Economic Incentive Effects of EPA's After-the-Fact Veto of a Section 404 Discharge Permit Issued to Arch Coal

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1. Introduction

In 2007 the Army Corps of Engineers issued a Section 404 discharge permit to Arch Coal in connection with the Spruce No. 1 Mine located in Logan County, West Virginia. Arch Coal subsequently operated the mine in compliance with its permit. Nonetheless, more than three years after the Corps issued the 404 permit, EPA proposed to withdraw the discharge authorization granted to Arch Coal. Both the Corps and the State of West Virginia disagreed with the EPA decision, finding that there was no reason to take away the permit. This precedential decision by EPA -- to exercise its limited authority to withdraw a discharge authorization so as to effectively revoke the permit over the objections of the Corps and State has the potential to affect a wide range of economic activities that require authorization under Section 404 of the Clean Water Act.

This report discusses the economic impacts of EPA's actions with respect to the Spruce Mine discharge permit. EPA's after-the-fact veto of Arch Coal's permit makes it more difficult for project developers to rely on essential 404 permits when making investment, hiring or development decisions, and proponents must now account for the possibility of losing essential discharge authorization after work on the project has been initiated.

2. Permitting under Section 404 of the Clean Water Act

There are a variety of public and private sector projects permitted under Section 404 of the Clean Water Act. These activities are vital to the American economy, and include: pipeline and electric transmission and distribution; housing and commercial development; renewable energy projects like wind, solar, and biomass; transportation infrastructures including roads and rail; agriculture; and many others. The Army Corps of Engineers issues roughly 60,000 discharge permits annually under Section 404, and estimates that over $220 billion of investment annually is conditioned on the issuance of these discharge permits. Given the breadth of the statute, a large share of public and

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private infrastructure or development projects must receive and depend on the certain operation of the 404 permit.

Public and private activities requiring Section 404 authorization generate significant indirect and induced benefits to affiliated industries. Reduced levels of investment in projects requiring discharge authorization translate directly into lost jobs and lost economic activity across essentially the whole economy. Tables 1 and 1a show the monthly value of new construction put in place in the United States, which is widely used as a measure of new construction spending. Table 2 gives the direct, indirect and induced output multipliers for key activities typically requiring a Section 404 permit.

There are numerous studies in the economics literature detailing the nationwide output and employment benefits various types of construction projects.[2] A study by the President's Council of Economic Advisors found that under the American Recovery and Investment Plan, construction and manufacturing were likely to experience particularly strong job growth from a recovery package emphasizing infrastructure, energy, and school repair.[3] Another study found that "greater use of renewable energy systems provides economic benefits through investments in innovation, and through new job creation, while at the same time protecting the economy from political and economic risks associated with [energy dependence]."[4] The benefits go beyond measures of output and employment – indeed, "research has shown that well designed infrastructure investments can raise economic growth, productivity, and land values, while also providing significant positive spillovers to areas such as economic development, energy efficiency, public health and manufacturing."[5]

As of 2010, commercial construction activity comprised around 2.5 percent of GDP while residential construction makes up another 2 percent. Spending in these industries will grow as the economy continues to recover from the recession. Standard & Poor's forecasts a 14 percent increase (to $44.8 billion) in commercial construction starts and a 1.8 percent increase in residential housing investment in 2011.[6] The National Association of Home Builders forecasts a 42 percent increase in residential construction starts between 2011 and 2012, from 615,000 to 873,000.[7]

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[2] See Heintz, James, Pollin, Robert and Heidi Garrett-Peltier, *How Infrastructure Investment Support the U.S. Economy: Employment, Productivity and Growth*, Political Economy Research Institute, University of Massachusetts Amherst, January 2009.

[3] CEA, *The Job Impact of the American Recovery and Reinvestment Plan*, January 9, 2009, p. 2.

[4] Kammen, Daniel, Kapadia, Kamal and Matthias Fripp, *Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?,* Energy and Resources Group, University of California at Berkeley, April 13, 2004, p. 3.

[5] Department of the Treasury with the CEA, *An Economic Analysis of Infrastructure Investment*, October 11, 2010, p.1.

[6] S&P, p. 4.

[7] A start is defined as excavation (ground breaking) for the footings or foundation of a residential structure. For a multifamily structure, all units are counted as started when the structure is started. NAHB/Housing Economics, April 2011.

In March 2011, public and private investment in the construction of residential and commercial structures totaled over $300 billion for the previous 12 months.[8]This economic activity stimulates other sectors of the economy. Table 2 shows that every $1 of spending on residential construction, utility and transportation infrastructure or commercial construction generates roughly $3 of economic activity throughout the economy.

Construction spending also generates large numbers of jobs. As shown in Table 3, for each $1 billion spent in new residential construction in the United States, over 10,000 new jobs are created directly and indirectly (i.e., in industries that support construction activity).[9] An additional 5,700 jobs are created through induced effects, meaning the economic activity resulting from increased earnings generated by the direct and indirect economic activity. Thus, in total every $1 billion of residential construction generates around 16,000 jobs. Spending on commercial and institutional facilities such as shopping centers, schools, office buildings, factories, libraries and fire stations has a somewhat larger job-creation effect, at around 18,000 jobs per $1 billion of spending.

Between 1987 and 2007, public spending on transportation and water infrastructure as a percentage of GDP remained steady between 2.3 and 2.6 percent.[10] In 2009, the federal government spent $39 billion on new highway infrastructure.[11] On balance, government spending on highway construction has increased during the past 30 years in real terms.[12] Not only are investments in these kinds of infrastructure critical to quality of life throughout the nation,[13] the multiplier effect on job creation resulting from such investment is substantial. In March 2011, the value of transportation and water infrastructure put in place amounted to roughly $160 billion. As shown in Table 3, every $1 billion in transportation and water infrastructure construction creates approximately 18,000 jobs total.

Renewable energy is an example of an emerging sector of the economy that also relies on discharge permits. The United States spends 0.3 percent of its GDP on the production of clean technologies.[14] The renewables industry, however, has been expanding at a rate of 28 percent per year since 2008.[15] Further, in its 2011 release of the *Annual Energy Outlook*, the U.S. Energy Information Administration forecasts that cumulative additions to electricity generating capacity[16] from renewable sources will exceed 20,000 megawatts

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[8] See Table 1.
[9]Direct and Indirect Effects.
[10] CBO, *Public Spending on Transportation and Water Infrastructure*, November 2010.
[11]CBO, *Spending and Funding for Highways*, January 2011.
[12]*Ibid.*
[13] See for example, Dalenberg, Douglas R. and Partridge, Mark D., "The Effects of Taxes, Expenditures, and Public Infrastructure on Metropolitan Area Employment," *Journal of Regional Science*, Vol. 35, No. 4, 1995, pp. 617-640.
[14]Associated Press, "China Leads Push to Go Green," *New York Times*, May 8, 2011, accessible: http://www.nytimes.com/2011/05/09/business/energy-environment/09clean.html?scp=2&sq=renewable%20energy%20gdp&st=cse.
[15]*Ibid.*
[16]Net Summer Capacity.

by 2020.[17] With fixed costs ranging from roughly $15 to $400 per kilowatt for renewable generation plants,[18] projected near-term future spending on infrastructure for renewables will be substantial.

Table 1. Annual Value of Public and Private Construction Put in Place, as of March 2011[1]

Type of Construction	($'m)
Residential Buildings	237,757
Commercial Buildings and Structures[2]	81,560
Health Care Institutions	39,448
Educational Institutions	80,764
Public Safety Institutions[3]	10,795
Transportation Infrastructure[4]	122,574
Communication Infrastructure	17,387
Power and Electric Infrastructure[5]	81,618
Sewage, Waste and Water Supply Infrastructure[6]	37,427
Total Construction[7]	*768,899*

[1] The annual value is calculated as the unadjusted Census survey estimate of new construction put in place during March 2011 multiplied by 12 and seasonally adjusted.
[2] Includes lodging and office.
[3] Includes correctional and fire/safety structures.
[4] Includes air, rail and water travel as well as highway and street-related infrastructure.
[5] Includes electric transmission and pipelines.
[6] Includes sewage and waste treatment and storage facilities as well as water supply treatment and storage facilities.
[7] The categories listed here do not add up to total construction because some categories have been omitted.
[8] March 2011 numbers are preliminary.

Source: US Census Bureau, *Value of Construction Put in Place*, March 2011.

[17] EIA, Table 9: Electricity Generating Capacity – Reference Case, *Annual Energy Outlook 2011*, April 2011.
[18] EIA, *Updated Capital Cost Estimates for Electricity Generation Plants*, November 2010.

Table 1a. Annual Value of Public and Private Construction Put in Place, as of March 2011[1] ($'m)

Type of Construction	Private	Public
Residential Buildings	229,065	8,692
Commercial Buildings and Structures[2]	65,770	15,167
Health Care Institutions	29,111	10,337
Educational Institutions	12,301	68,463
Public Safety Institutions[3]	n/a	10,658
Transportation Infrastructure[4]	9,043	113,408
Communication Infrastructure[5]	17,334	n/a
Power and Electric Infrastructure	70,139	11,479
Sewage, Waste and Water Supply Infrastructure[6]	n/a	36,272
Total Construction[7]	*476,111*	*292,788*

[1] The annual value is calculated as the unadjusted Census survey estimate of new construction put in place in March 2011 multiplied by 12 and seasonally adjusted.
[2] Public does not include lodging as it is not broken out separately but included in total.
[3] Not broken out separately for the private sector but included in the total.
[4] For private, Transportation Infrastructure spending does not include highway and street-related infrastructure as it is not broken out separately, but included in the total.
[5] Not broken out separately for the public sector but included in the total.
[6] Not broken out separately for the private sector but included in the total.
[7] The categories listed here do not add up to total construction because some categories have been omitted.
[8] March 2011 numbers are preliminary.

Source: US Census Bureau, *Value of Construction Put in Place*, March 2011.

Table 2. Output Impacts of $1 Spending in the US for Select Economic Activities

Area of Economic Activity	Corresponding IMPLAN Sector		Direct Effect[3]	Indirect Effect[4]	Induced Effect[5]	Total Effect
	Sector	Description				
Construction of Commercial and Institutional Structures[1]	34	Construction of new nonresidential commercial and health care structures	$1.00	$0.84	$1.16	$2.99
Construction of Utility, Energy and Transportation Infrastructure[2]	36	Construction of other new nonresidential structures	$1.00	$0.88	$1.15	$3.03
Construction of New Residential Housing Structures	37	Construction of new residential permanent site single- and multi-family structures	$1.00	$1.01	$1.00	$3.01

[1] Includes commercial development and public works such as schools, libraries and fire stations.
[2] Includes renewable energy projects, pipeline and electric transmission and transportation infrastructure such as roads and rail.
[3] The direct effect captures the initial change in economic activity resulting from the new investment.
[4] The indirect effect reflects new economic activity that is stimulated by the direct investment in industries that supply inputs to the sector of initial change.
[5] The induced effect captures the economic activity that results when the increased earnings generated by the direct and indirect economic activity is spent on local goods and services.
Source: IMPLAN version 3

Table 3. Employment Impacts of $1 Billion Spending in the US for Select Economic Activities

Area of Economic Activity	Corresponding IMPLAN Sector: Sector	Corresponding IMPLAN Sector: Description	Direct Effect[3]	Indirect Effect[4]	Induced Effect[5]	Total Effect
Construction of Commercial and Institutional Structures[1]	34	Construction of new nonresidential commercial and health care structures	7,843	3,624	6,591	18,057
Construction of Utility, Energy and Transportation Infrastructure[2]	36	Construction of other new nonresidential structures	7,400	3,912	6,550	17,862
Construction of New Residential Housing Structures	37	Construction of new residential permanent site single- and multi-family structures	5,103	5,136	5,718	15,957

[1] Includes commercial development and public works such as schools, libraries and fire stations.

[2] Includes renewable energy projects, pipeline and electric transmission and transportation infrastructure such as roads and rail.

[3] The direct effect captures the initial change in economic activity resulting from the new investment.

[4] The indirect effect reflects new economic activity that is stimulated by the direct investment in industries that supply inputs to the sector of change.

[5] The induced effect captures the economic activity that results when the increased earnings generated by the direct and indirect economic activity is spent on local goods and services.

[6] Employment impacts are given in full-time equivalent jobs, *i.e.*, each job is equivalent to 2,080 hours of work.

Source: IMPLAN version 3

3. Direct Economic Impacts of EPA's After-the-Fact Veto

EPA's precedential decision to revoke a valid discharge authorization alters the incentives to invest in projects requiring a permit under Section 404. Project development usually requires significant capital expenditure over a sustained period of time, after which the project generates some return. Actions like the EPA's that increase uncertainty, raise the threshold for any private or public entity to undertake the required early-stage investment. For this reason, the EPA's action has a chilling effect on investment in activities requiring a 404 authorization across a broad range of markets.

Increasing the level of uncertainty can also reduce investment by making it more difficult to obtain project financing. Land development activities, infrastructure projects and the like often require a significant level of capital formation. Reducing the reliability of the Section 404 permit will make it harder for project proponents to find financing at attractive rates as lenders and bondholders will require higher interest rates to compensate for increased risk, and some credit rationing may also result.

Permit Uncertainty and the Hurdle Rate

The decisions to undertake an investment in a project can be considered as a comparison of the benefit-cost ratio of the project to a hurdle rate. Letting B denote the present value of net benefits from the project and C denotes the investment cost, the investment condition is to undertake the project when

$$\frac{Benefit}{Cost} > 1 + hurdle\ rate\ .$$

The hurdle rate represents the expected rate of return a firm requires on its investment. When uncertainty exists on the future benefits and cost of a project, firms and public agencies often use risk-adjusted hurdle rates. For private firms, hurdle rates of three or four times the cost of capital are common (Summers, 1987). For government agencies, with a lower cost of capital and less risk aversion, hurdle rates are typically lower, but are usually well in excess of 1.

It is especially common for firms and public agencies to select high hurdle rates when engaging in a project that involves irreversible investment. In this case, high hurdle rates emerge through inertia as decision makers are forced to trade-off the possibility of making an error in an immediate investment decision against the opportunity cost of delaying the investment. The optimal timing of investment in this case would occur when the expected benefit foregone over the interval before the investment is made exceeds the (probability-weighted) downside losses from a wrong investment. Under a present value criterion, the hurdle rate reduces to the discount rate, which is denoted here by r.

In uncertain investment settings with irreversible investment, Pindyck (1982, 1991) and Dixit (1992) characterize the optimal timing of an investment as the tangency between two curves; one describing the value of investing and the other describing the value of waiting. The equation for the value of investing is based directly on present value calculations: the value of an investment is positive if the discounted present value of expected returns exceeds the present value of the sunk, irreversible investment cost, C. The expression for the value of waiting is determined according to the value of the option to delay investment from the present period to subsequent periods. Doing so allows the firm an opportunity to acquire relevant market information over time, which reduces downside risk. The necessary and sufficient conditions for an optimal investment decision are the so-called “value-matching condition” and “smooth-pasting condition,” effects that are described in Dixit and Pindyck (1994).

Abel (1983) shows that greater uncertainty over future market outcomes delays investment in situations where investments are irreversible. This outcome is a common theme in the early literature on quasi-option value (Arrow and Fisher, 1974; Henry, 1974; and Conrad, 1980), and the parallels between this literature and the more recent literature on investment under uncertainty have been demonstrated by Fisher (2000). It is also true for the case of uncertainty over future regulatory actions.

In the context of an investment decision, delaying investment essentially means reducing the level of investment in any given period. Consider a mine where the cost of extracting ore is $40/ton. With permit certainty, and considering the irreversible nature of investment in the mine, suppose the mine the hurdle rate test if the market price of ore were $50/ton. Market prices fluctuate and it may take some time for the price to hit this trigger point, but once it is achieved, the mine owner will commence investment. If the target price increases to \$55/ton, it is less likely that the market price of ore will reach this new, higher level, and investment is delayed, meaning that there is less investment expected in any given period.

It is demonstrated in the appendix to this report that an increase in the threat of permit revocation increases the hurdle rate, thereby delaying investment. The reason for this outcome is twofold. First, as in Abel (1983), delaying investment is valuable because market returns can be earned on financial capital during each period of delay, and this "outside option" is more valuable to firms the more volatile the expected future market returns from the project in relation to returns on the outside asset. Second, and quite unique to the present setting, delaying investment is valuable under the threat of permit revocation because delaying investment reduces the likelihood of stranded capital. This effect is strong --even in the case of small changes in the revocation probability-- as stranded capital can have substantial implications on the rate of return of firms relative to capital that simply earns below-market returns in response to adverse market outcomes. For these reasons, increasing the threat of permit revocation raises the hurdle rate that investors require to engage in projects, delaying investment.

The possibility of permit revocation has highly pernicious effects on investment. Investment, in some cases, is not only delayed, but entirely deterred. Indeed, under various circumstances in which investment would take place absent the threat of permit revocation, investment is deterred, and this is true even for extremely small probabilities of having a permit revoked. The reason is that firms cannot directly control the probability of having a permit revoked when revocation is not based on the firm's own compliance, and this fact introduces a new source of risk that makes investing in sectors of the economy that rely on discharge permits relatively unattractive. To better understand the deterrence effect of permit revocation on new investment, consider the effect of a small probability of revocation represented by the variable p. Taking p to represent the expected annual probability that a discharge permit is revoked, the benefit-cost ratio (derived in the Appendix) of an investment with an expected annual net benefit of \$$B$ and an irreversible one-time capital investment level of \$$K$ is

$$\frac{Benefit}{Cost} = \frac{B}{rK}\left(\frac{r(1-p)}{(r+p)}\right).$$

First consider the case in which discharge permits are certain and can be relied on by project proponents. In this case, the net present value of the benefit stream from the project is B/r and the initial capital outlay for the project is K. These terms, which appear to the left of the term in brackets, represent the standard benefit-cost ratio used in studies of irreversible investment (Dixit and Pindyck, 1994).

Now consider the distortion to the benefit-cost ratio of new investment projects under the threat of permit revocation. The term in brackets is the distortion to the benefit-cost ratio created by this threat. When $p = 0$, the distortion vanishes and the benefit cost ratio returns to the market value in standard case. Notice that this term is concave in the threat of permit revocation; that is, small changes in the threat of permit revocation in environments with little regulatory threat have larger impacts on investment decisions than small increments in the revocation probability at higher frequencies of government intervention.

An important implication of this result is that small changes in the probability that discharge permits are revoked have large effects on investment incentives even when revocation is infrequent in practice. To see this result, consider the magnitude of the distortion to investment incentives (the term in the brackets of the equation above) in the case of a 5% discount rate.

At a 5% rate of discount (r = 0.05), if investors expect a 1% chance per year of permit revocation, the expected benefit-cost ratio of projects involving discharge permits decreases by 17.5%. That is, $\frac{.05(0.99)}{(.06)} = 82.5$ in the term reflecting the regulatory distortion above. If an observed regulatory action subsequently causes investors to expect a 2% chance per year of having a discharge permit revoked, the expected benefit-cost ratio of projects involving discharge permits decreases by 30%, and, if it turns out investors expect a 5% chance per year of having a discharge permit revoked, the expected benefit-cost ratio of projects involving discharge permits decreases by 52.5%. **Thus, small changes in the threat of permit revocation can lead to dramatic reductions in private investment.**

It should also be noted that the possibility of revocation has the largest deterrent effect on large projects. This effect is independent of the fact that large projects are the most likely to be controversial and have a higher chance of having their discharge authorization revoked. Large projects by definition have a higher level of capital outlay than smaller projects. Permit revocation increases the downside risk associated with a project, as revocation results in some level of stranded investment. This principle is demonstrated formally in the appendix,

To summarize this mainly conceptual discussion, raising the possibility that discharge permits can be revoked reduces investment incentives in two essential ways: (i) revoking permits raises hurdle rates among private investors; and (ii) revoking permits reduces the expected benefit-cost ratio of new projects. These effects will dampen investment rates in industries that rely on Section 404 permits, both by delaying and by deterring new projects from being built.

Project Financing

Another issue related to the effect of permit revocation on investment relates to capital formation. It is common for both private and public projects to be debt financed. In this case, corporations and governments raise revenue by issuing bonds. Though some investors have developed their own models for measuring the probability that the borrower will default, there are three principal rating services that have developed their own corporate and government bond ratings: Moody's, Standard & Poor's and Fitch.

Debt ratings are based on a combination of quantitative and qualitative factors that each rating agency considers to estimate the probability of a bond defaulting payment. Of particular relevance to the EPA's actions is that rating agencies typically consider regulatory risk as a principal consideration in its bond ratings:

> The analysis of credit risk may include, for example, business risk and financial risk in the case of rating a corporation or financial institution, or geopolitical risk in the case of a sovereign government. When assessing structured finance issues, the broad fundamental areas we typically consider include: asset credit quality, legal andregulatory risks, the payment structure and cash flow mechanics, operational and administrative risks, and counterparty risk (Standard and Poor's, 2010).

Increased regulatory risks could thus lower a corporation's or government's credit rating. This circumstance in turn could make it much more expensive to access capital.

It is possible that some project developers will be unable to obtain financing due to the increased risk of their investment. The practice of a bank that is unwilling to lend money, even when the borrower is willing to pay higher interest rates, is called credit rationing. There are multiple circumstances that can lead to credit rationing, for example a shortage of credit or a temporary, exogenous shock to the credit market. But, Stiglitz and Weiss (1981) show that credit rationing could be an equilibrium outcome even without a credit shortage.

Land Markets and Incidence of Regulation

Land is an asset that has a fixed location. Regulation that affects the returns to land ownership in defined areas thus has the potential to alter the equilibrium price of land. At present, there are over 100 million acres of land in the contiguous United States that contain wetlands and other waters subject to regulation under the Clean Water Act. Many more acres are within the drainage of waters of the United States and thus potentially come under the jurisdiction of the Army Corps of Engineers.

In a competitive land market, land prices reflect the discounted value of the returns earned from dedicating land to its highest and best use (Capozzaand Helsley, 1998). For undeveloped land, this sum is typically equal to the value of rents when the land is in an undeveloped condition, plus the amount developers are willing to pay for land when they initiate their project.

Regulation that lowers the profits from future development will be capitalized into current land values, meaning that the equilibrium market price of land will be lower as a result. Thus, the EPA's action will, to a degree determined by local market conditions, be borne by landowners in areas containing wetlands and other waters of the United States.

4. Conclusions

The EPA's precedential decision to revoke a valid discharge permit will have a chilling effect on investment across a broad swath of the American economy. Activities ranging from residential and commercial development, roads, renewable energy, and other projects rely on discharge authorization under Section 404 of the Clean Water Act. These activities provide needed infrastructure, housing, and other services, and are a significant part of the annual value of economic activity in the country. They also generate hundreds of thousands of jobs nationwide, and stimulate economic activities in support sectors.

The types of projects that require discharge permits are usually capital intensive and involve irreversible investments, meaning that the project proponent cannot recoup costs if the necessary authorization is revoked by the EPA. Revoking discharge permits introduces two essential market distortions: (i) revoking permits raises hurdle rates among private investors; and (ii) revoking permits reduces the expected benefit-cost ratio of new projects. These effects are likely to dampen investment rates in industries relying on discharge permits, both by delaying and by deterring new projects from being built. Importantly, I show that even small changes in the probability of ex post revocation can have a large effect on project investment.

5. References

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6. Appendix

This appendix develops the model of expected investment returns under the threat of permit revocation discussed in the report.

Let $c_t(q)$ denote the cost of investment in a project of size q at time t. Investment costs are considered to be divided into an initial and irreversible expenditure at time *t*=0 (the date of project approval), which is denoted *K*, and a series of recurring costs associated with project operation in the subsequent periods *t*=1,…,*T*, denoted by the constant *c*. The present value of cost for a project of known size is

$$c_t = K + \sum_{t=1}^{T} \left(\frac{1}{1+r} \right)^t c \,, \tag{1}$$

where*r* is the discount rate.

The expected return from the project is positive, in the sense that the expected benefit to the operator exceeds the sum of investment cost and recurring operational costs of the project. Let *B* denote the expected net benefit of the project in each period of operation, which is defined as the gross benefit less operational costs, *c*. For a project with an operating lifetime of *T* periods, the present value of the net benefit of the project is

$$NPV_0 = \sum_{t=1}^{T} \left(\frac{1}{1+r} \right)^t B - K \,, \tag{2}$$

where costs in equation (1) are subsumed into the net benefit function. Equation (2) represents the standard present value criterion for evaluating projects.

Now suppose the regulator introduces threat of permit revocation. If firms perceive the likelihood of having their permit revoked in any given period to be *p*, then the net present value of a project with an operating lifetime of T periods is given by

$$NPV_0 = \sum_{t=1}^{T} \left(\frac{1-p}{1+r} \right)^t B - K \,. \tag{3}$$

Noting that the factor (1-*p*)/(1+*r*) < 1, the net present value can be expressed as

$$NPV_0 = \frac{(1-p)B}{r+p} \left(1 - \left(\frac{1-p}{1+r} \right)^T \right) - K \,. \tag{4}$$

In the case where a permit has no explicit terminal time, T, it is convenient to treat the discounted net return of the project as the present value of an infinite annuity from the investment. In this case, equation (4) can be expressed as

$$NPV_0 = \frac{(1-p)B}{r+p} - K\ . \tag{5}$$

Notice that equation (5) reduces to the conventional formula used by Pindyck (1991) and Dixit (1992) for the present value of an infinite annuity with expected return *B*/*r*.

Next consider the continuation value, or net payoff of an investment made in period *t*=1 as opposed to period *t*=0. To calculate the net payoff from an investment in period t=1, consider a discrete probability model of the form examined by Dixit and Pindyck (1994) and Fisher (2000) in which the expected net benefit function is given by

$$B = V\left[q(1+u) + (1-q)(1-d)\right].$$

In this expression, *q* is the probability of a high draw from the value distribution, in which case the net value of the project is (1+*u*)*V*, and1-*q* is the probability of a low draw from the value distribution, in which case the net value of the project is (1-d)*V*. Thus, if V is defined as net benefit, the value B in equation (5) can be interpreted as the contemporaneous expected net benefit of the project at time t=0.

To calculate option value from delaying investment until time *t*=1, suppose the true value of the project is revealed at time *t*=1 as being either *V*(1+*u*) or *V*(1-*d*) and that the continuation value of the project is driven by high-draws from the value distribution. In this case, when waiting until time t=1 to make the investment decision, the investment is "in the money" only if a high draw is revealed. Under circumstances in which the project is worthwhile in both states of nature, there would be no option value to delaying an irreversible investment and investment would always take place. Irreversibility of investment would not impact the hurdle rate in this was the case.

The expected continuation value for the project must satisfy (in present value terms of period *t*=0):

$$\left(\frac{1}{1+r}\right)E_0(F_1) = \frac{q}{1+r}\left[\frac{V(1+u)(1-p)}{(r+p)} - (1-p)K\right]. \tag{6}$$

Notice that, by delaying investment it is possible that the discharge permit is revoked between periods *t*=0 and *t*=1. The conditional probability of investment at time *t*=1 is *q*(1-*p*).

The value of the option to delay investment is given by

$$OptionValue = \left(\frac{1}{1+r}\right)E_0(F_1) - NPV_0\ . \tag{7}$$

The formula for option value in equation (7), which is analogous to a call option on a share of stock (Dixit and Pindyck, 1994), is the difference between the continuation value and the net present value of investment from the time t=0 perspective.

Substitution of terms from equations (5) and (6) and simplifying gives

$$OptionValue = \frac{-(1-p)}{(1+r)(r+p)}\left[rB + (1-q)(1-d)V\right] + K\left(1 - \frac{q(1-p)}{1+r}\right)$$

The option value of delaying investment for one period is the sum of two terms. The first term is the foregone benefit from development in period t=0. The term in the square brackets sums the lost interest on expected earnings during the period in which investment is delayed and earnings in the non-investment state associated with a low draw. This term is negative. The second term represents the capital savings from delaying investment. This term is positive, not only because of the one period delay in investment but also because with probability p the permit was revoked during the period in which investment is delayed, stranding capital in the case of early investment. If the first term is larger in magnitude than the second term, for instance if the capital investment, K, is small or if capital is fully recoverable through re-sale in a salvage market, then there is no option value and consequently no return for delaying the investment.

In many settings, capital investment levels are sufficiently large that delaying investment creates a positive option value for firms. This also delays social benefits from arising that are indirectly related to the investment, for instance employment and induced local spending. Introducing the potential for permit revocation compounds this problem. To see this, notice that the option value of delaying investment is larger for larger values of the revocation probability, p:

$$\frac{\partial}{\partial p} OptionValue = \frac{\left[rB + (1-q)(1-d)V\right]}{(r+p)^2} + \frac{qK}{1+r} > 0$$

The implication is that increasing the threat of permit revocation delays investment from taking place. Positive option value increases the hurdle rate that investors require to engage in projects. A greater threat of permit revocation raises the hurdle rate, delaying investment in cases where investment is not deterred.

The possibility of permit revocation has pernicious effects on investment. Under various circumstances where investment would have taken place absent the threat of permit revocation, investment is deterred entirely. To see this, it is helpful to convert net present value in equation (5) into a benefit-cost ratio,

$$\frac{B}{rK}\left(\frac{r(1-p)}{(r+p)}\right), \tag{8}$$

where the net present value of the future benefit stream from operating the project in an environment without threat of permit revocation is B/r and the initial capital outlay for the project is K. The term in brackets is the distortion to the benefit-cost ratio created by the threat of permit revocation. If $p = 0$ the distortion vanishes and the benefit cost ratio returns to the market rate.

Notice that equation (8) is concave in the threat of permit revocation. This implies that small changes in the probability that discharge permits are revoked for reasons unrelated to compliance greatly reduce investment incentives. To see this, consider the magnitude of the distortion to investment incentives (the term in the brackets of equation (8)) in the case of a 5% discount rate.

For $r = 0.05$, if investors expect a 1% chance per year of permit revocation, the expected benefit-cost ratio of projects involving discharge permits decreases by 17.5%; however, if investors expect a 5% chance per year of permit revocation, the expected benefit-cost ratio of projects involving discharge permits decreases by 52.5%. Accordingly, small changes in the threat of permit revocation can lead to dramatic reductions in private investment.