A Review of Information Published Since 1995,*DHHS (NIOSH) Publication No. 2011–172 (2011). Pneumoconiosis. Online: http://www.cdc.gov/niosh/docs/2011-172/pdfs/2011-172.pdf; Figure 14 shows age-adjusted death rates (per million) for decedents age ≥25 years with coal workers' pneumoconiosis as the underlying cause of death—United States, 1968–2006, Figure 15 Years of potential life lost (YPLL) before age 65 and mean YPLL per decedent for decedents aged ≥25 years with coal workers' pneumoconiosis as the underlying cause of death—United States, 1968–2006. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, *Work* Related Lung Disease Surveillance Report 1994, DHHS (NIOSH) Publication No. 94-120 (1994). http://www.cdc.gov/niosh/docs/94-120/pdfs/94-120.pdf. Table 3-1. identifies coal mining as occupation on death certificate in 69% of pneumoconiosis related deaths between 1985-1990.

The answer must be that there is embedded capital in coal mining. This not only includes the physical equipment marshaled for coal mining operations, but also the physical infrastructure built to service the coal mining industry. Less obviously, and potentially more importantly, a tremendous amount of social and human capital is wrapped up in coal mining, and its ancillary businesses. Coal mining, like ranching, fishing, and logging, do not generally require workers with a large amount of human capital. It is generally carried out in rural communities with relatively little human capital, and generally fewer resources with which to purchase physical capital. In the parlance of this paper, *social capital* could be the only capital to which coal miners and their communities have access. In such a context, a call to regulate coal mining poses a serious threat to this social capital, and because it may be the only means of generating income possessed by coal miners and people in coal mining communities, it may pose an existential threat to these communities. Ending this stream of benefits suggests an end to their *raison d'etre*. Similarly, rural ranching, mining, farming, fishing and logging towns also take place in rural communities characterized by low human capital and rich social capital.

This social capital may be the most "sticky" of all, since it may be the only form of capital for some individuals and communities, and may appear to provide the only possible stream of benefits for them. In the case of coal-mining communities, West Virginia had the luck of being represented by one of the most powerful legislators in the history of the United States Senate, former majority leader Robert Byrd. In a five-decade-long career in the Senate, Byrd regularly championed coal mining communities, know full well that regulation of air pollution would destroy these communities:

> Arguments have been made that costs and dislocations caused by the compliance requirements of this legislation pale in comparison to the public health benefits. But what will we really have accomplished if we succeed in removing certain pollutants from the air and at the same time level the economies of whole communities and regions? Is that progress? Is that kind of devastation not even to be considered here? Is it our intention to mindlessly punish communities that mine coal or produce steel or chemicals or automobiles? … When mines are shut down, not only do miners and their families suffer but whole communities also suffer…. In a region of our Nation already suffering from high unemployment, such losses would be devastating, creating a series of ghost towns through northern Appalachia and bringing economic ruin to thousands of American families….[88]

What capital does, then, is to set up a particularly acute public choice problem – the interests of capital owners are extremely and intensely concentrated, as opposed to those that would benefit from environmental protection that would reduce the value of capital. If anything, sticky human capital and social capital, when possessed by people and communities with few other forms of capital and few other possibilities, provide even more compelling reasons to resist change than physical capital. This dependence on continued exploitation of capital can generate psychological effects that defy objective facts. Desperate owners of threatened capital

88 136 Cong.Rec. S531-01, Tuesday, January 30, 1990.

can be expected to zealously reject notions that their practices and their capital have become anachronistic.

How Much Capital is Too Much Capital?

While the foregoing discussion recasts capital in a different light, it begs the question of exactly when this preference for capital becomes a societal mistake. When, exactly, does a preference for capital formation become a problem? When do the costs of operating capital outweigh the benefits generated by the capital? There is a static answer to this question, and a dynamic one. The static answer is an incomplete one.

The static answer to this question is a familiar one, and in a sense is orthogonal to the question of how much capital is optimal. A static environmental analysis simply postulates that when there is a production process with an unpriced negative environmental externality, there will be an oversupply of the product leading to an overall societal economic loss. The familiar deadweight loss triangle reflecting an oversupply of a product, with unpriced external costs, is a measure of the economic loss of putting up with an inefficiently large quantity of pollution. Static economic analysis, however, focuses on the suboptimal quantity of the underlying product, not on the capital inputs to production, which explain persistence. Were one to limit oneself to a static analysis, it would be a mystery as to why the winners of environmental policy change could not just compensate the losers.

The dynamic analysis is more interesting for two reasons. First, a dynamic analysis solves the mystery of how winners of policy change are unable to compensate the losers. As argued above, policy losers may only possess capital with narrow applications – sticky capital – and may perceive that they lack alternatives; under such circumstances, the value of capital will be understated in a static analysis. Thus the answer to the questions of why some environmental problems are so persistent and environmental policy reform so difficult might be better answered using a dynamic analysis.

Second, a dynamic analysis delves into the most serious of environmental consequences: irreversible environmental damages. A dynamic analysis can answer the question in these terms: when capital is persistent enough and degrades the environment quickly enough, it may exceed the environment's capacity to absorb degradation, and cause irreversible damage. In other words, it is a matter of whether the capital is "sticky" enough and harmful enough to overwhelm the capacity of the environment to withstand its harms. I illustrate this by reference to an analysis of a fishery. In drawing an analogy between overfishing and polluting, I model explicitly the economic and ecological relationship between capital and the environment.

The Fishing Model

Perhaps the most important unpublished paper in the field of resource economics is Jim Wilen's *Common Property Resources and the Dynamics of Overexploitation: the Case of the*

North Pacific Fur Seal,[89] which chronicled the tribulations of the fur sealing industry and of course, the fur seal populations themselves. Wilen's novel insight was that the capital structure of the fur sealing industry explained the boom and bust cycles that characterized fur sealing in the late nineteenth and early twentieth centuries.[90] What was needed to model the fur seal industry was not a static model of supply and demand, but a dynamic economic model that took into account the life of sealing boats and their ability to be used for other purposes. Wilen's dynamic model explained boom and bust years in terms of the rapidity with which fur sealers exited the industry when fur seals were scarce and hard to find (because of overexploitation) and re-entered once fur seal populations had recovered, and were somewhat easier to find. Wilen's work is one of the most original interdisciplinary works in the field of recourse economics. Not only does the paper create a mathematical representation the critical *dynamics* of fisheries economics, and not only does it create a mathematical representation of the population dynamics of fur seals, but it integrates the two models to explain the inter-relationship between fur seal fishers and fur seals in a single, elegant *bioeconomic* model.

This story is in part the story of almost every single instance of overfishing, ever. The boom and bust cycles that have characterized so many fisheries and fishing communities worldwide is, in a dynamic world, the product of the "stickiness" of capital that renders adjustments to changing conditions more sluggish than a static model would suggest. Because physical capital in the form of fishing boats can be difficult to redeploy in pursuit of a different fish species, the exploitation of a fish species can persist well beyond the point at which its scarcity renders it suboptimal to pursue, at least relative to other species. This dynamic is the story of the persistent and sometimes rapid descent of most fisheries into a depleted state, and has been one of humankind's most vexing problems. Even as stricter regulatory controls and shorter fishing seasons have sought to curb the race to fish, fishermen have circumvented almost all of these restrictions and continued to usher their target species onwards towards extinction. It has almost all been due to the nature of fishing capital – physical in the form of boats, human in the form of fishing know-how and knowledge of fish species, and social in the form of the cooperative networks that form the fabric of fishing communities that lack an alternative industry.

Modeling the dynamics of fisheries economics and biological populations is much more complicated than static economic models. Supply and demand curves represent just a starting point, as dynamic models do not so much attempt to pinpoint an equilibrium at a moment in time as they do try to identify an optimal *path* of behavior over time. So for dynamic modelers, the objective is to make a series of predictions rather than just one – what economic actors do at time *t, t+1, t+2,* etc.

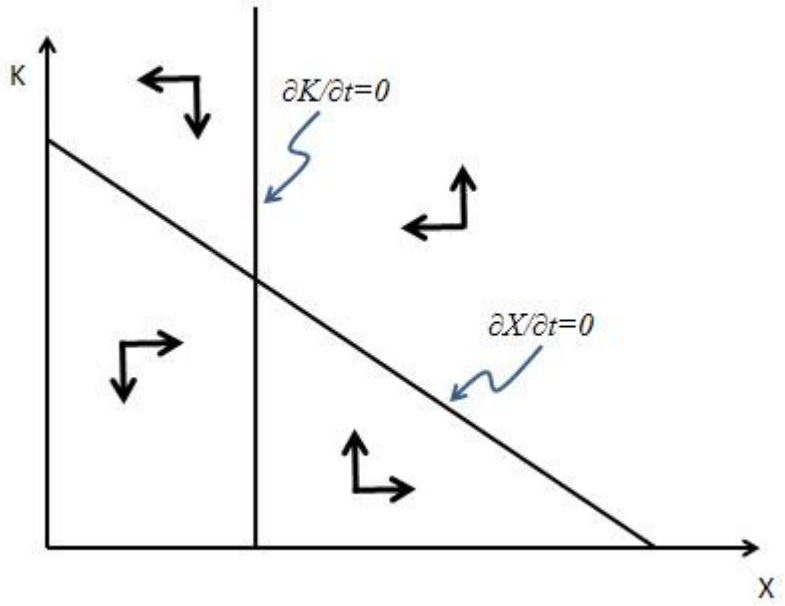
Dynamic models are often depicted as an interaction between the two variables of interest, rather than one variable of interest over time. In the fisheries case, the variables of interest are most often fish stock and capital stock. In the Wilen bioeconomic model of the fur seal

89 James Wilen, *Common Property Resources and the Dynamics of Overexploitation: the Case of the North Pacific Fur Seal,* University of British Columbia, Programme in Natural Resource Economics, Resources Paper No.3 (September 1976) (on file with author).

90 Wilen, *supra,* note 89, at __.

industry, the fur seal population is modeled as a logistic growth model, in which absent any harvesting pressures, large populations (in which fur seals have to compete for resources) grow slowly and small populations (in which resources are plentiful) grow slowly.[91] The change of capital stock over time is modeled as a simple linear function of economic variables such as price and marginal cost of harvesting, and a linear function of a "capital sluggishness" parameter, which reflects the difficulty of re-deploying capital for an alternative purpose. The resulting interrelationship between fish stock and capital stock is graphed in two-dimensional space of capital stock changes versus biological stock, and is known as a *phase diagram*. Wilen's phase diagrams is shown below as figure 3. The equations and derivations of this phase diagram are set forth in Appendix A.

Fig. 3



A phase diagram is more useful for showing an interrelationship between two variables and for modeling a path to equilibrium. By breaking up the graph in to four spaces, it also illustrates how relative abundance or scarcity of each of the variables leads to changes in stock, and how rapidly these changes in stock occur, relative to the other variable. This is interesting because it can illustrate just how "sticky" capital is. It is too sticky when it changes slowly relative to the environment's ability to adapt.

As opposed to a typical graph over time of one or more variables, a phase diagram such as this shows an equilibrium as a distinct point – the intersection of the two bisectors – rather than a leveling off of activity over time. In the fur seal example, a phase diagram illustrates the path of capital stock changes and fur seal stock changes. Whether an equilibrium is reached at all, or

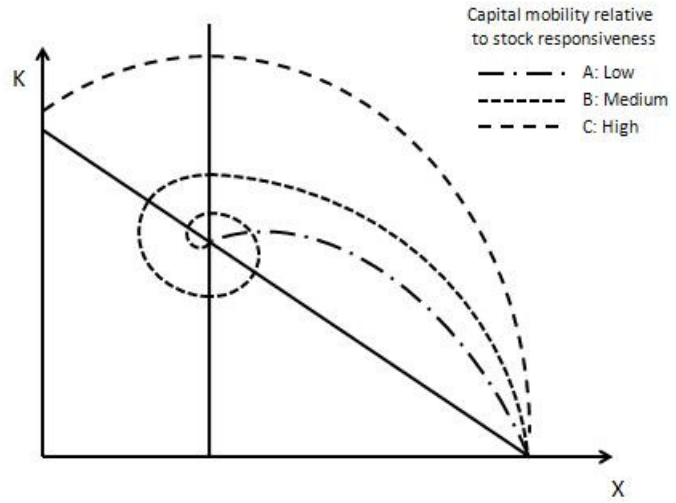
91 Wilen, *supra,* note 89 at __

whether the capital stock overwhelms the ability of fur seals to sustain a population at all depends upon, in addition to the usual economic variables (such as price and cost), two other critical parameters: (i) the rapidity with which the capital stock responded to economic variables, and (ii) the rapidity with which the stock of fur seals responded to biological conditions and harvesting pressure. In other words, whether fur seals are hunted to extinction depends whether the capital stock enters the fishery much more quickly than the fur seal population rebounds from overharvesting.

Three possible paths are shown in Fig. 4 below, all from Wilen's paper. They are as follows:

Case A (low capital mobility, high fur seal stock responsiveness)
Case B (capital mobility similar to fur seal stock responsiveness)
Case C (high capital mobility, low fur seal stock responsiveness)

Fig. 4



Cases A and B represent situations in which a harvesting and population equilibrium is reached. In case B, the equilibrium is only reached after several bouts with temporary overharvesting – incidences in which harvesting takes place to the left of the capital bisector, and in which the stock of fur seals is below the equilibrium point. Case C is the interesting case, as it illustrates the situation in which the ability of fur seals to rebound in response to overharvesting pressures is not robust enough, and a sufficiently mobile capital stock will harvest the fur seals into extinction.

The implications of Wilen's bioeconomic analysis reverberate well beyond the fisheries context. Wilen's applied insight of dynamic economic analysis speaks volumes about the dynamics of environmental damage, the ability of the environment to absorb it, and lends novel insights as to why we tolerate the persistence of environmental problems for much longer than seems rational. The Earth's capacity to absorb pollution, and degree and persistence of the overharvesting, or depletion, of this capacity, are analogous to the fur seal population. What

this bioeconomic model illustrates is how capital, once deployed for a particular use, cannot simply be unplugged and abruptly shut down.

In Wilen's model, a high mobility of capital and a low stock responsiveness rate (meaning that an overharvested population does not recover quickly) is the most dangerous combination, because starting from a point of zero exploitation, capital can quickly enter a fishery and exert pressure on a stock and overexploit it so quickly that the slow-growing stock will not have the opportunity to recover. In that "high capital mobility" scenario, capital can race into the fishery and overwhelm a target fish population and never allow the population a chance to recover. In this scenario, the most dangerous environmental outcome, overharvesting depletes the fish stock and makes harvesting more expensive. However, scarcity also drives prices up. These combined counteracting effects serve to muddle price signals so that capital does not exit the crashing industry as quickly as one would expect.

It is possible, moreover, to think of capital mobility asymmetrically: the speed with which it enters and the speed with which it exits. It could also be that capital enters quickly but exits slowly, so that capital could be "slick" going in, and "sticky" coming out, so that boats rush in, but once in, are stubbornly stuck in pursuit of a fish species long overfished. In fact, the thesis of this paper is that low capital mobility is the problem: given what is eventually learned about the harms from operations, capital *exits* an industry too slowly, persisting, along with its polluting byproducts, longer than would be socially optimal. If it is too slow, then the capital could persist to a point at which environmental degradation is complete, catastrophic and irreversible. In the fisheries context, it is the capacity for capital to rush in that poses the threat of hunting to extinction; in a pollution context, it is the "stickiness" of capital that poses a threat to overwhelm the capacity of the environment to absorb harm.

There are some other differences between the fisheries example and the pollution example. While Wilen focuses his analysis on the physical capital involved in fishing – boats and gear – this analysis in the pollution context highlights the need to account for human and social capital as well. Any income stream is made possible by a combination of physical, human, and social capital, and all of this capital is, to varying extents, worth defending for the stream of benefits that flow from them. Valuable capital which generates large income streams are obviously worth defending. But less obviously, even capital with a small monetary value may inspire vigorous defense if it is the only capital possessed by people, groups, or communities. It is important to consider a variety of forms of human and social capital.

The most critical difference, however, that in the fisheries example, what drives capital in and out of the fishery are economic factors, such as the price of the target fish species and the ease of catching it. These are, of course, related to the abundance of the target fish species. But there is no regulator in the fisheries example. In the fishery context, the bioeconomic relationship between capital and fish provides a built-in feedback mechanism that signals to fishers that overharvesting is occurring: the difficulty of catching fish becomes so great that the capital would be more profitably deployed in pursuit of another target fish species, or another aquatic adventure altogether. This price signal may or may not be strong enough to drive capital out quickly enough to allow the species to recover. But eventually capital exits, and does so without the impetus of regulation.

By contrast, in the polluting context, there is no built-in feedback mechanism to drive out capital. The only significant signal sent to polluters to redeploy their capital must be a regulatory one. The question is whether the regulatory signal is strong enough to overcome the propensity of capital to resist change. Just as the price signal from a crashing fishery must be strong enough to drive capital out, a regulatory signal from a degrading environment must be strong enough to drive capital out of the polluting activity. This places a tremendous amount of pressure on the regulator. The regulator must define the equilibrium level of pollution, and define at a low enough level so that polluters do not rush in with massive amounts of capital and overwhelm the ability of the environment to absorb the pollution. At the same time, pollution regulators face intense political pressure from polluters to define the equilibrium at a level that polluters find less costly.

A dynamic analysis focused on a problem like fisheries also highlights a factor that receives little attention in the environmental policy realm: the ability of the environment to recover, or the ability of the "stock" of environmental quality to bounce back from insult. This is particularly important in the area of climate change, since the longest-lived and most important (so far) greenhouse gas, carbon dioxide, has an effective global warming life of about a century,[92] giving rise to very significant stock effects. The fact that emission of a ton of carbon dioxide is an externality that will last a century is certainly an effect that must be accounted for in any model that seeks to answer the question of "how much capital is too much?"

Conclusion

This analysis expands theories of environmental degradation and regulation into new territory. Beyond public choice and regulatory capture theories, and beyond information asymmetry theories, and beyond various psychological theories of why people avoid dealing with environmental problems, a theory of capital introduces a new variable not previously considered carefully.

The prominence of physical, human, and social capital requires that some explicit treatment of actors at the individual, firm or sub-industry levels, so as to identify incentive structures at a more disaggregated scale than the typical unit of observation. At the firm level, capital is just another aspect of an agency problem; a firm may find it difficult to change practices if certain firm employees or groups have too much of their human or social capital inextricably wrapped up with an obsolescent practice. This mode of analysis is a way of more closely examining the nature of the divergence of interests that create an agency problem.

92 T.J. Blasing, Recent Greenhouse Gas Concentrations, Carbon Dioxide Information Analysis Center note 4)" For CO_2 the specification of an atmospheric lifetime is complicated by the numerous removal processes involved, which necessitate complex modeling of the decay curve. Because the decay curve depends on the model used and the assumptions incorporated therein, it is difficult to specify an exact atmospheric lifetime for CO_2. Accepted values range around 100 years.") (Updated February 2012) DOI: 10.3334/CDIAC/atg.032; online: http://cdiac.ornl.gov/pns/current_ghg.html.

Writ larger, the problem of dealing with environmental externalities is, in a macro sense, an agency problem. But the exact nature of the divergence of interests has not been examined very thoroughly. This analysis embarks upon a line of query that seeks to model sub-firm or sub-industry, or industry interests over time, and derive a relationship between these interests and the environmental externalities created by their polluting behavior. This paper is the beginning of an exploration of the role of physical, human, and social capital in perpetuating polluting behavior long after it is recognized as generating a net loss to society.

Appendix A

Wilen's bioeconomic model incorporates an logistic growth model for fur seals:

$$X(t) = \frac{\bar{X}}{1 - \left(1 - \frac{\bar{X}}{X_0}\right) e^{-gt}}$$

in which *X(t)* is the stock level at any time *t*, $\bar{X}$ is the maximum stock level, X_0 is the minimum stock level, and *g* is a growth parameter. In a dynamic model, the more interesting and important equation is one showing how the stock changes over time:[93]

$$\frac{\partial X(t)}{\partial t} = gX(t) + g\bar{X}X(t)^2$$

In Wilen's bioeconomic model, the capital stock is only modeled as a first partial derivative of time. This is sufficient to determine the level of capital at any time, since Wilen assumes, as is the case with all fisheries, that at some early point the fishery was unexploited and the level of capital stock at zero. The change of capital stock over time is modeled as a simple linear function of economic variables such as price and marginal cost of harvesting, and a linear function of a "capital sluggishness" parameter δ:[94]

$$\frac{\partial K(t)}{\partial t} = \delta[PAX(t) - C]$$

where *P* is price, *A* is the harvest rate, and *C* the variable harvesting costs. Contemporaneous changes in the capital stock and fish stock can thus be depicted as vertical and horizontal movements in a graph of capital stock versus fish stock, as shown in Figure 1.

93 Wilen, *supra,* note 89 at __
94 Wilen, *supra,* note 89 at __